Philosophies in SE Research: A Brief Primer

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Disclaimers ...

- This talk ONLY introduces the concept of the predominant research philosophies in SE.

- There are MORE philosophies.

- The 'rabbit hole' of philosophies is very deep. The more we know, more we realize how less we know.

- If you are planning any empirical study – then this is of utmost importance.

- There will be more questions than answers; but that's okay!

- This discussion might not help you to arrive at a 'solution', but it will help you to solve the problem!

- We are happy to answer all the questions and help you design and plan your future studies.

Why Philosophy of Science Matters in SE?

Have you ever wondered...

- What kind of knowledge are we trying to produce?

- How do we decide whether something is true or valid in SE?

- Why do we believe certain methods are better or more scientific than others?

These questions sit at the heart of the **philosophy of science.**

They deeply influence:

- *How you conduct research;*

- *How your work is evaluated;*

- and ultimately, *How it impacts the field.*

Question for you: WHAT IS RESEARCH? YOUR THOUGHTS...

Why Philosophy of Science Matters in SE?

1. Research Isn't Just Solving the Problem – It's about Creating and Claiming Knowledge.

2. It Helps You Choose the Right Methods (and Defend Them!)

3. It Shapes How You Interpret the Results.

1. SE Is a Multidisciplinary Field

What is the *Science* in SE

Science:

Systematically and objectively gaining, documenting and disseminating knowledge.

Question: **Is Software Engineering Research science?**

What do you think?

What is the *Science* in SE

Science can have different purposes:

Insight – oriented science AND Design-oriented Science (not to be confused with DSR methods, for now).

Insight-oriented science:

- Gaining and validating new insights.

- Often theoretical in nature.

- Typically addressed by natural and social sciences.

Design-oriented Science:

- Guiding the application of scientific methods to practical ends.

- Often, rather practical and pragmatic in nature.

- Typically addressed by engineering disciplines.

What is the *Science* in SE

Software Engineering Research:

- We (mostly) apply scientific methods to practical ends (treating design science problems).
- We also treat insight-oriented questions; thus, we are an insight-oriented science too.

Fundamental research: Typically has more 'theoretical impact/relevance'.

Applied research: Typically having more practical impact/relevance.

What is Empirical Software Engineering Research

The ultimate goal of empirical SE research is **theory building** and its **evaluation** to strengthen and advance the body of knowledge.

Practitioners Vs Researchers

- Researchers are usually concerned with understanding the nature of the artefacts and their relationship in a specific context.

E.g., What is its effects; Why is it so?

- Practitioners usually are concerned with improving their engineering tasks and outcomes using available (or sometimes) new knowledge.

E.g., What is the problem; What is the best solution?

WHO ARE YOU?

Inductive Research VS Deductive Research

What is Inductive Research?

- Inductive research is a method in which the researcher collects and analyzes data to develop theories, concepts, or hypotheses based on patterns and observations seen in the data.

- It uses a "bottom-up" method in which the researcher starts with specific observations and then moves on to more general theories or ideas.

- Used to 'explore' a phenomena OR when not much research / investigations have been conducted on a topic before.

Stages of Inductive Research process:

1. Observation: Make detailed observations of the studied phenomenon. This can be done in many ways, such as through surveys, interviews, or direct observation.

2. Pattern Recognition: The goal is to find insights and trends that can be used to make the first categories and ideas.

3. Theory Development: This means putting the data into groups based on their similarities and differences to make a framework for understanding the thing being studied.

Inductive Research VS Deductive Research

What is Deductive Research?

- Deductive research is a type of research in which the researcher starts with a theory, hypothesis, or generalization and then tests it through observations and data collection.

- It uses a top-down method in which the researcher starts with a general idea and then tests it through specific observations.

- Deductive research is often used to confirm a theory or test a well-known hypothesis.

- Usually used to 'explain' a phenomena . i.e., understand the cause-and-effect relationships. Improve the theory.

Stages of Inductive Research process:

1. Understand an existing theory or a phenomena.

2. Formulate a falsifiable hypothesis, based on the theory.

3. Collect data to test the hypothesis

4. Analyse and make sense of the data

5. Decide whether we can reject the null hypothesis, or not.

Qualitative VS Quantitative Research Approach

While, inductive and deductive research are two different approaches to data analysis, while qualitative and quantitative research are two different types of data; and not research paradigms.

Quantitative research is **expressed in numbers and graphs**. It is **used to test or confirm** theories and assumptions. This type of research can be used to establish **generalizable** **facts** about a topic.

Usually used to conduct 'deductive' research.

Qualitative research is **expressed in words**. It is **used to understand** concepts, thoughts or experiences. This type of research enables you to gather **in-depth insights** on topics that are not well understood.

Usually used to conduct 'inductive' research.

Quantitative and qualitative research use different research methods to collect and analyze data, and they allow you to answer different kinds of research questions.

Qualitative VS Quantitative Research Approach

Qualitative research:

- The focus is on exploring the topic area or formulating the theories.

- The data analysis process follows summarizing, categorizing and interpreting the rich data.

- Usually, the data is expressed in 'words' and 'dialogues'.

- Few samples utilized.

- The research questions are open-ended.

- The research is characterized by exploration, content, complexity and 'subjectivity'.

Quantitative research:

- The focus is on testing the hypothesis or theories.

- The data analysis process follows statistical tests.

- Usually expressed in numbers, graphs and tables.

- Many respondents or participants. Used to generalise the results.

- The research questions are closed-ended.

- The research is characterized by testing, measurement, replicability and 'objectivity'.

