School of E-education,
Hamdan Bin Mohammed e-University
http://www.hbmeu.ae/
Study book

Research methods in e-education

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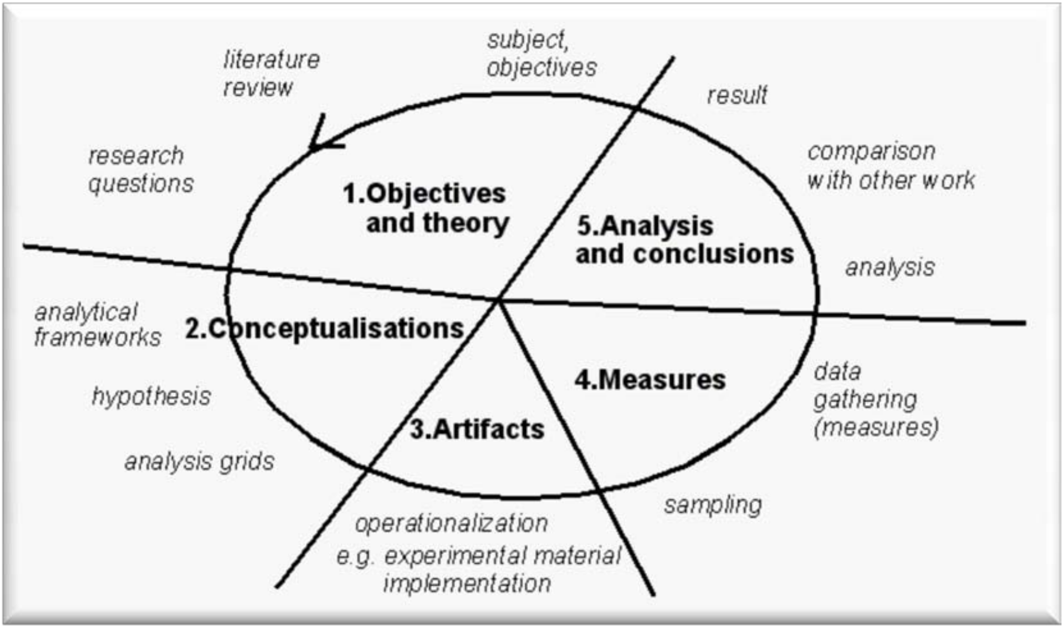

Foreword

This study book was written for the course ***Research Methods in e-Education*** of the new ***Master of Art in Online Curriculum & Instruction programme*** in the School of E-education, Hamdan Bin Mohammed e-University.

My teaching materials on research methodology have a longer history. Since my student days, I was interested in social science methodology. In 1979, I started teaching political science methodology seminars at the Department of Political Science, University of Geneva. Between 1995 and 2006, I taught a methodology crash course in a master degree program on Public Policy Analysis and

Management at IDHEAP, University of Lausanne. More recently, in 2005, I taught a 5-day intensive course on ***Research Design for Educational Technologists*** at VCLIT, University of Mauritius. Finally, I coordinate the ***Research Methods in Educational Technology*** course in our recent Master of Science in Learning and Teaching Technologies at TECFA. All these prior experiences did contribute to this study book.

My rather long experience in social science methodology teaching has taught me that methodology cannot be taught by just lecturing, a bit of exercising and testing. Students need be exposed to authentic exercises. In addition, they should create a research design for a real project like a master thesis. In both cases, it is important that they can count on tutoring and coaching. The course *Research Methods in e-Education,* for which this study book was produced, has been designed that way. However, we would like to add a word of caution. Research methodology cannot be mastered after a single course. An introductory course will "get you started". You will learn the rest from experience, from intensive reading of the research literature and from advanced manuals and web sites, and maybe through additional training.

Finally, I would like to thank Prof Alain Senteni (Dean of the School of e-Education, Hamdan Bin Mohammed e-University) for this invitation to design the course, this study book and the teaching slides. Our collaboration on teaching research methods started when he invited me to teach a first crash course in English for students in educational technology at the University of Mauritius. I wish this newly created mater program in Dubai the best luck and hope that my input will contribute to its future success.

Geneva, April 12, 2009 – DKS

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1 Introduction

This study book introduces ***research methods in e-education***. We will look at ***research designs, research methodologies***, research ***techniques,*** as well as ***practical considerations*** like planning and writing a master thesis.

E-education is better known as ***educational technology***. Other popular names of this interdisciplinary field of research and development are *Instructional technology, Educational communications and technology, Learning technology, e-learning* or *technology-enhanced learning.* However, the latter two refer to specific sub-fields of educational technology.

Educational technology in general can be defined either as a **design science** or as a ***collection of different research interests*** addressing ***fundamental issues of learning, teaching and social organization***. Educational technology relies on and influences other academic disciplines; in particular the so-called ***learning sciences*** and ***instructional design theory*** (pedagogy and didactics). Modern ***distance teaching, corporate training and classroom teaching*** are some of the application areas of educational technology.

This chapter will introduce the aims of this study book, present a short chapter outline and explain the typical chapter architecture.

Target population and aims

The target population of this text on **research design, research methodologies** and research **techniques** are Master Students in Educational Technology and related fields with little background in research methodology. Our principal aim is to help students understanding research papers and writing draft projects for smaller research projects.

The tutorial modules also could be used for methodology teaching in most other social science disciplines. Educational technology is mostly a field of the social sciences and research approaches are quite the same across its disciplines. Only preferences for given approaches and techniques are different.

As shown in Figure 1, we shall introduce both high-level concepts about academic research and more "down-to-earth" techniques like fundamentals of data analysis, or how to find a research subject.

