Novel Emprical Methods for Advance Software Engineering Research

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Abstract

Software engineering is an strongly people-oriented task, yet few concepts are known regarding the role of software engineers. In order to improve software engineering tools and practice, it is much essential to conduct field studies, i.e., to study real practitioners as they solve real problems. To aid this goal, we exhibit assorted data collection techniques for comparable studies, organized encompassing a taxonomy based on the degree to which synergy with software engineers is essential. For every technique, examples are provided ,along with analysis of some of its advantages and disadvantages, and a discussion of special reporting requirements.

Keywords—*ethnography, quasi-experiments, empirical, software engineering*

I. INTRODUCTION

In contempt of widespread passion in empirical software engineering, there is scant conveyance on which research methods are suitable to which research problems, and how to elect key questions to pretend in selecting a method, from philosophical considerations about the nature of knowledge to practical considerations in the application of the method. We speak key empirical practices relevant to empirical software engineering, and deliver the stableness and faults of each. Software engineering is a multi-disciplinary field, exchanging many social and Technological bounds.

Most of the investigators select inapplicable forms because they do not deduce the goals hidden in a method. As a elementary step in helping researchers select an appropriate method, this canvass retain complex, evolving software systems, we need to inspect not just the tools and processes they use, but also the social and cognitive processes encompassing them. This craves the survey of human activities. We need to master how individual software engineers evolve software, as well as how teams and organizations correlate their efforts. Because of the emphasis of human activities in software development, most of the research methods that are relevant to software engineering are taugt from disciplines that deliberate human behavior. These methods have known bugs, and each can only provide confined, competent confirmation about the phenomena being studied. Inspite, each method is flawed differently and doable research strategies use multiple methods, chosen in such a way that the skewness of each method are addressed by use of complementary methods .

Representing in deep the wide variety of possible empirical methods and how to handle them is beyond the scope . Preferably, we identify and compare five classes of research method that we believe are most correspond to software engineering:

- Controlled Experiments (including Quasi-Experiments)
- Case Studies (both exploratory and confirmatory)
- Survey Research
- Ethnographies
- Action Research

To illuminate the steps elaborating in deciding which method to use, we present two examples. Two fictive software engineering researchers X and Y, will explore how the diverse research methods can be applied for their work:

- Software researcher X is a new PhD student interested in the efficacy of a novel fisheye-view file navigator. Her research is inspired by the fact that exploration is a dominant task of software developers needing a lot of wrap around and many clicks to treasure files. “Fisheye-views” use a intuition usage that, if applied properly, reveal information in a firm format that could potentially reduces the amount of scrolling needed. X perception is that the fisheye-view file navigator is very much efficient for file navigation, but evaluators argue that the more compact information is complex to read and developers will not approve it over the traditional file navigator. Her research goal, is to fetch clue that supports or rejects her perception that fisheye-view file navigators are more adequate when compared to that of traditional file navigators for navigation.
- Y is a investigator in an industrial lab. His rampant interests are in deducing

QUESTION NUMBER	TYPE OF QUESTION	EXPLANATION
1.	Existence questions	"Does A exist?" X wish to ask, file navigation evidently that (certain types of programmers) really do?"and, "Is readiness actually a problem in file navigation?" Y might need to ask,"Do collaborative shared artifacts actually exist?"
2.	Description and Classification questions	"What is A like?", "What are its properties?", "How can it be categorized?", "How can we measure it?","What is its purpose?", "What are its components?", "How do the components relate to one another?", and "What are all the types of A?" X might ask, "How can we measure efficiency for file navigation?" and Y might ask, "What are all the types of collaborative shared artifacts?"
3.	Descriptive-Comparative questions	"How does Adiffer from B?" investigate similarities and differences between two or more phenomena. X might ask, "How do fisheye views differ from conventional views?" and Y might ask, "How do UML diagrams differ from other representations of design information?"

how developers in industry use (or not) UML diagrams in software design.

