Course: Research Method in Software Engineering

WEEK 10 – Empirical Research Methods in Software Engineering

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Week 10. Empirical Research Methods in Software Engineering

Contents

Learning Outcome

- Understand empirical research and the importance
- Differentiate empirical research techniques
- Understand the attributes of a well-designed questionnaire
- Understand the fundamental strategies of empirical software engineering
- Understand the framework for developing good questionnaires.

1. Introduction to Empirical Research

- Empirical research relies on gathering and studying real, observable data.
- The term **’empirical’** comes from the Greek word ’empeirikos,’ meaning ‘experienced’ or ‘based on experience.’
- Instead of using theories or opinions, empirical research depends on real data obtained through direct observation or experimentation.
- Empirical research is a "systematic approach for answering certain types of questions answered through the collection of evidence under carefully defined and replicable conditions. The evidence collected during empirical research is often referred to as **"data."**

[1]. Paperpal, Empirical Research: A Comprehensive Guide for Academics, Elizabeth Oommen George, January 18, 2024. https://paperpal.com/blog/researcher/empirical-research-a-comprehensive-guide-for-academics.

1. Introduction to Empirical Research …cont'd

Why Empirical Research?

- Empirical research plays a key role in checking or improving current theories, providing a systematic way to grow knowledge across different areas.
- By focusing on objectivity, it makes research findings more trustworthy, which is critical in research fields like medicine, psychology, economics, and public policy.
- In the end, the strengths of empirical research lie in deepening our awareness of the world and improving our capacity to tackle problems wisely.

[1]. Paperpal, Empirical Research: A Comprehensive Guide for Academics, Elizabeth Oommen George, January 18, 2024. https://paperpal.com/blog/researcher/empirical-research-a-comprehensive-guide-for-academics

1. Introduction to Empirical Research …cont'd

Types of Methodologies for Empirical Research

Qualitative and Quantitative Methods

- There are two main types of empirical research methods – **qualitative and quantitative.**

  Qualitative research delves into intricate phenomena using non-numerical data, such as interviews or observations, to offer in-depth insights into human experiences.

- **Quantitative research** analyzes numerical data to spot patterns and relationships, aiming for objectivity and the ability to apply findings to a wider context.

[1]. Paperpal, Empirical Research: A Comprehensive Guide for Academics, Elizabeth Oommen George, January 18, 2024. https://paperpal.com/blog/researcher/empirical-research-a-comprehensive-guide-for-academics

1.Introduction to Empirical Research …cont'd

Common types of Quantitative Empirical Research Techniques

1. Survey

- Survey research is designed to generate statistical data about a target audience.
- It involves large, medium, or small populations and can either be a one-time event or a continuing process
- In the past, surveys used to be expensive and time-consuming. But with the advancement in technology, new survey tools like social media and emails have made this research method easier and cheaper.

[2]. Research.com, What is Empirical Research? Imed Bouchrika, https://research.com/research/what-is-empirical-research

1. Introduction to Empirical Research …cont'd

Common types of Quantitative Empirical Research Techniques …cont'd

2. Experiment

- A research hypothesis is commonly tested using an experiment, which involves the creation of a controlled environment where the variables are manipulated.
- Experimental research in software methodologies to evaluate and compare different software development practices, tools, or techniques.
- **Example** :- Experimental research to evaluate the effectiveness of Agile vs. Waterfall methodologies in terms of project delivery time, code quality, and team satisfaction

[2]. Research.com, What is Empirical Research? Imed Bouchrika, https://research.com/research/what-is-empirical-research

1. Introduction to Empirical Research …cont'd

Qualitative Empirical Research Methods

Example for a general types of qualitative research methods.

Case Study

- This method is used to identify extensive information through an in-depth analysis of existing cases. It is typically used to obtain empirical evidence for investigating problems .
- When conducting case studies, the researcher must carefully perform the empirical analysis, ensuring the variables and parameters in the current case are similar to the case being examined.
- Case studies are commonly used in studying the experience of organizations, groups of persons, geographic locations, etc.