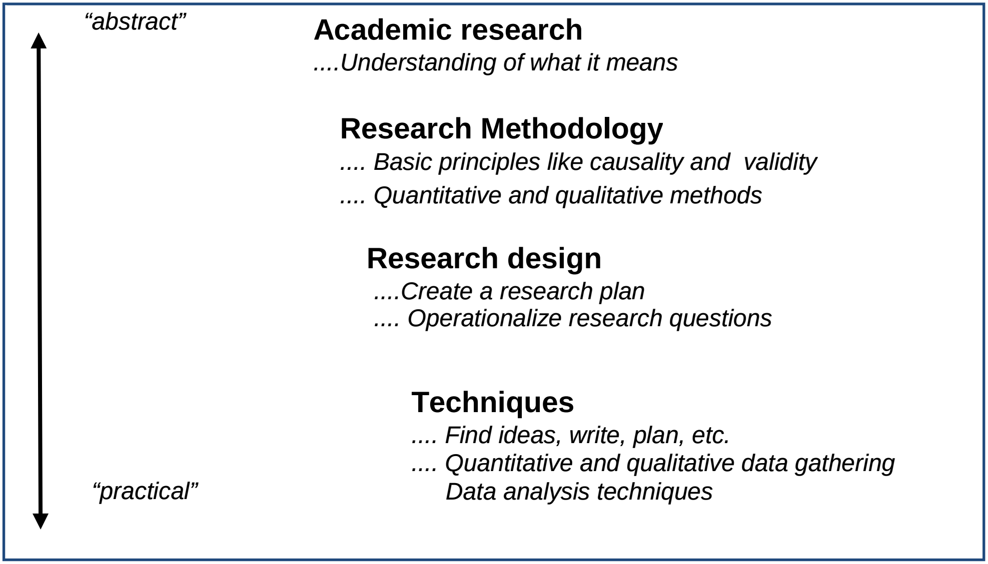


Figure 1: Aims of this introduction

Main Learning goals

- Know the fundamental principles of academic research.
- Be familiar with three major classes of research designs: (1) Theory-testing approaches, (2) Qualitative and theory-finding research, and (3) Design-science research.
- Understand the basic elements of a Research Design: (1) Definition of a subject, (2) Research Goals and Questions, (3) Literature review and selection of theoretical and conceptual frameworks, (4) Approaches and Methodologies: Operational Research Questions, Analysis frameworks and methodological techniques.
- Master the fundamental concepts and procedures of a few selected research methodologies, e.g. data gathering, sampling, and simple quantitative and qualitative data analysis.
- Learn some practical skills like finding a research subject or planning a thesis work.
- Know the structure of a dissertation.

1.1 Chapter outlines

This study book is organized into 4 parts and 17 chapters for which we provide the summaries here:

PART I – RESEARCH PRINCIPLES

Chapter 1: This chapter will introduce the aims of this study book, present a short chapter outline and explain the typical chapter architecture.

Chapter 2: This chapter introduces some general principles of academic research; in particular, we will define what we mean by “research” and identify its important components. We then will present different kinds of research approaches and discuss what is considered interesting research. There exist many ways to conduct educational technology research and development because of the very interdisciplinary nature of this field. Since this chapter introduces abstract concepts and does not address more operational questions, you may read it quickly and come back to certain issues later.

Chapter 3: The purpose of this chapter is to provide an overview of some essential principles that define ***empirical research, i.e. research that looks at data***. Most of the issues will be addressed again throughout the following chapters. Reading this chapter will help you thinking about the research design of a little project. We will explain how to formulate a general research question in terms of operational questions that will help you answering this general question. We also will point out some reasoning pitfalls and reliability and validity problems that may arise.

PART II – PRACTICAL ISSUES

Chapter 4: This chapter will help you identifying a research subject, a process that may be more difficult than you might think. Finding a research subject is trivial, if you have to pick it from a list that your professors define. On the other hand, if you have the liberty and the obligation to define your own, you may be surprised at how much time and effort it may take. The purpose of this chapter is to help speeding ***up the subject finding process by*** discussing some tricks and intellectual tools that include for example a recipe on how to conduct a literature review.

Chapter 5: This chapter provides a short overview of the research plan, i.e. its function and its elements. Reading just this chapter will not help you to prepare a precise research plan. We will define the main elements that should be part of a research plan and you will need to learn more about research methodology and conceptual frameworks in order to produce your own. In any case, you will need advice from a confirmed researcher, e.g. your professor.

Chapter 6: This chapter will introduce elementary planning techniques. Some planning will help you to estimate the workload for a given project and to control your progress later on.

PART III – INTRODUCTION TO RESEARCH APPROACHES

Chapter 7: This chapter will introduce conceptual frameworks that help structuring ideas and concepts. Any research project should relate to theory. Conceptual frameworks are key elements of academic thinking. It is important that you manage to identify useful frameworks in early stages of your research, since they help organizing concepts and structuring analysis. We put this chapter in the "practical part", since our purpose is not to introduce theory. Our aim is to get the message across that you should work with some central conceptual artifacts since they help bridging theory to research questions and define relationships among major concepts.

Chapter 8: In this chapter, we will provide some advice about the structure of a master thesis. The word "thesis" has several meanings. One is "*proposition that is maintained by argument*". A thesis-as-dissertation is just that: an **argument**, as we will argue.

Chapter 9: In the conclusion of chapter 2, i.e. in the Types of research section, we presented three big families of research approaches: explanatory theory testing, interpretive theory finding, and design research. This chapter will present explanatory theory-driven research designs, i.e. mainstream social science. Most research in educational technology published in high quality journals will adopt this approach. Many evaluation studies also rather use a top-down approach that is driven by theoretical constructs.

Chapter 10: This chapter will address general issues about theory-finding research designs. We ***will not*** discuss precise approaches in detail here for space reasons. We ***also should mention*** that ***some principles*** that apply ***to*** theory-testing approaches also could apply in theory-finding research designs. E.g., validity is always an issue.