As a student, his educators recommended UML diagrams used in software design, but his contemporary disclosure to industrial practices shows

that UML is seldom used. His research goal is to scrutinize how extensively UML diagrams are used in industry, and more particularly how these diagrams are used as synergistic shared artifacts during design. We scrutinize how X and Y develop research

Relationship questions such as, "How repeatedly do A occur?"and, "What is an moderate amount of ?"Recurrantly, these queries can be responded in terms of a standard distribution of a characteristic within a precise population.Y original question appears to be a frequency question, but there are innumerable ways for to formulate it more literally. Forinstance, he might ask,"How many definite UML diagrams are formulated in software development projects in massive software companies?" and might locate the results follow some typical statistical distribution.

- Descriptive-Process questions of the form, "How does A typically work?",

"What are the steps by which A happens?", "In what order do the events of

X occur?", "What are the processes A follows as it evolves?", "How does A

Complete its purpose?". For example, X might ask, "How do programmers

navigate files using extant tools?".

- Relationship questions such as, "Are A and B related?" and, "Do contingency of X associate with the occurrences of Y?" For instance, X might ask,

strategies for projects. We start with an analysis of the type of research question they are asking, and the issue of what incorporates accurate answers to them.

To address the eventual question, we tour the important philosophical instances that derive empirical research. We then depict the five classes of research method, and introduce criteria for distinguishing between them.

What kind of Research Question are You Asking? "Does expertise in file navigation interact with the programmer's closeness with the programming environment?" Y might ask, "Do managers' plea about how generally they use UML correspond with the actual use of UML?"

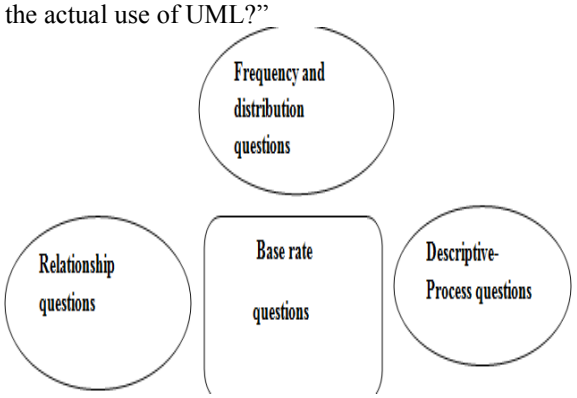


Fig.1. Classes of Research Questions

A. Casuality Questions Include:

- Causality questions of the form, "Does A motive B?" and "Does A stopB?"

Plus the more general forms: "What causes B?", "What are all the factors that

cause B?", "What effect does A have on B?" In software engineering we often ask whether using a

particular tool or technique causes an improvement in quality, speed, and so on. X initial question appears to be of this type: "Do fisheye-views cause an improvement in efficiency for file navigation?"

- Causality-Comparative questions investigate relationships between different causes: "Does X cause more B than does A?" or, "Is A better at preventing B than is C?" Unless A has good base-rate data for existing file navigation tools, X causality question would be given as "Do fisheye-views cause programmers to be more effective at file navigation than conventional views?"

- Causality-Comparative Interaction questions investigation how context affects a cause–effect relationship: "Does A or C cause more B under one condition but not others?" If X initial studies reveal a factor that affects causality, she might ask "Do fisheye-views cause programmers to be more efficient at file navigation than conventional views when programmers are diverted, but not otherwise?"

In comparison many non-empirical research in software engineering focuses on a very divergent type of question concerned with designing best ways to do software engineering (Simon, 1996)

What will You Accept as an Empirical Truth?
Positivitism:

- States that all instruction must be based on logical inference from a set of essential observable facts.
- Positivists are *reductionist*, in that they stud y facts by dividing them into lucid components.
- Scientific knowledge is finished up incrementally from *verifiable* observations.
- Positivism is most intimately unite with the *controlled experiment.*
- Positivists choose methods that begin with rigid theories from which

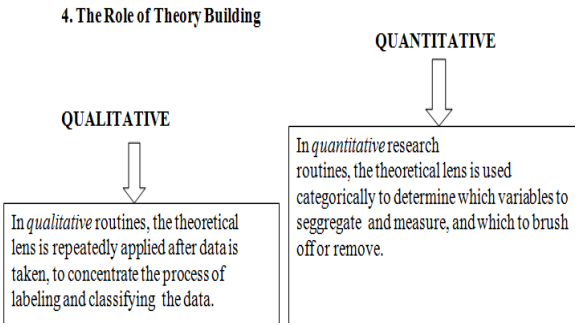
Confirmable hypotheses can be extracted, and tested in segregation.

