

Exploring Mathematical Beliefs – the Naturalistic Approach

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Introduction

This paper contains some reflections on qualitative social research, based on the author's experience with investigating the belief systems of teachers concerning computers and computer science applying qualitative methods (Berger 1997). The aim of the paper is far beyond providing a comprehensive overview of qualitative methodology or a philosophy of the 'qualitative paradigm'. It is rather aimed at giving some suggestions that might be useful to a novice researcher planning his or her doctoral dissertation within the framework of qualitative research. The interested reader is referred to the profound publications by Tesch (1990), Lincoln & Guba (1985) and Mayring (1993).

What is qualitative research? At present, the only generally accepted statement seems to be that "qualitative research means different things to different people" (Tesch) and there is little evidence that this will change in near future. What we can say, is that "since the 1970's more and more researchers have become interested in a 'new paradigm' that moves us away from numbers and back to asking people questions and to observing" (Tesch). Although differently labelled as *qualitative*, *naturalistic*, *ethnographic*, *interpretative*, *phenomenological*, *subjective*, *hermeneutic*, etc., these approaches share certain basic beliefs about the status and function of research in the human sciences and about how it should be done. It is possible to understand these basic beliefs by having a look at their antagonist positions, i.e. the 'quantitative' and the 'positivist' positions.

Aspects of the 'qualitative paradigm'

The transition from the pre-scientific to the scientific period at the end of the Middle Ages may be described as a change of the ways in which questions were answered. To get answers, more and more people preferred putting questions to nature rather than to authorities such as Aristotle and Albertus Magnus. The success of the new *empirical approach*, i.e. analysing nature by disassembling and dissecting, which vigorously changed even the thinking about the nature of reality and knowledge, owed a great deal to the power of quantitative methods,

i.e. modelling reality by counting and measuring. Under the leading metaphor of numbers, mathematics in a long process changed its role from a successful instrument to the actual 'language of knowledge', a generally accepted epistemological authority. In fact, during the development of the natural sciences, the original empirical paradigm was more and more shaped to be a *quantitative paradigm*.

The German philosophers Schleiermacher and Dilthey showed up a fundamental difference between the investigation of natural phenomena and that of human conduct "by holding that the former can (and must) be *understood* by grasping the subjective consciousness of that conduct, while the latter can only be causally *explained* 'from the outside'"(Giddens 1993, p.61).

Nevertheless, the 'objectivity' of the results gained in the natural sciences incited, from an early stage onwards, the human sciences to imitate the successful model and to assimilate their own paradigms. The ideas of the German hermeneutics, such as Dilthey, have "been subjected to attack by numerous critics. Most of these critics have held that the method of interpretative understanding may be a useful adjunct to social science, as a source of 'hypotheses' about conduct, but that such hypotheses have to be confirmed by other, less impressionistic descriptions of behaviour" (Giddens 1993, p.61). With the one exception of anthropology, many researchers in human sciences for a long time held only those phenomena that could be measured to be explorable and accessible to scientific investigation. While the only accepted non-numerical instruments had been the *case studies* in psychology and the *participatory observations* in sociology, most work had been done by applying the tool kit of statistics.

Unfortunately, not many phenomena in the human world come naturally in quantities. [...] Sigmund Freud discovered plenty about the way human beings function, and so did Jean Piaget. Neither of them tested hypotheses, or used large and representative enough samples of people to satisfy the rules of statistics. Yet they both made important assertions about human beings and created many psychological constructs for use in the description of their theories. Freud employed a perplexingly simple way of finding out why people acted and thought or felt the way they did. He asked them. Sometimes they didn't know. Or they were ashamed to tell, or they were afraid to acknowledge the matter to themselves. So Freud observed. [...] When we ask questions about human affairs, the responses come in sentences, not numbers. (Tesch 1990, pp.1-2)

On a methodological level, qualitative research can be defined as *non-quantitative research*. Here, analysis is the descriptive and interpretative process of making sense of 'number-less' data, which we may call narrative or textual. While quantitative research is based on the 'monolithic concept' (Tesch) of statistics, qualitative research has a wide spectrum of non-codified procedures developed by psycholinguistics, communication research, educational psychology, and cognitive science.

From a pragmatic point of view, qualitative research may be seen as a widening of the repertoire of research instruments and perspectives rather than as a change in research paradigms. And in fact, analyses are often performed by combining quantitative and qualitative methods.