Chapter 11: In this chapter, we will introduce the design science perspective. Educational technology as design science uses mostly qualitative theory finding methodologies, but also may rely on quantitative approaches, such as experiments or surveys. The difference with respect to theory-testing and theory-finding approaches is the important role of the design, i.e. design rules and artifacts, as you shall see.

PART IV – DATA COLLECTION AND ANALYSIS

Chapter 12: This chapter will introduce quantitative data collection methods and focus on survey research and questionnaire construction.

Chapter 13: In this chapter, we shall introduce qualitative data collection methods and techniques. We first will discuss sampling strategies since qualitative research often starts with open-ended questions. We then provide an overview of various data collection techniques and provide some details about interviewing.

Chapter 14: This chapter introduces simple descriptive statistics. The purpose of descriptive statistics is to summarize data distributions. In addition, descriptive statics (in particular the mean and standard deviation) are the basis of most statistical analysis techniques.

Chapter 15: This chapter introduces simple bivariate statistics. The purpose of so-called inferential statistics is to test relationships between two or more variables. We shall present the three most popular methods for analyzing relationships between two variables.

Chapter 16: This chapter will shortly introduce exploratory data analysis (EDA), multivariate data reduction and related subjects. We will focus on looking at distributions with boxplots and uncovering structure with data reduction techniques. We also introduce repertory grid technique, a qualitative method that uses quantitative data analysis techniques.

Chapter 17: This chapter introduces various aspects of qualitative data analysis. We shall present a “modern” structured approach in which the researcher is expected to code data. These codes will then allow him to conduct various types of analysis of which introduce some examples.

PART V – BIBLIOGRAPHY AND RESOURCES

Chapter 18: This bibliography includes first a few selected general purpose textbooks for further reading. We also include some specialized introductions as well as references for the examples we used.

Chapter 19: These online research resources include some useful on-line tutorials and methodology web sites.

The following mind map summarizes this organization:

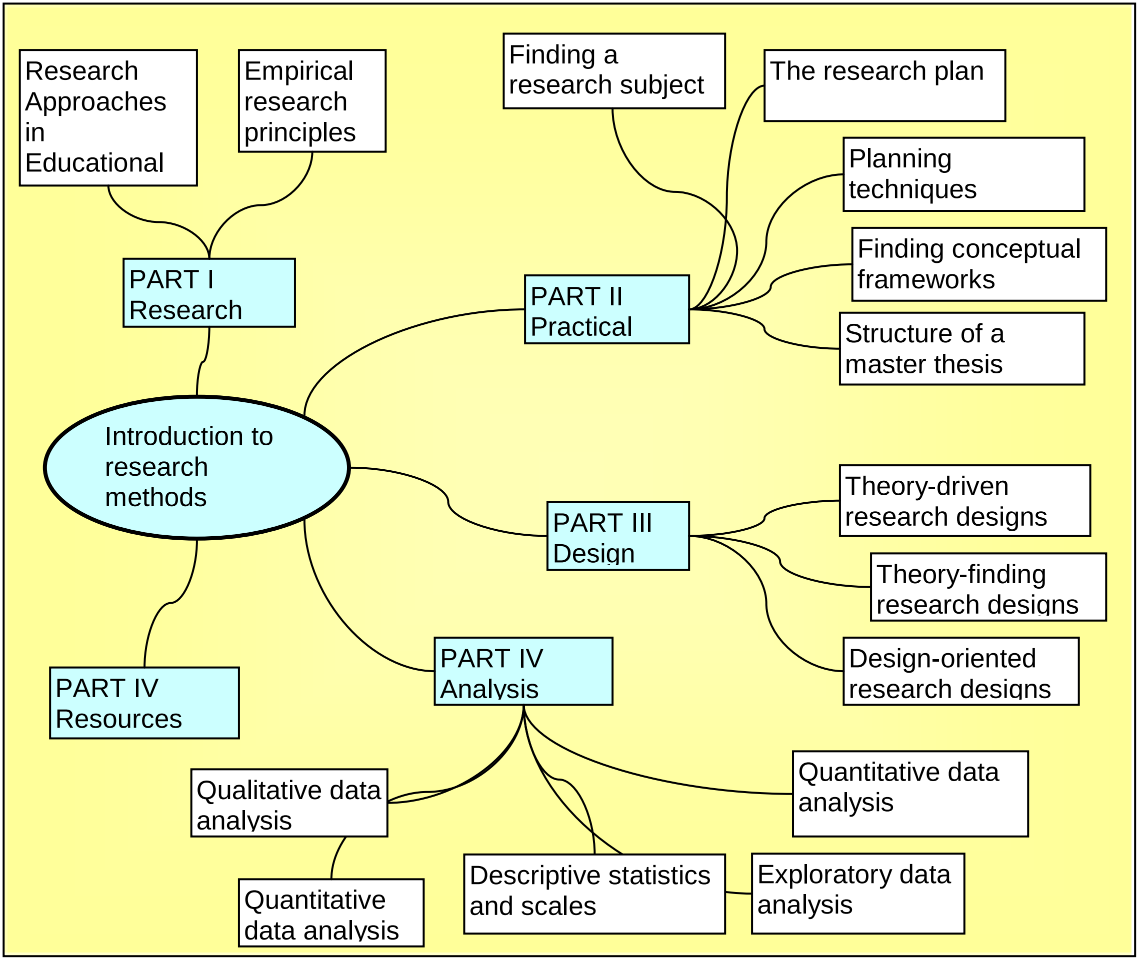


Figure 2: Chapter organisation

1.2 Chapter architecture

Chapters have a similar organization and we use some "boxes" to highlight important elements. We start a chapter with a short introduction and preview.

Introduction and preview

The introduction introduces the purpose of the chapter and may include a short preview.

The introduction is followed by an identification of the most important learning goals.

