Using Qualitative Methods in Empirical Studies of Software Engineering

Carolyn Seaman

University of Maryland Baltimore County

Fraunhofer USA Center for Empirical Software Engineering Maryland

Universidade Federal de Pernambuco

USP

26 March 2013

São Paulo, Brasil

UMBC

AN HONORS UNIVERSITY IN MARYLAND

Outline

- What, when, why qualitative methods?
- Data collection techniques
  - Participant observation
  - Interviewing
    - Hands on exercise
- Data analysis techniques
  - Coding
  - Constant comparison method
    - Hands on exercise
- Verification
- Mixed methods

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Definitions

- Qualitative data - data in the form of text and pictures, not numbers
- Qualitative analysis – analysis of qualitative data in order to discover trends, patterns, and generalizations
- Grounded theory – theory formed bottom-up from the (usually qualitative) data
- Rich data – data that includes a lot of explanatory and context information

Why Qualitative Methods?

- Problem: Difficult to answer complex SE questions with a purely quantitative approach because
  - Working with human subjects
  - Typically have small sample sizes
  - Experiments are expensive to run
  - Need some support for a hypothesis before investing effort in full experiment
- Solution: Use a qualitative approach that includes a quantitative aspect

Types of results

A qualitative study will result in:

- Propositions tied to a trail of "evidence"
- Well-grounded hypotheses
- Complex findings that incorporate the messiness of the phenomenon under study
- Explanations
- Areas for future study

Types of Research Questions

Qualitative methods are most appropriate when:

- Subject of study involves human behavior
- No concrete hypotheses
- Variables hard to define or quantify
- Little previous work
- Quantitative results may be hard to interpret

Advantages to Researchers

- Richer results
- Results more explanatory
- Closer to sources of data
- Avoid errors in interpretation

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Advantages to Practitioners

- Richer, more relevant results
- Terminology of results
- More part of the research process
- Opportunity to clarify and explain findings

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Overview of Techniques

Data Collection

- Prior Ethnography
- **Participant Observation**
- **Interviewing**
- Surveys
- Document Analysis

Data Analysis

- Coding
- **Constant Comparison Method**
- Cross-case analysis
- Member checking
- Auditing

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Participant Observation

Definition: non-covert direct observation of phenomenon

Example: Observation of code inspection meetings

- collected both qualitative and quantitative data
- did not participate in the inspection
- used data forms as well as field notes

Observation Data Form

Inspection Data Form

Class(es) inspected Inspection date: Time:

Author:

Moderator:

Reviewers:

Name	Responsibility	Preparation time	Present

Amount of code inspected:

Complexity of classes:

Discussion codes:

D = Defects Q = Questions C = Classgen defect U = Unresolved issues G/D = Global defects G/Q = Global questions P = Process issues A = Administrative issues

M = Miscellaneous discussion

Time logged (in minutes):

D_____ Q_____ C_____ U_____ G/D_____ G/Q_____ P_____ A_____ M_____

Field Notes Example

The "step" function is a very important but complicated function. [Reviewer1] did not have time to review it in detail, but [Author] said he really wanted someone to go over it carefully, so [Reviewer1] said she would later.

There was a 4-minute discussion of testing for proper default values. This is a problem because often the code is such that there is no way to tell what a particular variable was initialized to. [Reviewer2] said "I have no way to see initial value". This was a global discussion, relevant to many classes, including [Reviewer2]'s evidently.

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interviewing

- Interviews are good for getting
  - opinions
  - feelings
  - goals
  - procedures (both formal and informal)
- not facts

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Standard Interview Formats

- **Structured** (standardized)
  - Tightly scripted, almost verbal questionnaire
  - Replicable, but lacks richness
  - Analyze like questionnaire
  - *"How many times a day do you access the internet?*

    [0, 1-5, 5-10, 10-15, 15+]"

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Standard Interview Formats

- **Unstructured**
  (Open/Informal/Conversational)
  - Guided by a very scant script.
  - Rich, but not replicable.
  - Difficult to be systematic, problem of coverage.
  - Minimize interviewer effects, preserves interviewee point of view.
  - Interviewee led, interviewer probes.
  - *"Please, tell me about your internet usage..."*