From a more rigid philosophical point of view, however, there is every indication that the appearance of qualitative approaches complies with the characteristic features of a general change in research paradigm. Lincoln & Guba describe, from ontological and epistemological perspectives, the qualitative (naturalist) paradigm as a *post-positivist paradigm* with a fundamental change of basic beliefs about the nature of reality and of knowledge (cf. Table 1).

The authors point out that in natural or human sciences research “has passed through a number of *paradigm eras*, periods in which certain sets of basic beliefs guided inquiry in quite different ways”. The main periods are called the *pre-positivist era*, ranging over a period of more than two thousand years from Aristotle to David Hume, the *positivist era*, and the *post-positivist era*. From today’s perspective, the mere titles of the periods illustrate the pervasiveness and predominance of the positivist approach.

Critics always owe a great deal of their ideas to what they criticise, and even the followers of a new paradigm should be aware that they are ‘standing on the shoulders of giants’, i.e. on those of the successful adepts of the old paradigm.

<i>Basic beliefs about ...</i>	<i>Positivist Paradigm</i>	<i>Naturalist Paradigm</i>
the nature of reality	Reality is single, tangible, and fragmentable.	Realities are multiple, constructed, and holistic.
the relationship of the knower to the known	Knower and known are independent, a dualism.	Knower and known are interactive, inseparable.
the possibility of generalisation	Time- and context-free generalisations (nomothetic statements) are possible.	Only time- and context-bound working hypotheses (idiographic statements) are possible.
the possibility of causal linkages	There are real causes, temporally precedent to or simultaneous with their effects.	All entities are in a state of mutual simultaneous shaping, so that it is impossible to distinguish causes from effects.
the role of values	Inquiry is value-free	Inquiry is value-bound.

Table 1. Positivistic vs. qualitative (naturalist) basic beliefs (Lincoln & Guba 1985)

It is, however, not only the rise of a new paradigm which accounts for the attractiveness of qualitative methodology. An increasing number of social researchers even go so far as to question, from a more pragmatic perspective, the actual success of the quantitative method. Summing up the results of the last 30 years in *quantitative* research, Lamnek (1995, p.247-248), in his extensive textbook on the methodology of qualitative social research, draws the conclusion that “the quest of empirical proved theories had evidently not been very successful.” He considers it “astonishing that in spite of a relatively self-contained methodology, in spite of a rapidly increased use of computers, and in spite of a quantitative increase of empirical research the horizon of knowledge in social research could not have been extended decisively.” Lamnek quotes two of the most-undisputed authorities on natural science, i.e. Einstein and Heisenberg, as witnesses for the prosecution against a naive quantitative methodology.

As far as mathematical theorems refer to reality, they are not certain – and as far as they are certain, they do not refer to reality. (Einstein 1956, p. 119)

Natural science is not any longer facing nature as an observer, it is rather perceiving itself as a part of the interplay between man and nature. The scientific method of dissecting, explaining, and classifying is confronted with its limits which are set by the fact that by the use of this method its object is changed and altered, and hence, the method is not able anymore to keep its

distance from its object. Thus, the scientific world view ceases to be an imminently scientific one. (Heisenberg 1965, S. 21)

Here, we possibly encounter the first step away from the positivist perspective and, at the same time, perhaps the real starting point of the paradigm change in social research. There is a clear indication that the social researchers' turning away from the quantitative paradigm, once adopted from the shining example of physics, has again been initiated by certain ideas and findings of physicists. However, adopting them this time seems to follow a general process of mutual approximation and reconciliation between the natural and the social sciences, surmounting positivist thinking by a decisive widening of scientific reflection on both sides.

Characteristics of qualitative research

Tesch (p.2) points out that “conducting scientific investigations is not a matter of following recipes. Research does not take place in a neutral environment. It is guided by assumptions about the nature of knowledge, and it has political antecedents and consequences.”

It could reasonably be argued that the conflict between quantitative and qualitative social research originates in two epistemologically different conceptions of what a theory for sociology should look like. The quantitative sociologist's concept of a 'logico-deductive theory', which is empirically proven only in retrospect, is opposed by the naturalist's concept of an inductive or 'grounded' theory, i.e. generated by induction grounded in empirical data. “The adequacy of a theory for sociology today cannot be divorced from the process by which it was generated – and we suggest that it is likely to be a better theory to the degree that it has been inductively developed from social research.” (Glaser & Strauss 1967, p.5). That means that qualitative methods become emancipated from mere preliminaries to quantitative research – in order to achieve the status of important tools for the development of theories which, as they are grounded in empirical findings, will better fit to social reality.

