Course: Research Method in Software Engineering

WEEK 9– Research Strategies and Methods for Software Engineering

Lemlem Kassa (Ph.D.)
Addis Ababa Science and Technology University,
Ethiopia

Week 9. Research Strategies and Methods for Software Engineering

Contents

1. Research Methods in Software Engineering
2. Field Studies in Software Engineering
3. Action Research in Software Engineering
4. Overview of Empirical Research Evaluation

Learning Outcome

- Understand research methods in software engineering and commonly used methodologies
- Understand the pros and cons of Research and Development (R&D)
- Differentiate the most commonly used software engineering research methods
- Understand field study research
- Identify software engineering data collection methods in field Studies
- Understand the role of action research in software engineering
- Understand empirical research evaluation

1. Research Methods in Software Engineering

- Research methods in software engineering varies, but one commonly used methodology is **action research.**
  - Action research is a methodology that gained popularity due to its appeal to both researchers and organizations seeking practical application of scientific results.
- Another research methodology commonly used in software engineering is **research and development (R&D)**.
  - R&D supports communication between software developers and users, making it suitable for software engineering research.

[1]. Investopedia, Research and Development (R&D) Expenses: Definition and Example,
The Investopedia Team.October 08, 2024. https://www.investopedia.com/terms/r/research-and-development-expenses.asp

1. Research Methods in Software Engineering ..cont'd

What is Research and Development (R&D)?

- It refers to the systematic process of investigating, experimenting, and innovating to create new products, processes, or technologies.
- It encompasses activities such as scientific research, technological development, and experimentation conducted to achieve specific objectives to bring new items to market.
- Among the primary purposes of R&D activities is for a company to remain competitive as it produces products that advance and elevate its current product line.
- R&D projects may lead to patents, trademarks, or breakthrough discoveries with lasting benefits to the company.

[1]. Investopedia, Research and Development (R&D) Expenses: Definition and Example, The Investopedia Team.October 08, 2024. https://www.investopedia.com/terms/r/research-and-development-expenses.asp

1. Research Methods in Software Engineering ..cont'd

Importance of R&D in software product development and its activities

- Designing and developing new products that have increased effectiveness or functionality
- Developing enhancements/improvements of existing products
- Designing and developing new testing methods
- Developing improved technologies
- Development of automated processes to improve efficiency
- Development of software for product or process improvements

[1]. Investopedia, Research and Development (R&D) Expenses: Definition and Example,
The Investopedia Team.October 08, 2024. https://www.investopedia.com/terms/r/research-and-development-expenses.asp

1. Research Methods in Software Engineering ..cont'd

Pros and cons of Research and Development (R&D)

Pros

- Facilitates innovation
- Improved or new products and services
- Expands knowledge and talent pool
- Increased consumer choice and brand loyalty
- Economic driver

Cons

- Financial investment:-requires a significant investment of cash upfront
- Takes time: It takes a lot of time to bring products and services to market from conception to production to delivery.
- Shifting market trends: Because it does take time to go from concept to product, companies stand the risk of being at the mercy of changing market trends

[1]. Investopedia, Research and Development (R&D) Expenses: Definition and Example, The Investopedia Team.October 08, 2024. https://www.investopedia.com/terms/r/research-and-development-expenses.asp

1. Research Methods in Software Engineering ..cont'd

The most commonly used software engineering research methods

- **Controlled Experiments**: observe the effect of altering one variable while keeping others constant, making them ideal for testing specific hypotheses in controlled settings. While they excel at showing cause and effect, they may not fully capture the complexities of real-world scenarios.
- **Case Studies**: offer an in-depth investigation into specific instances, such as a project, process, or organizational structure. They provide valuable insights and detailed perspectives but are often criticized for their limited broader applicability. Despite this, they are invaluable for understanding rich contextual details within their study environments.

[2]. WebDevStory, Mastering Empirical Research Methods in Software Engineering, Mainul Hasan,November 19, 2023. https://www.webdevstory.com/empirical-research-methods-software-engineering/

1. Research Methods in Software Engineering ..cont'd

- **The most commonly used software engineering research methods**
  - **Surveys:** Employing questionnaires or interviews, surveys effectively collect data from many respondents. They excel at uncovering prevalent trends and attitudes but can be susceptible to biases and often face challenges with response rates.
  - **Action Research**: This method is particularly suited for addressing real-world problems. It involves iterative planning, acting, observing, and reflecting cycles, making it ideal for studies aiming to implement change in practices.

[2]. WebDevStory, Mastering Empirical Research Methods in Software Engineering, Mainul Hasan,November 19, 2023. https://www.webdevstory.com/empirical-research-methods-software-engineering/

2. Field Studies in Software Engineering

What is a field study?

- A field study is a research method that revolves around observing the research subjects in their natural environment without any interference on the researcher's part.
- One could think of field studies as the complete opposite of lab research where the subjects operate in a highly controlled setup.
- Field studies are a powerful research methodology that can prove to be particularly effective when researchers are looking to understand the impact that the environment can have on the behavior of a subject, as well as the context within which the subjects are operating.