[2]. Research.com, What is Empirical Research? Imed Bouchrika, https://research.com/research/what-is-empirical-research

1.Introduction to Empirical Research …cont'd

Empirical Research Cycle

1. Observation

- During this initial phase, an idea is triggered for presenting a hypothesis. It involves the use of observation to gather empirical data

2. Induction

- Inductive reasoning is then conducted to frame a general conclusion from the data gathered through observation. .

Fig. Empirical Research. https://www.voxco.com/wp-content/uploads/2021/04/Empirical-Research.jpeg

3. Deduction

- This phase enables the researcher to figure out a conclusion out of the experiment. This must be based on rationality and logic in order to arrive at particular, unbiased outcomes.

[2]. Research.com, What is Empirical Research? Imed Bouchrika, https://research.com/research/what-is-empirical-research

1.Introduction to Empirical Research …cont'd

Empirical Research Cycle ….cont'd

4. Testing

- This phase involves the researcher going back to the empirical research steps to test the hypothesis.
- Need to analyze and validate the data using appropriate statistical methods.

5. Evaluation

- This phase is often neglected by many but is actually a crucial step to help keep expanding knowledge.
- During this stage, the researcher presents the gathered data, the supporting contention/s, and conclusions.

1. Introduction to Empirical Research …cont'd

Empirical Research Writing

- The empirical writing follows a set of structures and each section has a specific role.

Some tips for empirical writing.

- **Define Objectives:** Start by making the goals clear.
  - Explain what we want to find out or prove in a simple and direct way. This helps guide the research and lets others know what we have set out to achieve.
- **Be specific in Literature Review:** Focus on research that directly relates to the research question. Keep it short and pick studies that help explain why the research is important.

[1]. Paperpal, Empirical Research: A Comprehensive Guide for Academics, Elizabeth Oommen George, January 18, 2024. https://paperpal.com/blog/researcher/empirical-research-a-comprehensive-guide-for-academics.

1. Introduction to Empirical Research …cont'd

Empirical Research Writing ….cont'd

- **Explain Methods Clearly**: Should be explain in detail.
  - Be clear about the research plan, who took part, and what to be done; this helps others understand and trust the study.
  - One should be honest about any rules he follows to make sure the study is ethical and reproducible.
- **Share Results Clearly:** share what is found in a simple way. Use tables or graphs to make it easier for audience to understand the research.
  - Ensure that others can see why the research findings matter.

[1]. Paperpal, Empirical Research: A Comprehensive Guide for Academics, Elizabeth Oommen George, January 18, 2024. https://paperpal.com/blog/researcher/empirical-research-a-comprehensive-guide-for-academics.

1. Introduction to Empirical Research …cont'd

Empirical Research Writing …..cont'd

- **Talk About What the Findings Mean**: Discuss the research results, explain what they mean.
  - Discuss why the findings are important and if they connect to what others have found before.
  - Be honest about any problems with the study and suggest ideas for more research in the future.
- **Wrap It Up Clearly:** Finally, end the empirical research paper by summarizing what is found and why it's important.
  - Remind everyone why the study matters.
  - Keep the writing clear and fix any mistakes before sharing it.
  - Ask someone trusted to read it and give us feedback before finish.

1. Introduction to Empirical Research …cont'd

Advantages of Empirical Research

- **Used for authentication**. Empirical study is used to authenticate previous findings of experiments and empirical observations.
    - This research methodology makes the conducted study more authentic and accurate.
- **Empirical approach is useful for understanding dynamic changes**. Due to the detailed process of literature review, empirical analysis is used in helping researchers understand dynamic changes in the field.

[3]. Voxco,Definition, Types and Examples of Empirical Research, April 1, 2021. https://www.voxco.com/blog/empirical-research/

1. Introduction to Empirical Research …cont'd

Advantages of Empirical Research ….cont'd

- **Provides a level of control**.
  - Empirical approach empowers researchers to demonstrate a level of control by allowing them to control multiple variables under study.
- **Empirical methods Increase internal validity**.
  - The high level of control in the research process makes an empirical method demonstrate high internal validity.