Learning goals

These goals should help you understand what you will learn and sometimes why. They are formulated in very general terms since you will have to demonstrate learning through design projects that your teacher will assign in class. This study book only will help you to engage in learning, you will acquire applicable knowledge by doing authentic (almost) “real” tasks.

Chapters are structured in several sections. These sections may include taxonomies, examples and case problems or summary information:

Some boxes are used to highlight information, e.g. examples or data from case problems.

Some boxes may include intermediate summary information or important taxonomies.

At the end of each chapter, we usually present a short conclusion.

Conclusion

Conclusions recall important concepts.

At various moments, we include review questions or review assignments. However, the latter also may be redesigned by your instructor in order to fit his course design.

Review questions

Review questions are meant to help you go over the text and consolidate learning goals.

Review case studies

We invite you to download articles from open access journals and answer a few questions. They have been chosen for didactic purposes and simplicity.

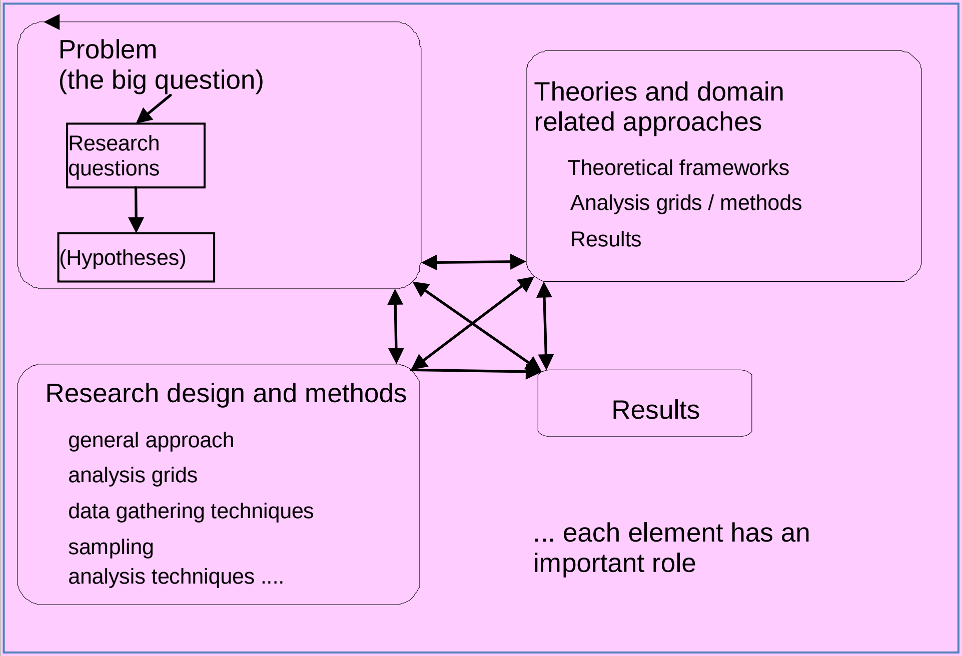
PART I - PRINCIPLES

This part includes two chapters:

1. Research Approaches in Educational Technology
2. Empirical research principles

Both chapters look at what we mean by “research” and “research methods”.

As we shall see in PART II in more detail, ***research is an interrelated whole***. For a given research problem, ***prior research*** provides you with useful theories and ways of doing research. Your research problem must be presented in terms of ***research questions*** and you will have to find the right ***research design*** for answering these. Again, you will find a lot of prior research that will suggest ***appropriate instruments*** like methods and techniques. Finally, your research results must be confronted with prior research and therefore ***contribute*** to the field.


Problem
(the big question)
Research questions
(Hypotheses)
Theories and domain related approaches
Theoretical frameworks
Analysis grids / methods
Results
Research design and methods
general approach
analysis grids
data gathering techniques
sampling
analysis techniques ....
Results
... each element has an important role

2 Research Approaches in Educational Technology

This chapter introduces some general principles of academic research; in particular, we will define what we mean by “research” and identify its important components. We then will present different kinds of research approaches and discuss what is considered interesting research. There exist many ways to conduct educational technology research and development because of the very interdisciplinary nature of this field. Since this chapter introduces abstract concepts and does not address more operational questions, you may read it quickly and come back to certain issues later.

Learning goals

- Acquire an understanding of what we mean by "research"
- Get an idea of the "research process"
- Understand what different sorts of elements (theory, methodologies, practical skills) you need to develop
- Understand why researches may look at things in a given way and that there are different research paradigms
- Learn about different types of research
- Learn what is considered interesting research in educational technology.

2.1 Introduction - A first look at research

Research can be summarized with a very simple formula:

Ask a question, investigate and then answer it.

What distinguishes research from other investigation is **how** the investigation, i.e. the "digging", is being done. Good research ***asks clear questions*** including limitations, i.e. what is not being done. The investigation then must use ***clear concepts and definitions***. Most importantly, and this the main focus of this learning module, ***appropriate intellectual tools*** (e.g. frameworks, methods and technologies) must be used. Furthermore, research is always conducted with respect to other research. The theoretical framework must be based on prior research and results should be discussed in the light of prior research. Finally, there are accepted ways for presenting research results. *Figure 3: What is research?* illustrates this principle.