[3].QuestionPro, What is Field Research: Definition, Methods, Examples and Advantages, Adi Bhat. https://www.questionpro.com/blog/field-research/

2. Field Studies in Software Engineering …cont'd

What are field studies? ….cont'd

- Field studies aim to integrate theory and practice to increase and deepen knowledge on a given subject. However, to implement a study of the environment effectively, it is necessary the following some steps:
  - Planning and deciding the study theme;
  - Collection of authorization from families to take students to the chosen location;
  - Definition of the specific and general objectives of the activity;
  - Elaboration of the field notebook, where the relevant observations should be noted;
  - Disclosure of achieved results.

[3].QuestionPro, What is Field Research: Definition, Methods, Examples and Advantages, Adi Bhat. https://www.questionpro.com/blog/field-research/

2. Field Studies in Software Engineering …cont'd

- Field research is a valuable approach in software engineering that helps bridge the gap between theory and practice, ensuring that software development is aligned with real user needs and organizational contexts.
- In order to improve software engineering tools and practice, it is therefore essential to conduct field studies, i.e., to study real practitioners as they solve real problems.
- To aid this goal, we describe a series of data collection techniques for such studies, organized around a taxonomy based on the degree to which interaction with software engineers is necessary.

[4]. Guide to advanced empirical software engineering (Vol. 93). Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008. Page -9

2. Field Studies in Software Engineering …cont'd

Data Collection in field studies

- Brainstorming, focus groups, interviews, questionnaires, conceptual modeling),
- **Observational**
  - Techniques provide a real-time depiction of the studied phenomena.
  - Can be used at randomly chosen times or when a software engineer is engaged in a specific type of activity.
  - Careful consideration of this effect is therefore warranted in implementing the research and explaining its purpose and protocol to the research participants.

[4]. Guide to advanced empirical software engineering (Vol. 93). London, Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008. Page-12

2. Field Studies in Software Engineering …cont'd

Data Collection in field studies …cont'd

Brainstorming

- In brainstorming, several people get together and focus on a particular issue. The idea is to ensure that discussion is not limited to "good" ideas or ideas that make immediate sense, but rather to uncover as many ideas as possible.
- Brainstorming works best when there is a simple "trigger question" to be answered and everybody is given the chance to contribute their opinions.

Focus Groups

- Similar to brainstorming. However, focus groups occur when groups of people are brought together to focus on a particular issue (not just generate ideas). They also involve moderators to focus the group discussion and make sure that everyone has an opportunity to participate.

2. Field Studies in Software Engineering …cont'd

Data Collection in field studies …cont'd

Interviews

- Interviews can be conducted in two ways→ structured interview, a fixed list of carefully worded questions forms the basis of the interview.
- In a semi-structured interview, the interview generally follows more of a conversational flow. New questions may be devised as new information is learned.
- **Example**:- interviews of experienced personnel and senior management to examine how changes in the requirements engineering process affected software development practice

[4]. Guide to advanced empirical software engineering (Vol. 93). London, Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008. Page-13

2. Field Studies in Software Engineering …cont'd

Data Collection in field studies …cont'd

Questionnaires

- Questionnaires are sets of questions administered in a written format.
- These are the most common field technique because they can be administered quickly and easily.
- However, very careful attention needs to be paid to the wording of the questions, the layout of the forms, and the ordering of the questions in order to ensure valid results.

Example : questionnaires that were partly web-based and partly paper-based to learn what knowledge software engineers apply in their daily work, and how this relates to what they were taught in their formal education.

[4]. Guide to advanced empirical software engineering (Vol. 93). London, Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008. Page-15

2. Field Studies in Software Engineering …cont'd

Data Collection in field studies …cont'd

Conceptual Modeling

- During conceptual modeling, participants create a model of some aspect of their work – the intent is to bring to light their mental models. In its simplest form, participants draw a diagram of some aspect of their work. For instance, software engineers may be asked to draw a data flow diagram, or a control flow diagram.
- The most important thing to report for conceptual models is the exact instructions given to the participants and a precise description of the tools that they had available to them to model.
- The way the data is recorded should also be outlined.

[4]. Guide to advanced empirical software engineering (Vol. 93). London, Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008. Page-16

2. Field Studies in Software Engineering …cont'd

Data Collection in field studies …cont'd

Participant Observation

- In this method of field research, the researcher is deeply involved in the research process, not just purely as an observer, but also as a participant.
- This method too is conducted in a natural environment but the only difference is the researcher gets involved in the discussions
- Researchers live in a comfortable environment with the participants of the research design, to make them comfortable and open up to in-depth discussions.
- Researchers can develop a deeper understanding of software engineering tasks after performing them in the context of a software engineering group.