Qualitative VS Quantitative Research Approach

When to use qualitative vs. quantitative research?

- Use quantitative research if you want to confirm or test something (a theory or <u>hypothesis</u>)
- Use qualitative research if you want to understand something (concepts, thoughts, experiences)

Frequently used data collection methods:

Quantitative research: Quantitative surveys, questionnaires, field experiments, observations.

Qualitative research: Interviews, focus groups, ethnography and literature reviews.

JYU SINCE 1863.

What is Empirical Truth?

- Different individuals make different assumptions about scientific truth.

- These differences are due to different take on philosophical stances.

- To understand the different stances, philosophers make a distinction between:

Epistemology---the nature of human knowledge, and how we obtain it;

Ontology---the nature of the world irrespective of our attempts to understand it.

Some of the different philosophical standpoints are:

- Empiricists argue that all knowledge is derived from our experiences and observations of the world.

- Rationalists argue that some part of our knowledge is innate, hence not derived from experience.

- Constructivists argue that we cannot separate knowledge from the language we use to express it – because the meanings of words are constructed by social convention, so is our knowledge.

What is Empirical Truth?

The four dominant philosophical standpoints:

"Imagine you want to study how different software testing tools affect the number of bugs found in a codebase."

1. **Positivism**:

Emphasizes the independence of the researcher from the subject of study, and the use of empirical evidence to draw objective conclusions.

Observable Fact: *The number of bugs identified by each tool can be measured.*

Reductionism in Action: *We isolate the impact of testing tools by keeping other factors (e.g., developer experience, code complexity) constant.*

Controlled Experiment:

Hypothesis: *Tool A will find more bugs than Tool B.*

Experiment: *Two groups of developers use Tool A and Tool B on identical codebases under controlled conditions. The number of bugs detected is compared.*

Outcome: *The observable data supports or refutes the hypothesis.*

What is Empirical Truth?

2. The four dominant philosophical standpoints:

1B. **Post Positivism:**

Acknowledges that the researcher's values, background knowledge, and theories can influence what is observed, and that experiences of truth are imperfect. Post-positivists pursue objectivity by recognizing the possible effects of biases.

Observation Isn't Perfect: Maybe some bugs go undetected, or tools behave differently in real-world environments.

The Context Matters: Positivism assumes testing tools can be studied in isolation, but real-world use involves many interacting factors (team size, deadlines, tool integration).

Post-Positivist Perspective: Instead of proving *Tool A is better*, post-positivists aim to refute hypotheses systematically, increasing confidence in a theory over time.

They might combine experiments with real-world case studies to account for context.

What is Empirical Truth?

2. **Constructivism**:

- NOT THE SAME AS 'interpretivism',

- Rejects the idea that scientific knowledge can be separated from its human context.

- Constructivists concentrate less on verifying theories, and more on understanding how different people make sense of the world, and how they assign meaning to actions.

- Constructivists prefer methods that collect rich qualitative data about human activities, from which local theories might emerge.

NOTE: Constructivism and Interpretivism believe that reality is subjective and socially constructed by individuals; i.e., the ontological assumption.

However, constructivism and interpretivism differ in their epistemology:

- Constructivism focuses on how individuals construct their own realities through interactions with others.

- Interpretivism focuses on understanding how individuals experience and interpret their reality. The researcher seeks to **understand those interpretations** from the participants' perspectives.

What is Empirical Truth?

3. **Critical Theory**:

- Critical theorists argue **that research is a political act, because knowledge empowers different groups within society**.

- Critical theorists therefore **choose what research to undertake based on whom it helps**. They prefer participatory approaches in which the groups they are trying to help are engaged in the research, including helping to set its goals.

- In software engineering, it includes research that actively seeks to challenge existing perceptions about software practice, most notably **the open-source move**ment, and, arguably, the **process improvement community and the agile community.**

- The research method of *Action Research* most closely reflects the philosophy of critical theorists.

What is Empirical Truth?

4. Pragmatism:

- All knowledge is approximate and incomplete, and its value depends on the methods by which it was obtained.

- For pragmatists, knowledge is judged by how useful it is for solving practical problems.

- Basically, truth is whatever works at the time.

- In software engineering, pragmatists adopt an engineering approach to research – it values practical knowledge over abstract knowledge, and uses whatever methods are appropriate to obtain it.

- Pragmatists use any available methods, and strongly prefer mixed methods research, where several methods are used to shed light on the issue under study.

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What is Empirical Truth?

5. Critical Realism:

- Critical realism is fundamentally different from both positivism and constructivism.
- Positivism embraces epistemological realism; Constructivism embraces epistemological and ontological relativism.
- Critical Realism (CR) is a middle ground between **positivism** (which assumes reality is fully measurable) and **constructivism** (which assumes reality is socially constructed).

- Key Characteristics:
- **There is a reality independent of our perceptions** (ontological realism).
- **Our knowledge of that reality is always fallible and theory-laden** (epistemic relativism).
- Science's goal is to understand the *underlying mechanisms* that generate observable events, not just describe patterns.

What is Empirical Truth?

5. Critical Realism:

Why It's Relevant to SE?

- Software engineering is full of **complex socio-technical systems**. Purely positivist approaches can miss human/contextual factors, while pure constructivist approaches can sometimes underplay the role of actual constraints (like compiler limitations or algorithm complexity).
- CR gives you a way to **study both the "real" structures and the human interpretations** that shape SE phenomena.

Methodological Implications:

- Often uses **mixed methods**:
- **Quantitative** to detect patterns (e.g., productivity vs. tool adoption rate).
- **Qualitative** to uncover the mechanisms and context that explain those patterns.