UMBC
AN HONORS UNIVERSITY IN MARYLAND

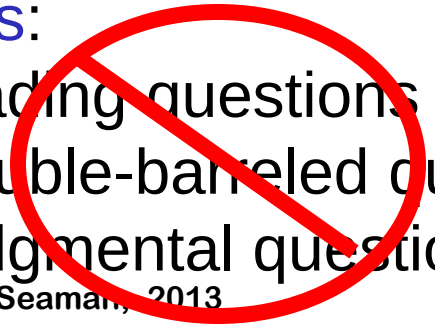
Standard Interview Formats

- **Semi-structured**
  - Guided by a script (interview guide), but interesting issues can be explored in more depth.
  - Good balance between richness and replicability.
  - Mixed analysis techniques.
  - *"In a typical day, how often do you use the internet?"*

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interview questions

- Closed
  - Predetermined answer format (e.g. Yes/No)
  - Easier to analyze
- Open
  - No predetermined answer format
  - More complete response
- Combination
  - Closed, with opportunity to elaborate
- Probes
- Pitfalls:
  - leading questions
  - double-barreled questions
  - judgmental questions



UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interview Guide

- A script for use by interviewer only
- “Wish list” vs. structured
- Flow/direction to interview
- Required topics
- Transitions between topic areas
- Important for replicability
- Wording and sequence are critical

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interview Design Considerations

- Context switching
- Flow between open and closed questions
- "**Shape**" of interview
- Most important stuff first
- Wording

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interview Shapes

- Funnel
  - Begin with open, gradually become more closed
  - Good if you're not sure what you're going to get
- Pyramid
  - Begin with closed, gradually become more open
  - Good with nervous interviewees
- Hour glass
  - Begin with open, gradually become more closed, then open up again at end to pick up things you might have missed
  - Good if you know what you want, but suspect there are important things you don't know about yet

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interviewing Pointers

- give clues about the level of detail you want
- establish rapport, but be subject neutral
- avoid jargon, esp. academese
- dispel any notion of the "right" answer
- play the novice when appropriate
- probe, but do not lead
- always be aware of your biases
- be sensitive to their work (environment/schedule)
- no more than 60 minutes
- let interviewee know next steps
- end with "anything else I should know?"
- say Thank you!

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Recording of interviews

- Audiorecording
- Notetaking
- Scribing

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Audiorecording

- Best memory mechanism
- Full transcription or just verbatim quotes
- Still take notes
  - Tapes fail, digital files are deleted
  - Does not record all aspects (esp. context / facial expressions)
- Required consent
  - Always ask first.
  - Do NOT hide recorder, keep it visible at all times.
  - Give the option to turn it off at any point.

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Notetaking

- **Very** hard to take notes and interview at the same time
- There are some super-researchers who can do it
- Inevitably results in incomplete notes
- Slows down the interview
- Sometimes inevitable

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Scribing

- Partner-based interviewing
- Advantages of a single contact vs. trading-off
- Can share roles (interviewer/scribe)
  - BOTH take notes, though to different degree
- Group debrief: what did you get/miss?
- Synchronize notes: overlap and emphasis
- Clarify while it is still in your head

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Writing up the interview

ASAP!!!!

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interview Notes

- Write it up immediately
- Descriptive vs. reflective notes
- Use Observer's Comments
  - Impressions, state of mind, assumptions, notes to self
- How detailed?
  - Verbatim transcript
    - only possible with audiorecording
    - Extremely labor-intensive
  - Summaries with major points quoted
    - OK, but use LOTS of quotes
  - Start closer to verbatim at the beginning of a study

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interviewing Exercise

- **Background**:
  - The National Federation of Makers of Feijoada (FNFF) is concerned that the national consumption of feijoada is declining due to decreasing quality of feijoada.
  - So they have asked us to interview the top feijoada chefs in the country (as determined by regional competitions)
  - The goal is to find out the secrets to master feijoada making, so that it can start to be taught in elementary schools.