[3]. Voxco,Definition, Types and Examples of Empirical Research, April 1, 2021. https://www.voxco.com/blog/empirical-research/

1. Introduction to Empirical Research …cont'd

Disadvantages of Empirical Research

- **Time consuming**. Empirical studies are time consuming because it requires researchers to collect data through multiple sources. It also requires them to assess various parameters involved in the research.
- **Empirical approach is Expensive**. The researcher may have to conduct the research at different locations or environments which may be expensive.
- **Difficult to acquire consent/permission**. Sometimes empirical studies may be difficult to conduct due to the rules that are to be followed when conducting it.
- **Data collection in the empirical approach can be a problem**. Since empirical data has to be collected from different methods and sources, it can pose a problem to the researchers.

[3]. Voxco,Definition, Types and Examples of Empirical Research, April 1, 2021. https://www.voxco.com/blog/empirical-research/

2. Empirical Research in Software Engineering

- Scientific use of qualitative and quantitative to understand and improve software products and software development process
- Empirical Research aims to use statistical testing techniques to test the hypothesis and hence reduces the gap between theory and practice.
- It helps in improving, analyzing and assessing the procedures and processes of software development.
- It also provides guidelines in decision making.
- Thus, the empirical research guides towards determining the best of the resultant software processes and products.

[4]. Wikipedia, Empirical Software Engineering. https://en.wikipedia.org/wiki/Empirical_software_engineering

2. Empirical Research in Software Engineering ..cont'd

- Empirical software engineering (ESE) is a subfield of software engineering (SE) research that uses empirical research methods to study and evaluate an SE phenomenon of interest.
- The phenomenon may refer to software development tools/technology, practices, processes, policies, or other human and organizational aspects.
- The fundamental strategies of empirical software engineering
  - Surveys
  - Case Studies
  - Experiments
  - Action Research.

[5]. Empirical Research in Software Engineering (Doctoral dissertation, HSR), Kapferer, S., 2019. https://eprints.ost.ch/id/eprint/820/

2. Empirical Research in Software Engineering ..cont'd

Fundamental strategies of empirical software engineering

a) Surveys

- With a survey we can collect data from or about people. This strategy is typically used to derive a generalized opinion of a population regarding a method or tool which is already in use.
- In the context of software engineering this strategy it could be used to find out what the developers in a company think about a new method or a new tool.
  - Surveys collect data usually with questionnaires or interviews .
  - By taking a survey on a sample, conclusions are derived for the whole population.
  - A good survey has to fulfill quality attributes such as accuracy to achieve the intended goal, being available at the requested time (timely), and being accessible to the subjects . The objective of conducting a survey is either descriptive, explanatory or explorative

2. Empirical Research in Software Engineering ..cont‘d

Fundamental strategies of empirical software engineering …cont’d

b) Experiments

- An experiment provides more control than a case study and must therefore typically be conducted in a laboratory environment.
- In an experiment researchers aim for measuring the impact of changing one or more factors.
- It is important that only these factors or variables change and the rest of the environment is kept at a fixed level.

[5]. Empirical Research in Software Engineering (Doctoral dissertation, HSR), Kapferer, S., 2019. https://eprints.ost.ch/id/eprint/820/

2. Empirical Research in Software Engineering

Fundamental strategies of empirical software engineering …cont'd

c) Action Research

- The aim of action research is to experiment through intervention and to use the feedback directly to improve the underlying theory or hypothesis. Thereby it is possible to try out an approach with practitioners in real situations and use the experience to modify the theory.
- After the modification, the theory can be tested with the practitioners again.

Example:- Action research can be used to implement and evaluate the effectiveness of Agile methodologies on improving software quality within a development team.

[5]. Empirical Research in Software Engineering (Doctoral dissertation, HSR), Kapferer, S., 2019. https://eprints.ost.ch/id/eprint/820/

2. Empirical Research in Software Engineering

Fundamental strategies of empirical software engineering …cont'd

d) Case study

- Software engineering field depends heavily on human behavior and human creativity. It is often not possible to clearly distinguish the subject of study from the environment and thus difficult to design experiments. Case studies provide a solution for such use cases.
- Case studies are most appropriate for research questions that are of the "how" and "why" variety .
- **Example:-** Case Study: Enhancing Software Quality in a Mobile App Development
  - We can investigate the underlying causes of the quality issues and implement a structured approach to enhance software quality in the mobile app project.
  - Thus, one should identify key factors contributing to software quality issues, implement quality improvement practices and ,measure the impact of these practices on software quality.