As implications of the post-positivist axioms for doing research, Lincoln & Guba (pp. 39–43) list fourteen characteristics of operational qualitative (naturalistic) research, the central aspects of which will be quoted in the following:

Natural setting. N (the naturalist) elects to carry out research in the natural setting or context of the entity for which study is proposed because naturalistic ontology suggests that realities are wholes that cannot be understood in isolation from their contexts, nor can they be fragmented for separate study of the parts (the whole is more than the sum of parts); [...]

Human instrument. N elects to use him- or herself as well as other humans as the primary data-gathering instruments (as opposed to paper-and-pencil or brass instruments) because it would be virtually impossible to devise a priori a nonhuman instrument with sufficient adaptability to encompass and adjust to the variety of realities that will be encountered; [...]

Utilization of tacit knowledge. N argues for the legitimation of tacit (intuitive, felt) knowledge in addition to propositional knowledge (knowledge expressible in language form) because often the nuances of the multiple realities can be appreciated only in this way; [...]

Qualitative methods. N elects qualitative methods over quantitative (although not exclusively) because they are more adaptable to dealing with multiple (and less aggregatable) realities; [...]

Purposive sampling. N is likely to eschew random or representative sampling in favor of purposive or theoretical sampling because he or she thereby increases the scope or range of data exposed (random or representative sampling is likely to suppress more deviant cases); [...]

Inductive data analysis. N prefers inductive (to deductive) data analysis because that process is more likely to identify the multiple realities to be found in those data; because such analysis is more likely to make the investigator-respondent (or object) interaction explicit, recognizable, and accountable; [...]

Grounded theory. N prefers to have the guiding substantive theory emerge from (be grounded in) the data because *no* a priori theory could be possibly encompass the multiple realities that are likely to be encountered; [...]

Emergent design. N elects to allow the research design to emerge (flow cascade, unfold) rather than to construct it preordinately (a priori) because it is inconceivable that enough could be known ahead of time about the many multiple realities to devise the design adequately; [...]

Negotiated outcomes. N prefers to negotiate meanings and interpretations with the human sources from which the data have chiefly been drawn because it is their constructions of reality that the inquirer seeks to reconstruct; [...]

Case study reporting mode. N is likely to prefer the case study reporting mode (over the scientific or technical report) because it is more adapted to a description of the multiple realities encountered at any given site; because it is adaptable to demonstrating the investigator's interaction with the site and consequent biases that may result (reflexive reporting); [...]

Idiographic interpretation. N is inclined to interpret data (including the drawing of conclusions) idiographically (in terms of the particulars of the case) rather than nomothetically (in terms of lawlike generalizations) because different interpretations are likely to be meaningful for different realities; [...]

Tentative application. N is likely to be tentative (hesitant) about making broad application of the findings because realities are multiple and different; [...]

Focus-determined boundaries. N is likely to set boundaries to the inquiry on the basis of the emergent focus (problems for research, evaluands for evaluation, and policy options for policy analysis) because that permits the multiple realities to define the focus (rather than inquirer pre-conceptions); [...]

Special criteria for trustworthiness. N is likely to find the conventional trustworthiness criteria (internal and external validity, reliability, and objectivity) inconsistent with the axioms and procedures of naturalistic inquiry. Hence he or she is likely to define new (but analogous) criteria and devise operational procedures for applying them. [...] it is worth noticing that the conventional criterion of internal validity fails because it implies an isomorphism between research outcomes and a single, tangible reality onto which inquiry can converge; that the criterion of external validity fails because it is inconsistent with the basic axiom concerning generalizability; that the criterion of reliability fails because it requires absolute stability and replicability, neither of which is possible for a paradigm based on emergent design; and that the criterion of objectivity fails because the paradigm openly admits investigator-respondent (or subject) interaction and the role of values.