B. Constructivism:

- Termed as interpretivism, dismiss the idea that scientific knowledge can be disunited from its human context.
- Constructivists focuses less on substantiating theories, and more on responsing how peculiar people make sense of the world, and how they hire context to actions.
- Constructivists consider methods that gain rich qualitative information about human activities, from which local facts emerge.
- Constructivism is more deeply linked with ethnographies.
- Constructivists much use exploratory case studies and also survey research.

C. Critical Theory:

- Judges scientific knowledge by its capacity to free people from confining classification of logic.
- Critical theorists squabble that research is a political act as knowledge entrust distant groups within society, or fortify existing power structures.
- They select participatory approaches in which the groups that they are trying to help are involved in the research.
- Critical theorists tend to share emancipatory or backing acts.



II. SELECTING METHODS

A. Controlled Experiments

- ✓ A controlled experiment is an exploration of a deductible axioms where one or more self _contained variables are managed to grade consequence on one or vulnerable variables.
- ✓ Each combination of values of the experiment self _contained variables is a remedy.
- ✓ Many software engineering analysis require human subjects to perform some process.
- ✓ For instance, X might set to run an research to validate the assumption that fisheye views cause more efficient file navigation than traditional file tree explorer views.
- ✓ Control is essential.
- ✓ Variants on analysis are accessible and can be used in conditions where a true is analysis not conceivable.
- ✓ For instance, in quasi- analysis the subjects are not given randomly to the treatments.
- ✓ Quasi-experiments may used, for ethical logics, subjects must be allowed to choose their treatment.
- ✓ In time-series experiments, the effect of a treatment is measured in discrete time steps over a period of time. These variations are little powerful than real analysis, and need more keen interpretation.

B. Case Studies

- ✓ Yin (2002) introduced the case study as "an empirical inquiry that inspects a current phenomenon within its real-life context, keenly when the boundaries between phenomenon and context are unclear.

- ✓ Case studies bid deep understanding of how and why assertive phenomena pass, and can confess the mechanisms by which cause–effect relationships occur.
- ✓ Exploratory case studies are used in basic investigations of some phenomena to get new hypotheses and build theories.

Confirmatory case studies validate existing theories.

- ✓ The last are essential for refuting theories: a deep case study of a original situation in which a theory fails may be more convincing than "failed" analysis in the lab.
- ✓ A precondition derives a study proposition that describes precisely what the study is intended to display.
- ✓ The choice of cases is a main task in case study research.
- ✓ Case study research uses predetermined sampling other than casual sampling.
- ✓ The goal is to choose cases that are more correlated to the study proposition.
- ✓ Sometimes only one case is enough. This is be because it is a critical case for testing a well-formulated theory.
- ✓ Sometimes it is enough to locate a typical case to get more insight into common conditions.
- ✓ For confirmatory case studies, these can be chosen as literal replications, where every case is familiar to display the same results, or as theoretical replications, where cases are expected to show different results for predictable reasons.
- ✓ Data accumulation is done with respect to a well-defined unit of analysis.
- ✓ The criteria for assessing is based on which philosophical instance is considered.

C. Survey Research

- ✓ Survey research is used to analyze the features of immense population of Individuals.
- ✓ The defining feature of survey research is the choice of a representative sample from a well-defined population.
- ✓ A major deal in survey research is to control for sampling intolerance.
- ✓ An even complex deal is to provide that the queries are designed in a way that produces valid data.
- ✓ Survey research falls solely into the positivist custom.
- ✓ Theaspiration to characterize complete population via sampling techniques needs a trust in reductionism, and a firm with generalizable theories.
- ✓ If Y is more passionate in understanding the tradition of information sharing within development teams, he might instead follow a constructivist instance, and ethnography or action research.