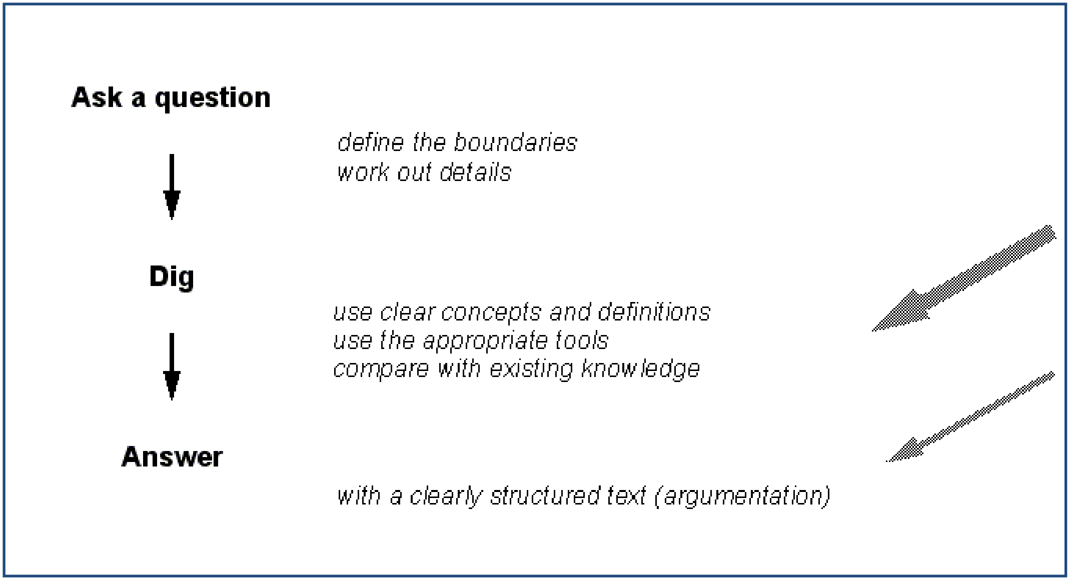


Figure 3: What is research?

Let us now examine the major stages of a research project. We distinguish between four stages as shown in *Figure 4: The four stages of a research project*:

(1) Finding a good research subject is a task that is often underestimated, in particular by young researchers. (2) Research requires some planning. This planning should demonstrate *how* research questions are going to be answered. (3) Research must be carried out. During this most important stage, new research questions may spring up and the research design may have to be altered. This is particularly the case in intervention and exploratory research, as we shall see later. (4) Writing up the research is usually done at the end, but parts of it can be conducted in very early stages, e.g. the so-called literature review.

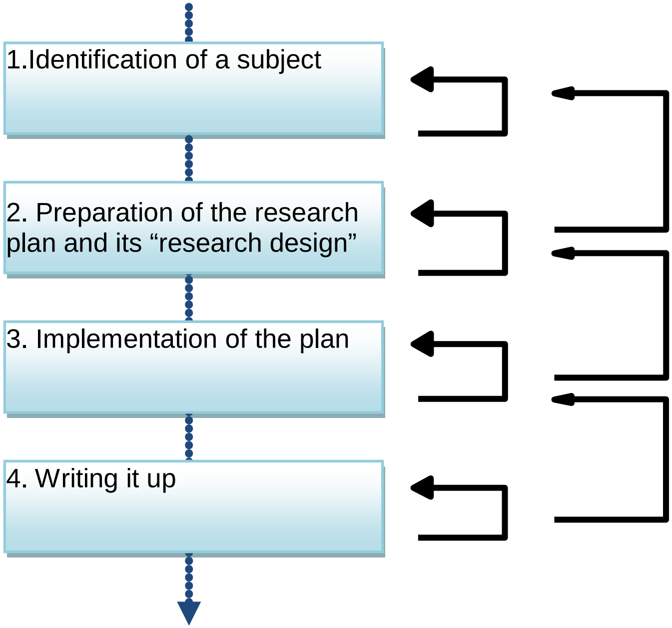


Figure 4: The four stages of a research project

In order to carry out a research project, one relies on various kinds of knowledge. We distinguish between three kinds of knowledge in *Figure 5: What do you need to know in order to get a project done?*:

1. ***Research methodology*** at various levels of abstraction: Research logic, global methodologies and approaches, and particular methodologies and techniques.
2. Other more ***informal skills*** like being able to find information, to summarize and synthesize or project management skills.
3. Domain knowledge, e.g. ***conceptual frameworks***

We shall not directly teach any domain knowledge, however as you shall see later, research instruments are often found in the research literature and good research always tries to reuse existing instruments if they fit the purpose. E.g. if you plan to analyze whether an on-line course favored active learning, you should try to find published questionnaire items that have shown to successfully measure "active learning".

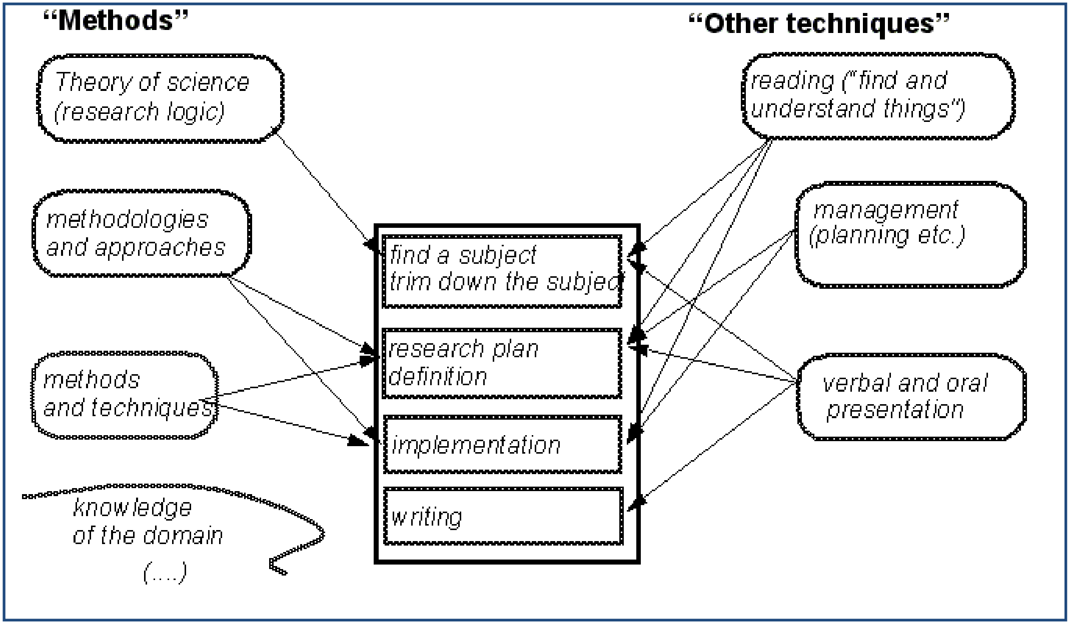


Figure 5: What do you need to know in order to get a project done?