A novice researcher, at the stage of planning his or her own work, will usually be looking for orientation. Within the framework of quantitative research, orientation will be sufficiently provided by applying the 'codified recipes' of statistics. With qualitative research, however, matters are different as recipes are obsolete. The more texts on qualitative research the newcomer consults, the more similar but miscellaneous aspects will be explicated and the more often he or she will be confronted with the advice to follow his or her own ways and not to listen to others' advice. It is a question of economy to provide a list of subjective research guide-lines by extracting the texts according to personal needs. Far from being a recipe, such guide-lines may serve as landmarks of orientation. Permanent re-arrangements and reformulations of the list according to the growth and change of experiences will accompany

the research process and establish it as a permanent process of reflection. The author's guidelines took the form of a 'decatalogue' (cf. Table 2).

I	Whatever the research questions may be – all research is focused on and aimed at subjects, i.e. human beings.
II	The research subjects should be observed in their natural environment.
III	All research is based on individual cases.
IV	Generalisation of results can never be done by applying a general method; generalisation in any individual case requires individual arguments.
V	Establishing results in any case requires interpretation.
VI	All interpretation must be based on exact and comprehensive description.
VII	The research process has to be open for changing and developing both the research questions and the research methods.
VIII	Each change or development in the research process must be extensively justified and documented.
IX	All analysis is constructed by the researcher; all analysis requires an introspection (self-analysis) of the researcher.
X	All research is interactive – it changes both the research subject and the researcher.

Table 2. Personal 'decatalogue' of qualitative research

Exploring belief systems by interviews

To start with an anecdote from an interview with a teacher: "You are teaching both mathematics and computer science. Do you prefer one of those subjects?" — "No. Definitely not. No." The respondent seemed to have a clear self-concept as a teacher. With a questionnaire, things might have been clear at this point, however, it was an interview and after giving a detailed explanation of his view of the two subjects for about ten minutes, the respondent ended with the remark: "All that, you simply can't do in maths classes and that's why I like teaching computer science so much."

The teacher apparently did not realise a contradiction, and in fact, there was none. It was only a normal inconsistency of conscious and subconscious attitudes which became evident, or in terms of beliefs, between a 'surface belief' (I do not prefer any of my subjects) and a 'deeper belief' (I like teaching computer science so much).

Interviews provide an appropriate method of gathering data within qualitative research. In her above quoted statement referring to Sigmund Freud, Tesch emphasised the techniques of asking and observing. Both are put to use in interviews. Even what the interview partners will not tell can be made accessible for observation by a thorough discourse analysis.

Exploring belief systems has some analogy with doing research in palaeontology (cf. Figure 3). What we are looking for, i.e. a person's belief system, may be authentic and complete, but it is hidden, just like a dinosaur. The only thing accessible to us is a fossil, an authentic and present, but fragmentary approximation to the original, an imprint or mark left by the original. So is the interview. After excavation and preparation, video taping and transcription, modelling of the original will be possible in some cases by the aid of reconstruction or interpretation. The model that we construct may be complete and present, but unfortunately it will be hypothetical. The fact that beliefs did not die out is of little help. We will never be able to lay our hands on a belief, as we will never encounter a dinosaur. They may both be real, but nevertheless they are just mental constructs.