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Interviewing Exercise

- Three versions of the interview guide
- I will be the interviewer
- You will be the interviewees
  - So take a moment to think of your favorite feijoada recipe

UMBC
AN HONORS UNIVERSITY IN MARYLAND

1. How often do you make feijoada and how long does it take you?
2. What do you think makes your feijoada the best?
3. Of course, you always wash your hands thoroughly before you start, right?
4. Do you add the sausage near the beginning or near the end of the cooking?
5. What kind of pot do you use?

3. How long does it take to make feijoada?
4. What are the ingredients you use?
5. What do you think makes your feijoada the best?

- Switching from topic to topic
- Switching between open and closed

Constant Comparison Method

- Qualitative analysis method
- Meant to generate grounded theory
- Operates on a set of field notes
- Basic process:
  - coding
  - grouping
  - writing field memo
  - forming hypotheses
- Repeated periodically in parallel with data collection

What's a Code?

- A label
- A concept
- A topic
- A category
- A relationship
- A theme

UMBC
AN HONORS UNIVERSITY IN MARYLAND

What's Coding?

- Open coding - assigning codes to pieces of textual data
  - Coded "chunks" can overlap
  - One chunk can have several codes
- Axial coding - grouping, categorizing, combining coded chunks
- Selective coding - making sense of it

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Open Coding

What's here? What are the pieces?

- Identification/discovery of concepts
- Classification (labeling of phenomena)
- Abstraction (this is part of that)
- Comparative analysis (this is different from that)
- Categorization (organization, grouping)
- Value-neutral, at least initially
  - "complexity" not "high complexity" or "low complexity"

Open Coding Process

- Preparing for coding
  - Read the data
  - Read background material and research design
  - Create pre-formed codes, if applicable
- Coding by hand
  - Document markup (colored pens, etc.)
  - Photocopy, scissors, and envelopes
  - MS Word comments
  - Excel
- Coding tools – NVivo, Atlas TI
- Coding scheme
  - *Pre formed* or *post formed* codes
  - Constant iteration
  - Structure develops over time

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Open Coding Exercise

- Background:
  - Study sources of information in software maintenance
  - Interviews with experienced software maintainers in several organizations
- Process:
  - I'll show you an example
  - Then you'll try it – code one excerpt with one code
  - Find a partner – compare your codings
  - I'll show you my coding of the excerpt

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Coding Scheme

Respondent Background

Information Gathering

Transition to maintenance

T

C

C

R

M

C

L

I

H

Quality of Process

Great Quotes

Human Sources of Information

Open Coding and Quantification

- One form of coding
- Objective is to derive quantitative data from qualitative data for future statistical analysis
- Usually involves counting
  - How many subjects said…?
  - How many times did subjects use the term …?
  - How many times did …?
- Or timing
  - How long did subjects spend doing…?
  - How long did it take to …?
- Inevitably loses richness
- Often seems a little like missing the point
  - What's the point of collecting rich data when you're just going to condense it down to numbers?
- But often is an effective and necessary way to reduce the size of the data

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Inspection Data Form

Class(es) inspected: Inspection date: Time:
Author:
Moderator:
Reviewers:

Name	Responsibility	Preparation time	Present

Amount of code inspected:
Complexity of classes:

Discussion codes:

D **Defects**
Reviewer raises a question or concern and it is determined that it is a defect which the author must fix; time recorded may include discussion of the solution

Q **Questions**
Reviewer asks a question, but it is not determined to be a defect.

C **Classgen defect**
Reviewer raises a defect caused by classgen; author must fix it, but it is recognized as a problem to eventually be solved by classgen

U **Unresolved issues**
Discussion of an issue which cannot be resolved; someone else not at the meeting must be consulted (put name of person to be consulted in () beside the code); this includes unresolved classgen issues. It also includes issues which the author has to investigate more before resolving.