[4]. Guide to advanced empirical software engineering (Vol. 93). London, Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008. Page-22

3. Action Research in Software Engineering

Action Research

- As its name suggests, action research conducts research and takes action at the same time.
- A highly interactive method, action research is often used in the social sciences, particularly in educational settings.
- Particularly popular with educators as a form of systematic inquiry, it prioritizes reflection and bridges the gap between theory and practice.
- Sometimes called a **cycle of action** or a cycle of inquiry.

Fig. Action Research cycle. https://www.scribbr.com/wp-content/uploads/2023/04/action-research-cycle.webp

[5]. Scribbr,Action Research: Definition, Process, and Examples. https://www.scribbr.com/methodology/action-research

3. Action Research in Software Engineering ..cont'd

Action Research ….cont'd

- Software is everywhere, it produces the best solutions of human and society needs, which is a mix of technology and social sciences, action research is a choice that helps to increase the impact of academic research and impact of new technology development, where academia and industry can work together, and researchers and practitioners learn from each other.
- Action research is a research methodology that is primary focuses on solving a real problem rather than experimental studies,
- Conducted in a human or an organizational context, in which a researcher can play a helping role becomes part of the study - and working together with a client of an organization that is being studied in order to solve the organization's problem.

[6]. LinkedIn, Action Research in Software Engineering, Maha Alolyan, October 15, 2022.https://www.linkedin.com/pulse/action-research-software-engineering-maha-alolyan/

3. Action Research in Software Engineering ..cont'd

Action Research ….cont'd

- It is a method for co-development of research results, where academia and industry can work together.
- Through this collaborative approach, the researchers and practitioners learn from each other, and thus they develop research results which contribute to both the industrial practice and academic theories, tools, methods, and knowledge development.

[5]. Scribbr,Action Research: Definition, Process, and Examples. https://www.scribbr.com/methodology/action-research

4. Overview of Empirical Research Evaluation ..cont'd

Empirical studies in software engineering

- The aim of empirical studies in software engineering is to provide a scientific and thus more rational basis for understanding, evaluating, predicting, controlling, and improving tools, methods, and techniques used in software engineering.
- Empirical studies collect and analyze observations about theories, models, and systems, based on instances from either the real world or the models of the real world.
- Controlled experiments and case studies are examples of empirical studies.
- Empirical evaluation especially focuses on providing evidences that support research results.

[7]. 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.

4. Overview of Empirical Research Evaluation ..cont'd

- A good empirical evaluation is the proper design and execution of the experiments so that the particular factors to be tested can be easily separated from other confusing factors.

Example:-

  - Test whether a software system with a user model works better
  - Test the effect of different levels of user modeling or different user model parameter settings,
  - Test different user interfaces.

- These factors, which are under the control of the experimenter, are termed **independent variables** because their values can be varied independently of other variables by the experimenter.

[8]. Empirical evaluation of user models and user-adapted systems. User modeling and user-adapted interaction, Chin, D. N. (2001)., Page-181.

4. Overview of Empirical Research Evaluation ..cont'd

- Dependent variables are variables whose values depend on the values of other variables.
- Include response variables or recorded measures such as:
  - **Example** : system usage, qualities of a behavior in a particular situation, number of errors, error rate, time to complete a task, interaction patterns, learning time/rate, and/or subjective evaluations (e.g., user satisfaction).

[8]. Empirical evaluation of user models and user-adapted systems. User modeling and user-adapted interaction, Chin, D. N. (2001)., Page-181.

Summary

- Research and Development (R&D) is a systematic process of investigating, experimenting, and innovating to create new products, processes, or technologies.
- Controlled Experiments, case studies, surveys and action researches are the most commonly used Software Engineering Research methods .
- A field study is a research method that revolves around observing the research subjects in their natural environment without any interference on the researcher’s part.
- Action research is a choice that helps to increase the impact of academic research and impact of new technology development in software engineering.
- Empirical evaluation obtains a generalized prevision of how successful software engineering result would be in the real world practices and also it is based on statistical theory of sampling which is widely accepted by many other science discipline as well.

References

1. Investopedia, Research and Development (R&D) Expenses: Definition and Example, The Investopedia Team. October 08, 2024. https://www.investopedia.com/terms/r/research-and-development-expenses.asp

2. WebDevStory, Mastering Empirical Research Methods in Software Engineering, Mainul Hasan,November 19, 2023. https://www.webdevstory.com/empirical-research-methods-software-engineering/

3. QuestionPro, What is Field Research: Definition, Methods, Examples and Advantages, Adi Bhat. https://www.questionpro.com/blog/field-research/

4. Guide to advanced empirical software engineering (Vol. 93). Shull, F., Singer, J., & Sjøberg, D. I. (Eds.), Springer, 2008.

5. Scribbr, Action Research: Definition, Process, and Examples. https://www.scribbr.com/methodology/action-research

6. LinkedIn, Action Research in Software Engineering, Maha Alolyan, October 15, 2022.https://www.linkedin.com/pulse/action-research-software-engineering-maha-alolyan/

7. 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.

8. Empirical evaluation of user models and user-adapted systems. User modeling and user-adapted interaction, Chin, D. N. 2001.

Thank You!