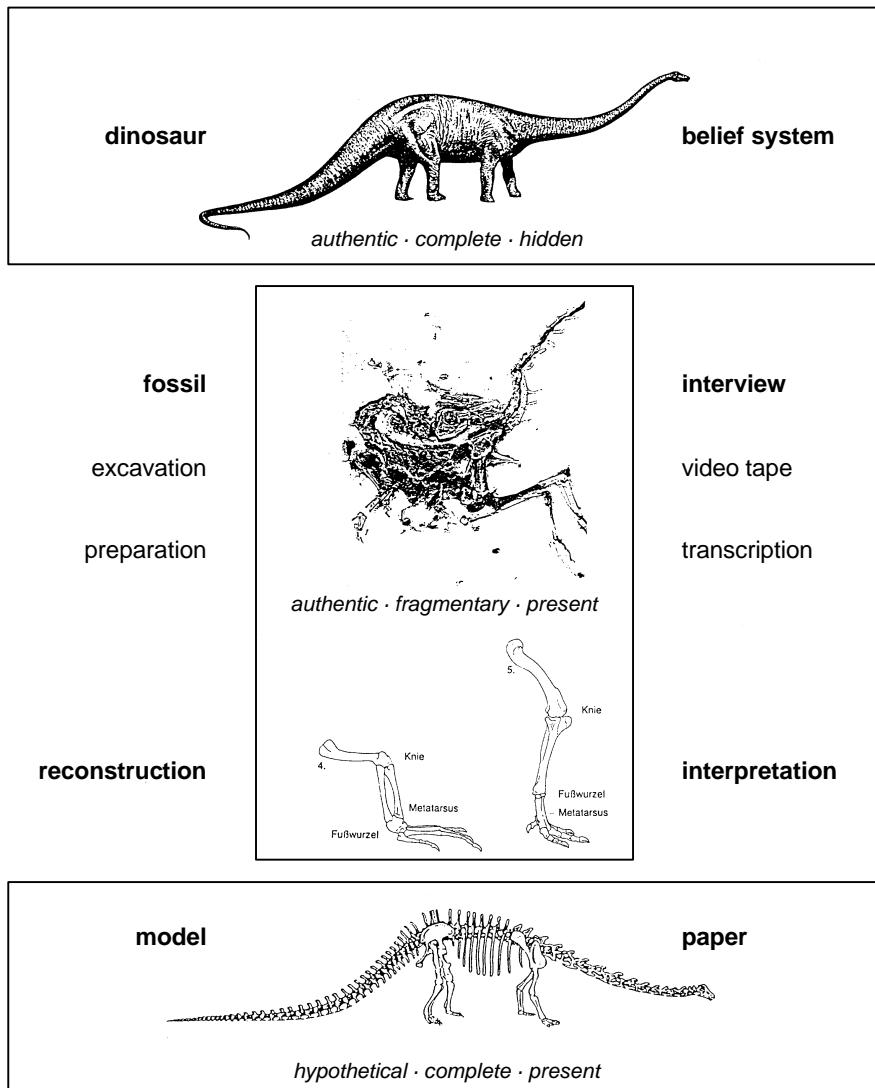


Figure 3. The 'palaeontology paradigm'

Data gathering: interviews

Interview-based beliefs research can be organised according to a six-phase model:

Phase 1. Developing research questions

Phase 2. Developing interview techniques (adapting the ‘human instrument’)

Phase 3. Interviews (data gathering)

Phase 4. Transcriptions of the interviews (data processing)

Phase 5. Interpretation (data evaluation)

Phase 6. Writing a paper

According to the research characteristics described by Lincoln & Guba, adapting the *human instrument* and allowing the research design to *emerge* may be realised by occasional backtracking between or combination of phases. Especially for novice researchers, sub-structuring the interview phase (or combining phases 1–3) will give way to both refining the research questions and to improving the interview techniques. With the author’s own research project, the following sub-structure has proved to be well-suited for the purpose (cf. Figure 4).

The preliminary set of interviews provides the researcher with an empirical basis for designing the main set, i.e. a ‘pool of themes and topics’ and experience of what respondents will bring up on their own account. It allows to standardise the catalogue of interview questions of the main set without risking the loss of relevant information. At the same time, it offers the opportunity of training the researcher’s skills in conducting interviews.

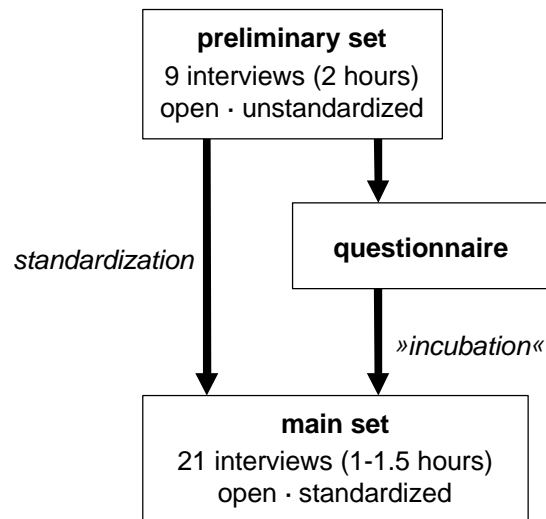


Figure 4. Sub-structuring the interview phase

Within the framework of qualitative research a questionnaire may serve as an instrument of ‘incubation’ which prepares the respondents for the interviews. Qualitative inquiry is not aiming at taking the respondent by surprise. An interviewee who is familiar with the project’s topics is altogether preferable.

Data processing: transcriptions

To guarantee a high degree of authenticity of the empirical data yielded by the interviews, those should preferably be video taped. Audio taping should be used only if demanded by circumstances. In any case, the taped interviews have to be transcribed.