[6]. Runeson, P., Host, M., Rainer, A., & Regnell, B. (2012). *Case study research in software engineering: Guidelines and examples*. John Wiley & Sons, Page 17-21.

3. Qualities of Good Questionnaire

- The design of a questionnaire will depend on
  - whether the researcher wishes to collect exploratory information (i.e. qualitative information for the purposes of better understanding or the generation of hypotheses on a subject)
  - Or quantitative information (to test specific hypotheses that have previously been generated).
  - Preliminary decisions in questionnaire design
- **There are nine steps involved in the development of a questionnaire**:
  1. Decide the information required.
  2. Define the target respondents.
  3. Choose the method(s) of reaching the target respondents.
  4. Decide on question content.

[7]. Food and Agriculture Organization (FAO), Chapter 4: Questionnaire Design. https://www.fao.org/4/w3241e/w3241e05.htm

3. Qualities of Good Questionnaire ...cont'd

There are nine steps involved in the development of a questionnaire .....cont'd

5. Develop the question wording.

6. Put questions into a meaningful order and format.

7. Check the length of the questionnaire.

8. Pre-test the questionnaire.

9. Develop the final survey form.

3. Qualities of Good Questionnaire ...cont'd

Types of Questionnaires in Research

- **Postal:** a paper surveys that participants receive through the mail. Once respondents complete the survey, they mail them back to the organization that sent them.
- **In-house:** researchers visit respondents in their homes or workplaces and administer the survey in person.
- **Telephone:** With telephone surveys, researchers call respondents and conduct the questionnaire over the phone.
- **Electronic:** Perhaps the most common type of questionnaire, electronic surveys are presented via email or through a different online medium.

[8]. Cint, What Is a Questionnaire and How Is It Used in Research, June 29, 2022.https://www.cint.com/blog/what-is-a-questionnaire-and-how-is-it-used-in-research

4. Quiz

Say True or False

1. The primary goal of empirical research is to generate knowledge about how the world works by relying on verifiable evidence obtained through observation and experimentation. **TRUE**
2. Empirical research is based on abstract ideas and concepts without necessarily relying on real-world data. **False**
3. Common challenges in conducting empirical research include difficulties in data collection, time-consuming processes, obtaining permissions for certain methods, high costs, and potential misinterpretation of statistical significance. **TRUE**
4. The correct steps involved in conducting empirical research include establishing the research objective, framing hypotheses, reviewing relevant literature defining research design and methodology, collecting data, analyzing data, and making conclusions. **False**

Summary

- Empirical research is a "systematic approach for answering certain types of questions which are answered through the collection of evidence under carefully defined and replicable conditions.
- Empirical research plays a key role in checking or improving current theories, providing a systematic way to grow knowledge across different areas.
- Empirical Research Cycle involved observation , induction, deduction ,testing and evaluation.
- The empirical writing follows a structure such as Define Objectives, be specific in literature review, explain methods clearly, share results clearly, etc.
- A questionnaire designed depending on whether the researcher wishes to collect qualitative information or quantitative information. Also, steps involved in the development of a questionnaire is significant for the quality:

References

1. Paperpal, Empirical Research: A Comprehensive Guide for Academics, Elizabeth Oommen George, January 18, 2024. https://paperpal.com/blog/researcher/empirical-research-a-comprehensive-guide-for-academics.

2. Research.com, What is Empirical Research? Imed Bouchrika, https://research.com/research/what-is-empirical-research.

3. Voxco, Definition, Types and Examples of Empirical Research, April 1, 2021. https://www.voxco.com/blog/empirical-research/

4. Wikipedia, Empirical Software Engineering. https://en.wikipedia.org/wiki/Empirical_software_engineering

5. Empirical Research in Software Engineering (Doctoral dissertation, HSR), Kapferer, S., 2019. https://eprints.ost.ch/id/eprint/820/

6. Runeson, P., Host, M., Rainer, A., & Regnell, B. (2012). Case study research in software engineering: Guidelines and examples. John Wiley & Sons, Page 17-21.

7. Food and Agriculture Organization (FAO), Chapter 4: Questionnaire Design. https://www.fao.org/4/w3241e/w3241e05.htm

Thank you!