G/D **Global defects**
Discussion of global issues, e.g. standard practices, checking for null pointers, which results in a defect being logged (does not include classgen defects)

G/Q **Global questions**
Same as above, but no defect is logged

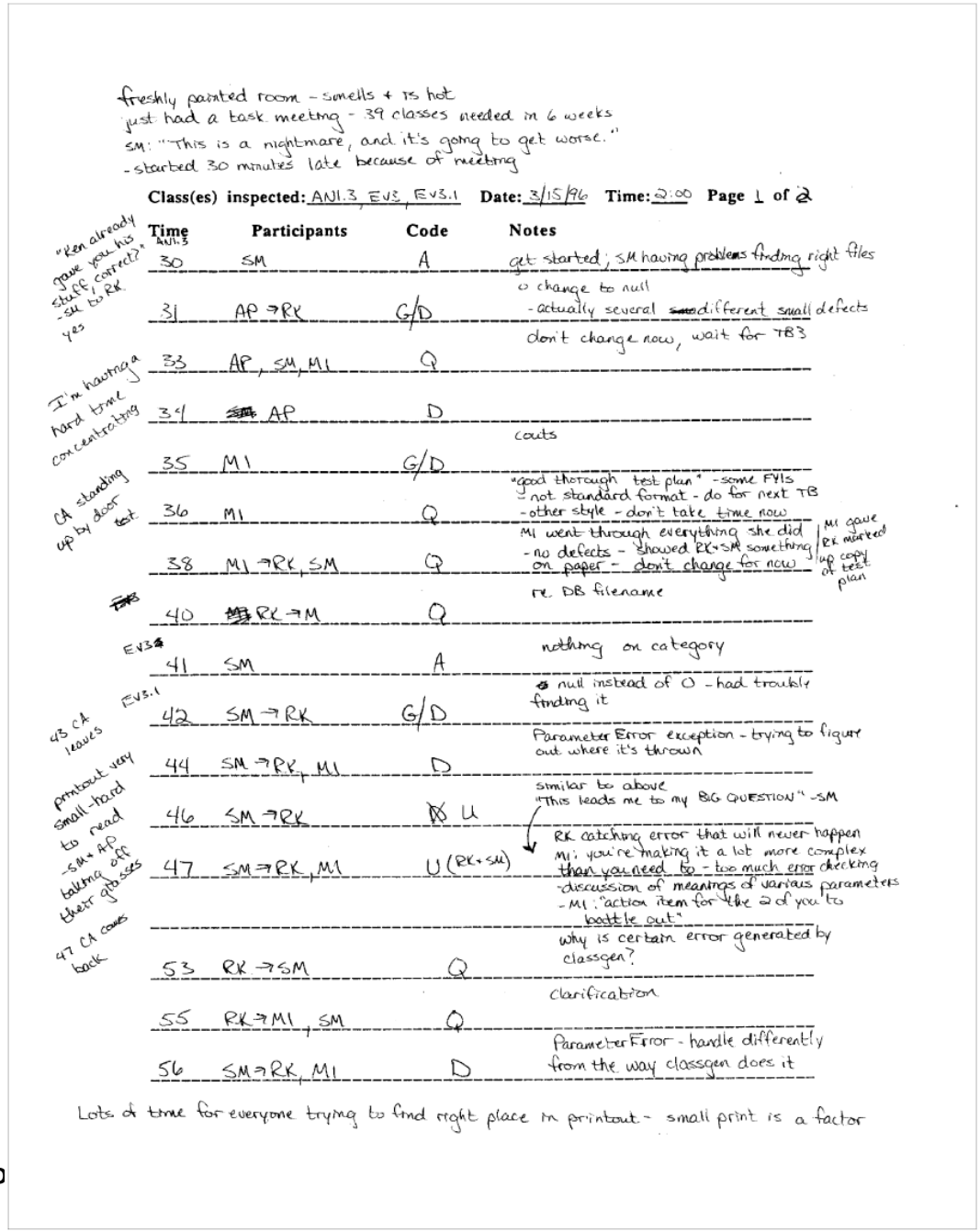
P **Process issues**
General discussion and questions about the inspection process itself, including how to fill out forms, the order to consider material in, etc., but not the actual execution of these tasks.