Producing interview transcripts means an arduous and lengthy work. The transcription, however, is necessary because written texts allow easier handling, documentation, and analysis of the interviews than video tapes would do.

Video taped interviews have their own ‘dramaturgy’ which may

- restrict the researcher’s view
- capture the researcher’s eye
- guide the researcher’s understanding
- direct the researcher’s attention to surface information
- make the researcher watch the respondent’s statements, failing to notice what she or he does not say
- lead the researcher to be passive (consuming), instead of being active (observing, analysing).

The same may apply to simply reading transcripts as a whole text. As a thorough analysis of the interviews requires a detailed exploration from various points of view, transcripts should, for interpretational aims, be processed in manifold ways. This can be done by re-arranging and re-structuring the transcribed texts, for instance by sampling or extracting quotes referring to a certain topic (cf. *Data evaluation: interpretation*).

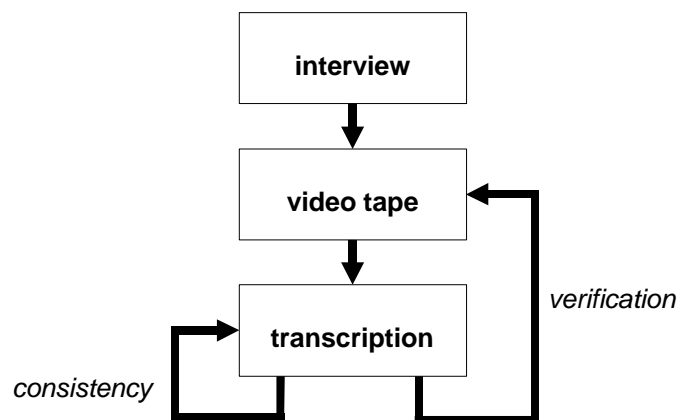


Figure 5. The process of making interview transcripts

The transcripts will consist of about 35,000 characters per hour of interview, however, transcribing means more than just typing – as is shown by the mere fact that punctuation may clarify or confuse the original. Transcripts have to be produced with a very high degree of accuracy and, moreover, repeatedly require *proofs of the consistency* of the transcribed text (internal text control) as well as *verification* of the text on the basis of the video tapes (external text control) as shown in Figure 5.

The cycles of consistency test and verification are the main instruments of approximating the transcript to the original interview. Yet, for economical reasons, one is bound to cut short these processes (after some cycles of verification and consistency testing) and to take the transcript as a basis for evaluation.

Although the transcription and interpretation phases should not be merged, even transcription may occasionally require some interpretation (because of insufficient intelligibility, audibility, and clarity of the respondents' statements). It should therefore be done by the researcher him/herself rather than by a typist (this holds especially for the process of verification).

Data evaluation: interpretation

The qualitative paradigm has some vital affinities to another set of powerful new ideas, i.e. the concept of *radical constructivism*. The constructivist approach provides ways of better understanding the nature, origin and development of knowledge. It may help the researcher to better conceive the respondents' ideas – and even improve the researcher's introspective insight into his or her own understanding. For a short outline of some basics of constructivism we quote from Noddings (1990, p.7):

Constructivism is a popular position today not only in mathematics education but in developmental psychology, theories of the family, human sexuality, psychology of gender, and even computer technology. [...]

Constructivism may be characterised as both a cognitive position and a methodological perspective. As a methodological perspective in the social sciences, constructivism assumes that human beings are knowing subjects, that human behaviour is mainly purposive, and that present-day human organisms have a highly developed capacity for organising knowledge. These assumptions suggest methods – ethnography, clinical interviews, overt thinking, and the like – specially designed to study complex semi-autonomous systems.

As a cognitive position, constructivism holds that all knowledge is constructed and that the instruments of construction include cognitive structures that are either innate or are themselves products of developmental construction.

At current constructivist discourse, various conceptual differences are discussed. However, there is agreement about the following (Noddings, p.10):

1. All knowledge is constructed. Mathematical knowledge is constructed, at least in part, through a process of reflective abstraction.
2. There exist cognitive structures that are activated in the process of construction. These structures account for the construction; that is, they explain the result of cognitive activity in roughly the way a computer program accounts for the output of a computer.
3. Cognitive structures are under continual development. Purposive activity induces transformation of existing structures. The environment presses the organism to adapt.
4. Acknowledgement of constructivism as a cognitive position leads to the adoption of methodological constructivism.
 - a. Methodological constructivism in research develops methods of study consonant with the assumption of cognitive constructivism.
 - b. Pedagogical constructivism suggests methods of teaching consonant with cognitive constructivism.