D. Ethnographies

- ✓ Ethnography is a way of research concentrating on the sociology of essence through field observation.
- ✓ The aim is to study a group of people to understand how the members of that group make sense of their social synergies.
- ✓ The preconditions for an ethnographic study involves a research question that concentrates on the traditional practices of a specified group and access to members of that group.
- ✓ The output of an ethnographic study is a rich confession of the group being studied that helps to make a deep frame of that group's culture.
- ✓ A peculiar form of ethnography is participant conception, where the researcher becomes a member of the group being studied for a period of time.
- ✓ Ethnographic researchers create local theories to improve understanding.
- ✓ This philosophical instance differentiates ethnography from case studies, surveys and field experiments.

E. Action Research

- ✓ In Action Research, the researchers endeavour to elucidate a real-world problem while simultaneously considering the experience of solving the task
- ✓ Precondition for action research is to take a problem owner in favour to hook up to identify a problem, as well as involve in an effort to solve it.
- ✓ Two key criteria for testing the essence of action research are whether the original problem is authentic and if there are authentic knowledge outcomes for the participants.
- ✓ Action research is also defined by a commitment toreact to real change, and an iterative approach to problem solving.
- ✓ Action research is deeply affiliated with critical theory.

F. Mixed-Methods Approaches

- ✓ This approach can be represented as mixed methods research – a complex research strategy that evolved in the recognition that every methods contain conditions, and the weaknesses of one method can be balanced for by the strengths of other methods (Creswell, 2002).
- ✓ The description of three most familiar strategies described by Creswell (2002):
- ✓ The Sequential explanatory strategy is defined by the seggretation and analysis of quantitative data proceeded by the cumulation and analysis of qualitative data.
- ✓ The Sequential exploratory strategy is symbolized by the selection and analysis of qualitative data proceeded by the accumulation and analysis of quantitative data.

- ✓ Its task is to use quantitative data and outputs to aiding in the clarification of qualitative findings.
- ✓ The Concurrent triangulation strategy is the most known and widely used amongst the mixed-method approaches.
- ✓ This strategy use definite methods, in an attempt to check, cross-validate or corroborate findings.
- ✓ Therefore, mixed methods research is more often associated with a pragmatist instance.

III. EMPIRICAL VALIDITY

For empirical work to be admissible as a grant to scientific knowledge, the

Researcher wish to convince readers that the consequences drawn from an empirical study are laid. Positivists usually analyze four criteria for validity:

● Construct validity concentrates in case the theoretical constructs are interpreted

and measured accurately.

● Internal validity concentrates on the study scheme, and especially whether the outputs really follows from the data.

● External validity concentrates on whether claims for the observation of the results are justified.

● Reliability concentrates on whether the study produces the same results if other researchers to dupe it.

Creswell (2002) identifies eight strategies for developing validity of constructivist

research, which are most suited to ethnographies and exploratory case studies in software engineering:

1. Triangulation: uses divergent source of data to affirm consequences and build a coherent frame work.

2. Member checking: reach back to research participants to certify that the interpretations of the data make sense from their viewpoint.

3. Rich, thick descriptions: wherever possible, use precise definitions to deliver the setting and findings of the research.

4. Clarify bias: honest with respect to the intolerances delivered by the researchers to the study, and use this self-reflection when reporting findings.

5. Report discrepant information: when reporting findings, report not only those

Consequences which approve the derived theory, but also those to present distinct prospects on the findings.

6. Prolonged contact with participants: Makes clear that disclosure to the subject

population is satisfied to provide acceptable understanding of the controversies and phenomenon under study.

7. Peer debriefing: Before broadcasting findings, detect a peer debriefer who can ask queries about the study and the constraints in the reporting of it, so that the ultimate account is as valid as possible.

8. External auditor: Similar as peer debriefing, instead of using a person who is

known to the researcher, an external auditor to scrutiny the research process and findings is found.