A **Administrative issues**
Includes recording prep time, arranging rework, announcing which products are being inspected, silence while people look through their printouts, filling out forms.

M **Miscellaneous discussion**

Time logged (in minutes):

D_____ Q_____ C_____ U_____ G/D_____ G/Q_____ P_____ A_____ M_____



freshly painted room – smells + is hot
just had a task meeting – 39 classes needed in 6 weeks
SM: "This is a nightmare, and it's going to get worse."
– started 30 minutes late because of meeting

Class(es) inspected: ANI.3, EV3, EV3.1 **Date:** 3/15/96 **Time:** 2:00 **Page** 1 **of** 2

Time	Participants	Code	Notes
30	SM	A	get started; SM having problems finding right files
31	AP → RK	G/D	○ change to null – actually several different small defects don't change now, wait for TB3
33	AP, SM, MI	Q	
34	AP	D	couts
35	MI	G/D	
36	MI	Q	"good thorough test plan" – some FYIs not standard format – do for next TB – other style – don't take time now
38	MI → RK, SM	Q	MI went through everything she did – no defects – showed RK+SM something on paper – don't change for now
40	RK → M	Q	re. DB filename
41	SM	A	nothing on category
42	SM → RK	G/D	○ null instead of 0 – had trouble finding it
44	SM → RK, MI	D	Parameter Error exception – trying to figure out where it's thrown
46	SM → RK	U	similar to above "This leads me to my BIG QUESTION" – SM
47	SM → RK, MI	U (RK+SM)	RK catching error that will never happen MI: you're making it a lot more complex than you need to – too much error checking – discussion of meanings of various parameters – MI: "action item for the 2 of you to battle out"
53	RK → SM	Q	why is certain error generated by classgen?
55	RK → MI, SM	Q	clarification
56	SM → RK, MI	D	Parameter Error – handle differently from the way classgen does it

"Ken already gave you his stuff, correct?" – SM to RK
yes

I'm having a hard time concentrating

CA standing up by door

MI gave RK marked up copy of test plan

EV3

EV3.1

43 CA leaves

printout very small – hard to read – SM + AP talking off their gbs

47 CA comes back

Lots of time for everyone trying to find right place in printout – small print is a factor

Axial Coding

How are things related?

- Initial process of reassembling
- Relationships among categories and codes
- Structure (why?)
- Process (how?)
- Explanations not causal prediction

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Selective Coding

How does it all fit together?

- Also called **sense making**
- Relationships among relationships
- Theory construction
- The central category
- Storyline memos
- Role of literature
- Write, write, write!!!
- **Field Memos**

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Field Memos

- The "*single most powerful analytical tool*" for qualitative researchers
- Simply, a piece of writing
- Maybe will later become part of a report, maybe will be thrown out
- Summarizes and synthesizes:
  - A proposition
  - An open question
  - A chain of evidence and logic
  - The complexity of a concept
  - Rich description
- Version control and organization

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Verification

- Process of establishing a study's trustworthiness and quality
- Analogous to *assessing validity* in quantitative studies
  - Relevant quantitative validity issues include internal, external, and construct validity, reliability, etc.
  - Some qualitative researchers simply adopt this terminology but translate
- **Big difference**: in qualitative work, verification is a *continuous process* that occurs throughout the study
  - Thus verification is an integral part of the techniques used to carry out a study, not a set of techniques applied after the study.
- Multiple sets of terms and concepts exist for verification of qualitative studies

Lincoln & Guba's Verification Terms

- Credibility
  - Length of time and degree of contact
  - Triangulation
- Transferability
  - Thick description, lots of context
- Dependability
  - Results not subject to change and instability
- Confirmability
  - Strength of chain of evidence

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Verification Techniques

- Prolonged engagement and persistent observation
- Triangulation
- Peer review and debriefing
- Negative case analysis
- Clarifying researcher bias
- Member checks
- Rich, thick description
- External audits