2.2 What is good and interesting research?

Since the old times, philosophers have been asking the question "***how we can know?***". Philosophy of science, also called epistemology, aims to define conditions of knowledge and good ways to reason, and particularly, how we can relate theory to observations. General principles from epistemology are taken up by major research approaches. While we cannot introduce its schools of thought in this text, the reader should be aware that various views *on what good science is* do exist.

Below we shall first provide you with the elements that could characterize the scientific approach. You need to know what "science" and "research" means in order to understand how to write a research plan, to understand your academic partners (e.g. to find out why your thesis advisor doesn't like your initial research subject), and to be able reading research papers

Let us first examine what major elements may define how you would conduct a given research project. On one hand, there exist general ideas and intellectual instruments for conducting research. On the other hand, the research object, your research goals and your means also will enter the equation. Table 1 lists some of these elements.

Theory of science • Tries to answer questions like: What is knowledge? Academic knowledge? • How should you reason? Deduce? Induce? Model?
The methodology : • should fit your research subject • be accepted by a given research community
The research object • should be considered interesting by a given research community • should be clearly defined in terms of objectives and research questions

The research purpose • You should identify clear purposes of your study?
Your means • time, money, knowledge, data access

Table 1: Constitutive elements of a research project

All these elements influence each other; in particular, a researcher must find equilibrium between methods, object, goals and means:

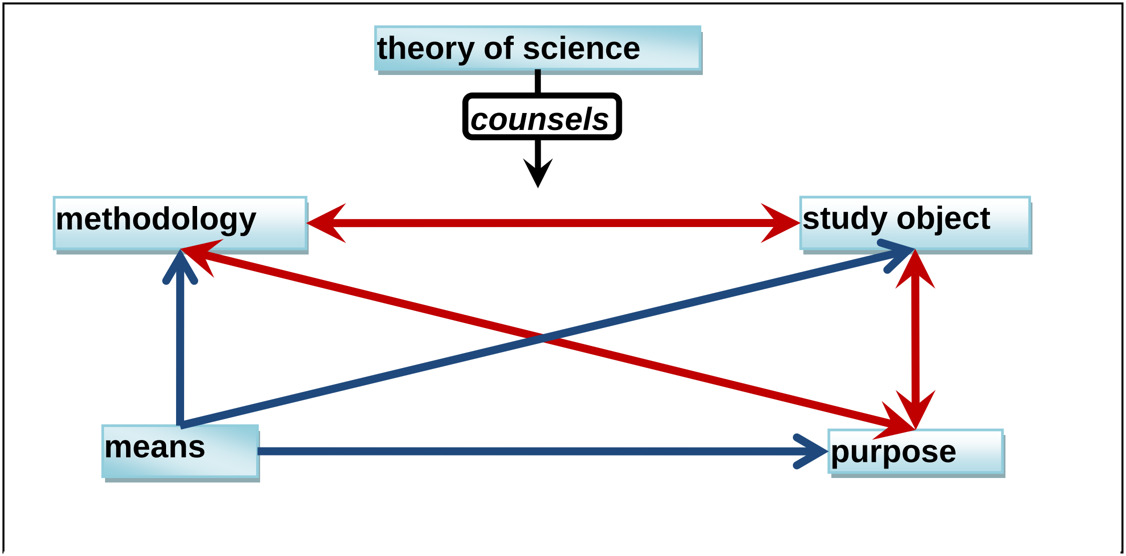


Figure 6: An equilibrium between various elements that define research

Figure 6 attempts to convey the message that in educational technology research, there is rarely a ready solution for your problem! There exist suggestions (e.g. there will be a set of methods that are appropriate for answering specific questions) as well as interdictions (things not to do). In other words, you will have to come up with your own research design and justify it.

Let us now have a look at what we mean by academic empirical research. Empirical research is research that relates to reality, i.e. takes into account data. The most important tenets about ***good research*** are the following:

1. Research is a systematic activity:
    - Produced knowledge is a coherent whole
    - Results should integrate with a system of knowledge. (i.e. you build on literature and compare with literature)
2. Research is centered on reality,
    - e.g. nature, society, people’s behavior, people’s attitudes,
    - In other words: don’t just speculate, look at things
3. Research uses precise tools:
    - Such tools are hypothesis, theories, methods, reliable techniques etc.
    - You also should be aware of your "confirmation bias", test your conclusions against alternative explanations,
4. Research aims at generalization:
    - It contributes to theories by using (and testing) their theoretical statements.
    - It reuses intellectual instruments (frameworks, analysis grids, etc.)
    - It suggests modifications of existing knowledge (or even new theories)
5. A belief in determinism:
    - Phenomena are the necessary consequence of conditions (causes).
    - In other words: randomness in explanation is only due to ignorance, complexity, etc.
6. A principle of relativism:
    - Our knowledge is not perfect , in particular in social sciences where humans are subject and object, observer and observed and where many variables influence a phenomenon.

Table 2: The nature of empirical research

Research is not only required to be "good" it also should be interesting. An **interesting** piece of research contributes something that is **new**. More precisely, you will have to produce something that is ***new*** in *one way or another*.