The research process of asking and observing people, of interviewing and interpreting, is structured in phases for methodological reasons. The phase model, however, involves the risk of what we may call a ‘methodological routine-blindness’. The research stages *person*, *interview*, *video tape*, *transcription*, and *interpretation* form the layers of a more and more constructed reality (cf. Figure 6). To prevent blindness, it will be necessary to keep the research subject in view, i.e. the human being. And that means to ‘keep the layers transparent’ and to conceive of the stages as facets of a whole with multiple realities.

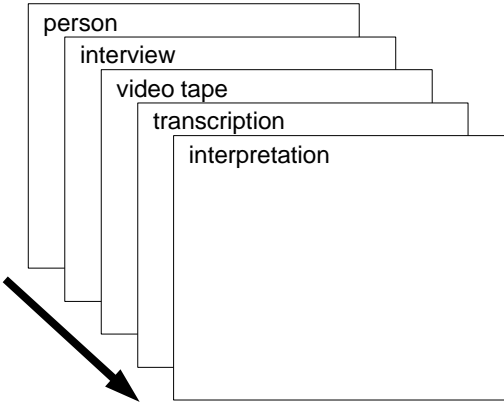


Figure 6. Layers of a constructed reality

To provide an introduction to the art of interpretation would be far beyond the scope of this paper. In the following, we therefore confine ourselves to giving some technical hints. For a general survey of hermeneutics, the reader is referred to the profound publications of Beck & Maier (1994), Oevermann (1986), Oevermann et al. (1979), and Titzmann (1993); a deep understanding of the process of interpretation is provided by the work of the French philosopher Paul Ricœur (Ricœur 1975 & 1985).

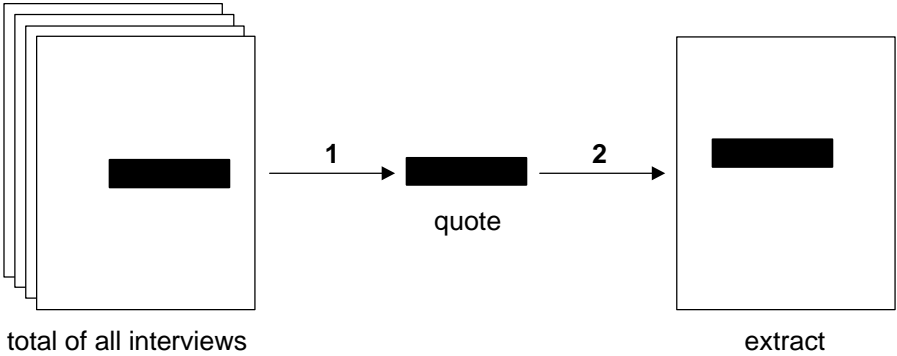


Figure 7. De-contextualization (1) and re-contextualization(2)

The processing of the transcription texts mentioned above can be described as ‘cutting’ it from one context and ‘pasting’ it into another, according to Marton (1986, p.43): ”Each quote has two contexts, [...] first the interview from which it was taken, and second, the ‘pool of

meanings’ to which it belongs.” From a more formal point of view, these operations are referred to as *de-contextualization* and *re-contextualization* (cf. Figure 7). They provide one of the main techniques of interpretational qualitative analysis.

Especially with standardised interviews, extracts from the total of all transcripts will allow the researcher to re-read the original interview texts. The ‘multiple realities’ encountered in an interview will often only surface when the perspective of observation is changed, e.g. by analysing a quote within a new, but relevant, context. At the most basic level, the extracts take the form of a whole transcription (‘vertical extract’, cf. Figure 8).