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Triangulation

- Simply put, getting your evidence from multiple sources in multiple ways
- Ideally, **each** proposition put forth should be supported by data that is
  - From at least two different sources,
  - Of at least two different types, and
  - Collected in at least two different ways
- Trick is to merge data during analysis, but keep track of where it came from

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Negative Case Analysis

- Search for data that will disconfirm your proposition
- If you don't find it, be able to show convincingly that you tried
- If you do find it, show how you modified your proposition to reflect it
- Negative evidence *doesn't mean you're wrong*, just that you have to bend a little
- Requires constant skepticism – sometimes not possible for an immersed researcher – need a skeptical buddy

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Member Checks

- Checking intermediate propositions, results, findings with **subjects**
- Subjects will suggest alternative interpretations, sources for negative evidence, terminology
- A variety of settings:
  - Extra round of interviews
  - “Thank you” workshop
  - Wrap-up presentation
  - Sending a report – almost never works

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Showing Verification

- Creswell recommends applying *at least 2* of the verification techniques on every study
- I would recommend **more**
- Transparency
  - Provide evidence in your writings that you have applied the techniques
  - Examples of negative cases and how they were handled
  - Accounts of member checks and results
  - Explicitly describe data sources and methods to show triangulation

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Using Qualitative and Quantitative Methods Together

- Qualitative and quantitative methods best used in combination
- Can simply be used in parallel to address the same research questions
- There are other strategies to better exploit the strengths and weaknesses of the methods

Example Design 1: Statistical Hypothesis Testing with Follow-up Interviews

- Classic design – often done without fully exploiting the interview data
- Example scenario:
  - Blocked subject-project experiment to evaluate a new testing technique
  - Statistical results show that technique is more effective on some applications than on others
  - Qualitative results show why

Example Design 2: Using Grounded Theory to Identify Variables

- Want to evaluate a new technique, but not sure what the evaluation criteria should be
- Example scenario:
  - Evaluating a collaborative design process
  - Use participant observation of design meetings to generate hypotheses about properties of the resulting designs
  - Grounded hypotheses are used to design a quantitative evaluation of the resulting designs

Example Design 3: Using Prior Investigation to Operationalize Variables

- Relevant variables are known, but the range and types of values is difficult to specify
- Example scenario:
  - Want to study the relationship between developer experience and types of defects
  - First use interviews to identify the range of developer experience (in its complexity) and a taxonomy of defect types
  - Quantitative study then is much more effective when using this operationalization

Conclusions

- Empirical software engineering researchers are addressing complex research questions that have human elements
- Qualitative methods, usually in combination with quantitative methods, can be helpful in handling this complexity
- Qualitative methods are both flexible and rigorous
- Qualitative analysis provides richer, more relevant, and more explanatory results
- The most effective research designs combine qualitative and quantitative methods

UMBC
AN HONORS UNIVERSITY IN MARYLAND

Bibliography

- Dey, I. *Qualitative data analysis: A user-friendly guide for social scientists.* New York: Routledge. 1993.
- Eisenhardt, Kathleen M. "Building theories from case study research." Academy of Management Review, 14:4, 1989.
- Gilgun, J.F., "Definitions, Methodologies, and Methods in Qualitative Family Research." *Qualitative Methods in Family Research*. Sage, 1992. pp. 22-29
- Glaser, Barney G. and Anselm L.Strauss. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. de Gruyter, 1967.
- Jick, Todd D. "Mixing qualitative and quantitative methods: Triangulation in action." Administrative Science Quarterly, 24:4, 1979.
- Judd, Charles M., Eliot R. Smith, and Louise H. Kidder. *Research Methods in Social Relations*. Harcourt, Brace, Jovanovich, 1991.
- Merriam, Sharan B. *Qualitative Research: A Guide to Design and Implementation*. Jossey-Bass, 2009.
- Miles, Matthew B. and A. Michael Huberman. *Qualitative Data Analysis: An Expanded Sourcebook*. Sage Publications, 1994.