Interesting research may:

- answer new questions
- answer old questions without good answers
- answer otherwise to questions addressed by the literature
- provide support to answers found in literature with a new argumentation
- Apply a theory to new types of cases (e.g. does it apply to the Dubai school system?)

Table 3: What is interesting research?

According to Randolph (2008:23), the American Education Research Association (2006:34) suggests that research can contribute to knowledge in the following ways.

- It can contribute to an already established theory or line of empirical research,
- It can help establish a new theory,
- It can meet a practical need, or
- It can make up for a lack of needed information about a problem or issue.

There is also a more personal and social component. An interesting piece of research should provide **satisfaction** both to you and to a certain community. As you may discover, even writing a master thesis is quite an endeavor. Knowing that you may find it interesting and that it can be useful for your future career is a strongly motivating factor and will help you getting it done.

According to Randolph (2008:19), *typically, research in educational technology is conducted for one or more of the following purposes:*

1. *to answer questions that are important for the development of an educational intervention;*
2. *to answer questions that are important to local stakeholders to improve, come to understand, or assign value to a program; or*
3. *to answer questions that are important to the scientific community.*

These purposes are very different from each other and you may add your own. It is therefore very important that you have a clear picture about the goals of your research. This also will have an impact on research methodology. "*The research traditions that correspond primarily with the purposes of research listed above are (1) design-based research, (2) evaluation research, and (3) education research, respectively.*" (Randolph, 2008: 19). We should add (3b) the *learning sciences* and (3c) *applied computer science*.

2.3 Kinds of method and theory

Good research relies both on method and theory and we will come back to this issue in this text all the time. In this short section, we just will clarify some terminology and introduce **different levels** or kinds of method and theory.

Let us now look first at the epistemological dimensions of research methods. As we mentioned before, there exist a number of philosophical theories about "knowing" and good science. However, at a more practical level, you will first have to think about general **methodologies** (also called **approaches**) and that will determine globally how you plan to answer your research questions. At a lower level there exist **methods,** e.g. global sets of recipes that will tell how to address a given research problem, e.g. conduct a survey research. We finally add ***reasoning*** methods and ***techniques***.

Table 4 provides an overview. It is particularly important to ***distinguish*** between methodologies, methods and techniques. I.e. you should be aware that a piece of research usually has a global "methodological orientation" (what we call methodology or approach here); that for each approach you may use a set of methods and for each method a set of techniques. However, a given technique may be used within several methods and approaches. E.g. you can compute averages (a technique) in both quantitative and qualitative research designs.

1. Theories of science
   - Sets from a philosophical perspective the conditions of scientific knowledge
   - Example: "you can't prove a hypothesis" (only evidence, show that alternatives are wrong...)
2. Methodologies (also called approaches)
   - *General recommendations on how you should design a research plan*.
   - Draws from a theory of science and suggests a set of legitimate methods.
   - Example: "you should draw hypothesis from theory and then test it with quantitative research".
3. Methods
   - *Are general* recipes to study a given class of phenomena.
   - Examples: "survey research methodology", "participatory software design"
4. Reasoning Methods
   - How to pass from data to theory and from theory to data?
   - .... (influenced by theories of science and doctrine of approaches)
5. Techniques
   - Are *practical tools* to collect, manipulate, and analyze data; manipulate concepts, etc.

Table 4: Epistemological dimensions of research method

In a similar way, different levels of theories exist and in your research you may refer to one or another. Table 5 lists the five most important levels of theory.

1. Big theories
   - Go after complex topics and cannot be fully be tested.
   - Examples: evolution of children's minds, learning, evolution of society …
2. Theories with limited scope
   - Concern more restricted domains.
   - Examples: usability guidelines for software, conditions under which multimedia animations are effective, conditions under which e-learning projects can be sustainably implemented…
3. Formal models
   - Are based on formal systems, e.g. mathematics, logics, rule systems, formal learning designs.
   - Such models are often tested with empirical data
4. Conceptual models
   - e.g. Systems analysis, activity theory
   - These are conceptual tools that allow you to talk about a phenomenon, to look at them in a certain way
5. Hypotheses
   - Are frequently part of a theory with limited scope or of a formal model. They are clear propositions that can be tested with data
   - Example: "to introduce technology in schools, you need to provide a pedagogical support structure"

Table 5: Levels of theories

In a given piece of research, you will have to find the "right combination" of method and theory. *Figure 7:Levels of method and theory and the approach* shows how all these elements may fit together. As you may guess, finding the right combination of all these elements is not obvious. This is way we shall introduce now the concept of "research approach" and "research paradigm", i.e. standardized and popular ways to do research.