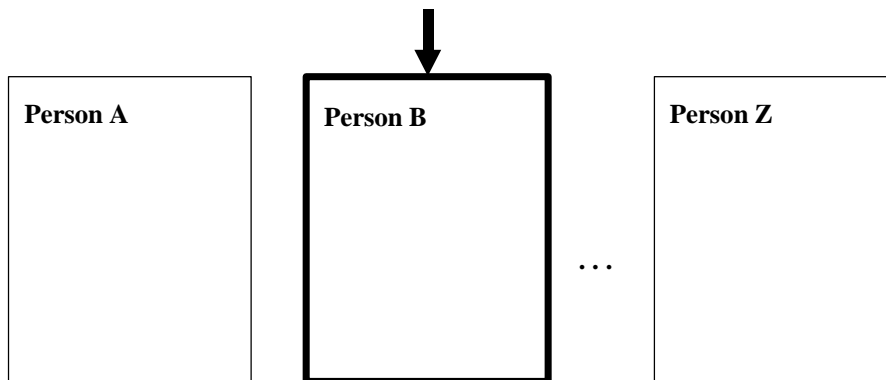


Figure 8. Vertical extract

The second type of extract is provided by sampling all the contributions to a specific question (‘horizontal extract’, cf. Figure 9). This can easily be done with a computer by using the standard ‘cut’ and ‘paste’ features of text programs.

The third type of extract (‘discrete extract of keywords’, cf. Figure 10) consists of all transcription contexts containing a certain keyword. This, too, can be done by a text program, using the standard features of ‘searching’ and ‘sorting’. All those procedures can be automated by macros.

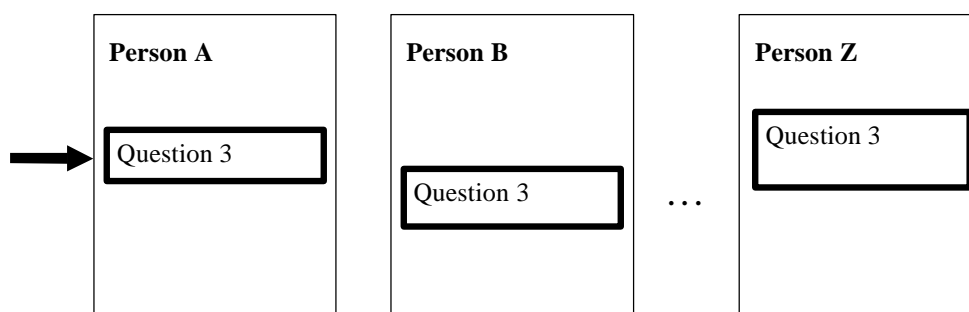


Figure 9. Horizontal extract

These three varieties of extracts can be sampled by simple syntactic operations (pattern matching). Yet one of the most important principles of interpretative discourse analysis re-

quires extensive semantic operations and can therefore not be automated, or at the utmost only partially, i.e. here we encounter the *principle of exhaustion*. To gain a profile of the respondents' views concerning a certain topic, *all* meaning units (statements, phrases, etc.) referring to this topic have to be sampled. Following the maxim that no meaning unit is meaningless, each instance has to be found and registered. Interpretation has to consider each single instance by assigning it to at least one 'interpretational category'. As meaning units are semantic, and not syntactic, entities, this requires a thorough non-automated interpretation by the researcher.

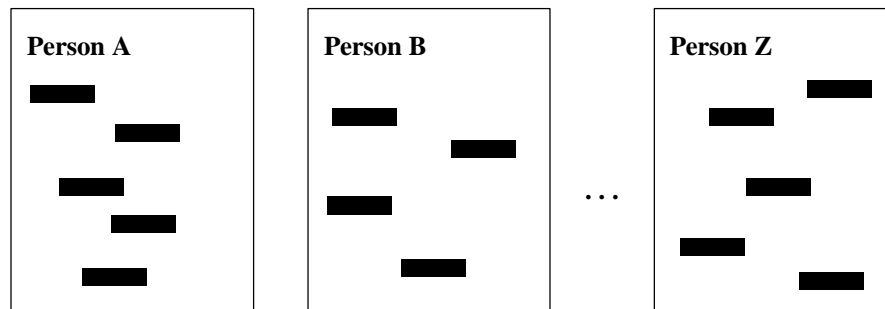


Figure 10. *Discrete extract*

Hence, there is a fourth, and most important, type of extract, i.e. the 'discrete extract of meaning units', which demands all the interpretative skills and creativity of the (human) researcher. Computers may often increase or even encourage human creativity – however, it is one of the author's conscious and deeply rooted beliefs that before he sees a computer doing qualitative research he will encounter a dinosaur.

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