Technique	Advantages	Disadvantages
Brainstorming and Focus Groups	Brainstorming and focus groups are sterling data collection technique when one is new to a domain and getting ideas for further expedition. They are very useful for collecting from giant communities of people at once.	Except the moderator is well trained, brainstorming and focus groups can become too unfocused. It is difficult to catalogue a brainstorming session or concentrate group with the busy schedules of software engineers.
Interviews	Structured interviews are an effective means of cumulating the same data from a numerous amount of respondents. Semi-structured interviews contribute to be more highly interactive. Researchers can clarify queries for respondents and probe foreseen responses.	Interviews are time and cost inept. If the data from interviews contains audio- or videotapes, it need to be converted or coded; careful note-taking may, be an suitable substitute for audio or video recording.
Questionnaires	Questionnaires are time and cost effective. Questionnaires can easily acquire data from a numerous number of respondents in geographically diverse locations.	As there will be no interviewer, ambiguous and poorly-worded queries are problematic. Response rates can be less which adversely alter the representativeness of the sample.
Conceptual Modeling	Conceptual models gives an exact portrayal of the user's design of his or her mental model of the system. Those models are easy to gather	The outputs of conceptual modeling are often complex to interpret.

	and requires only less-tech aids.	
Work Diaries	Work diaries provides best self-reports of events as they record activities on present rather than in review.	May be interfered with respondents as they work. Also forget or neglect to record few events and may not record at the expected level

Fig.3.Popular Research Mechanisms With Pros And Cons

Technique	Advantages	Disadvantages
Instrumenting Systems	System monitoring requires negative time commitment from software engineers. As, people turn to be very poor judges of factors such as relative frequency and duration of the various activities they perform, this technique can be used to provide such data correctly.	It is complex to analyze data from instrumented systems ;means that , it is complex to decide software engineers' intentions and aims from a series of tool invocations.
Fly on the Wall	The fly-on-the-wall technique needs very less time from the participants and is very unobtrusive. Though there may be little discomfort in the starting, it fades fastly.	The participants may forget to circulate on the recording equipment at the right time and as a consequence the record may be incomplete or missing. Requires more cost in analyzing data.

Fig.4.Indirect Mechanisms With Pros and Cons

IV. PRACTICAL CONSIDERATIONS

Approaches that are chiefly qualitative accommodate ethnography, case study, and action research. These methods depends on fieldwork, using practices such as participant observation and interviews. Key dares involves adapting good questions for structured or semi-structured interviews, and decisioning the time and resources is required to gather and analyze potentially numerous sets of data. The researcher requires a thorough training to observe and record social behavior. Entries to the field situation may need delayed time in creating a relationship with the subject organization such that specific project information is made available. For ethnography, the researcher requires to search for a community where she is included as a member, which might not be possible except if she has appropriate technical experience.

For action research, the researcher requires to compensate the need to get into the organization in serving to set appropriate aim for the research with the need to remain objective, such that the research do not turn into purely consulting.

Approaches that are primarily quantitative involve controlled experiments and survey research. These methods needs more suggestive time in the outlining of the research than strictly qualitative methods. To acquire external validity for both experiments and surveys, the researcher requires the time and budget to (1) determine, recruit and randomly choose a sample population that is illustrative of the target population,

(2) Architecture and pilot the queries such that all respondents are granted with querie

that they interpret and understand in exactly the same way.

(3) Determine statistical attempts in the lead of time, in order to interpret the gathered data.

The aim here is to plan ahead, for smooth analysis and interpretation of consequences.

All research performed in industrial settings brings a number of trials. It can be very

difficult to collect data to search what practitioners actually do, or what requires to be revised in the organization, rather than what practitioners say they do or think require improvement.

V. CONCLUSION

A key message throughout the paper is that empirical research never produces certain knowledge. Each of the methods we have available for empirical investigations help to elucidate the phenomena being studied, but each also has significant flaws. Awareness of the limitations of each method should allow you to design a study that minimizes the

weaknesses. Furthermore, the flaws can be overcome by mixing methods, and/or by conducting replications . We believe that clearer distinctions between research methods are necessary to facilitate better study designs and clearer criteria for evaluating empirical research. The definitions and distinctions we offer in this paper are by no means widely agreed upon, neither in the empirical software engineering community, nor in related disciplines. For example, we have avoided the usual distinction between qualitative and quantitative methods, as we believe the distinctions between methods are more subtle than simply the type of data collected. Instead, we have emphasized differences in philosophical stance, and in criteria used for designing studies for each type of method. We hope that this paper provides a first step towards a consensus on empirical methodology in software engineering.

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