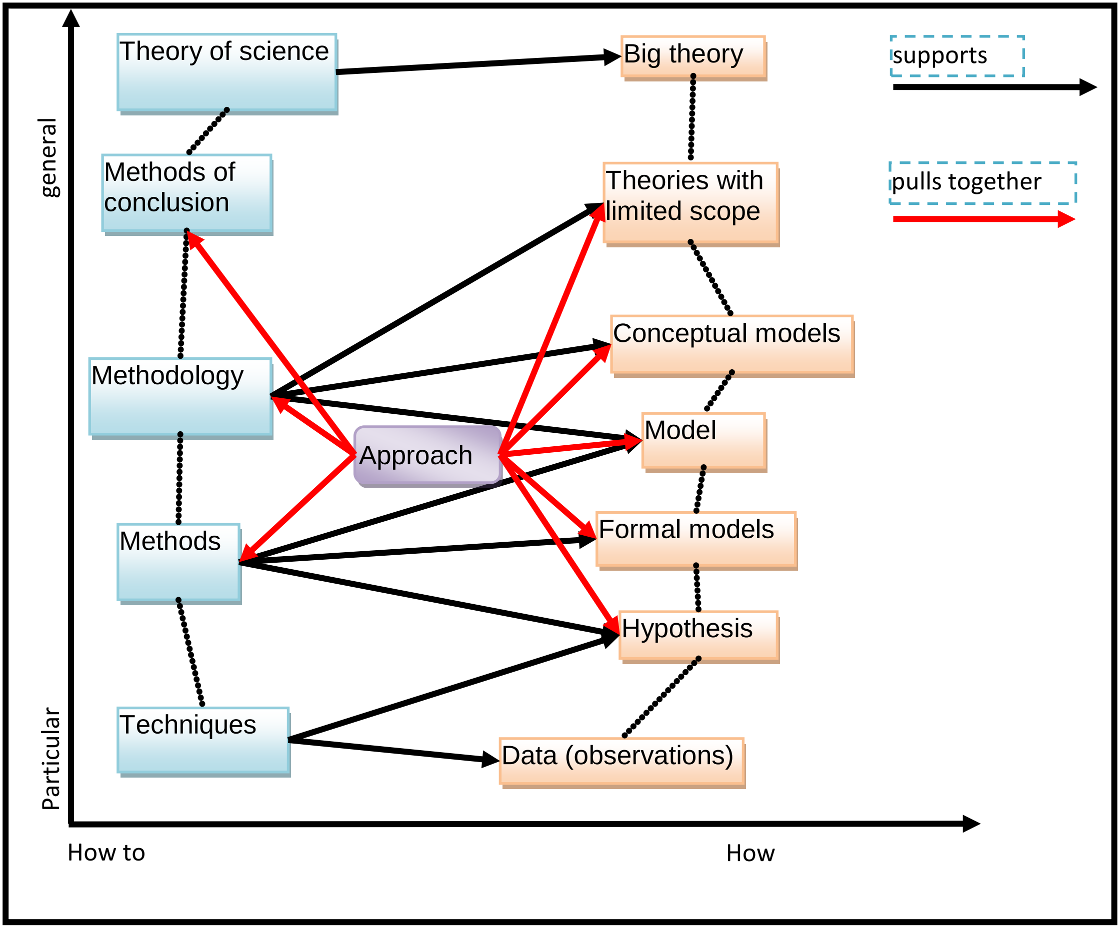


Figure 7:Levels of method and theory and the approach

Research paradigms and approaches

The term “paradigm” has been coined by Thomas Kuhn who wrote extensively on the history of science and developed several important notions in the philosophy of science. He coined the term “normal science” to refer to the relatively routine, day-to-day work of scientists who share an understanding with a community of other researchers regarding the nature of research and the nature of problems that constitute interesting research. Such views are called paradigms. Table 6 includes a list of the most important elements of a research paradigm.

1. A general and asymptotic research goal
    - Example: Understand how to teach (instructional design).
    - At this level, you will find general ideas at what you should look at.
2. Intermediate level: partial theories.
    - Example: to teach sustainable knowledge, one must engage students in practice and gradually introduce authentic problems that must be solved by themselves
3. Operational level: empirically tested theories.
    - Example: how to teach procedural programming, drive a car, solve a simple geometry problem.
4. Each paradigm favors certain methodologies and provides you with “toolkits”, i.e. methods and techniques.

Table 6: Elements of a research paradigm

Why is important that you know about this research paradigm, or more precisely why should you prefer “paradigmatic research”? Here are some arguments:

1. You are *more productive* if you can count on confirmed research methodology.
2. Different researchers can *work together* , or at least profit from each others’ results if they use the same language and the same theories

Now, what happens if you don’t??

1. People will not understand you and therefore ignore you, and
2. your results are not comparable.

Remark: In experimental psychology, "paradigm" refers to a proto-typical experiment that can and is replicated in various studies. This does not convey the same meaning, but then experiment, comparison and replication are fundamental pillars of this field. In other words, a researcher in experimental psychology does not need to reflect about very general ways of doing things. It is a "paradigmatic science" and therefore the word "paradigm" can be used for a different purpose…

Let us now discuss what we mean by **research approach**. There are in fact two different definitions. "Approach" refers either to a ***general methodology*** (how to conduct research) or to a more ***global paradigm*** that extends sharing of methodology to common goals and theoretical elements.

(1) ***Approach = general methodology***

- A way to conduct research.
- It includes a set of useful and tested methods for studying a set of phenomena.
- An approach is often transdisciplinary. For example, the quasi-experimental approach was developed in educational science but has been exported to public policy analysis and many other domains

(2) ***Approach = paradigm (see above)***

- For example: you might use "activity theory approach" to say that you believe in a Marxist activity-based scheme of looking at social phenomena, that you adopt Engeström's related educational theories, that you favor qualitative methodology and that you are interested in change.

Let us now address the issue of **interdisciplinarity**. Interdisciplinarity combines various approaches or paradigms and therefore is not what Kuhn would call "normal science". We can distinguish among four kinds of interdisciplinarity.

1. **Multi-disciplinary**: juxtaposition on the same object of various research paradigms, each one keeping its own language.
2. **Inter-disciplinary**: confrontation and exchange of methods and/or adoption of a mix from various fields for a new field.
3. **Trans-disciplinary**: usually a conceptual model at high abstraction level, e.g. systems theory.
4. **Cross-disciplinary**: explaining a phenomenon belonging to a discipline with theories and methods of another, e.g. educational economics.

Table 7: Multi-, inter-, cross- and transdisciplinarity

Interdisciplinary research is very popular with decision makers and the public at large, but very ***little*** with most researchers. For each kind of these non-paradigmatic research avenues, there exist problems you will have to cope with:

- Multi-disciplinary research is difficult to coordinate. Participants need wide knowledge and very good communication skills to talk to each other.
- Interdisciplinary research is easier to conduct because only methods and concepts that fit your research problems are taken from other fields. However, the concerned scientific communities may dislike that. Interdisciplinary research takes *more time* than disciplinary research. For example, doing a "complete" educational technology thesis that involves pedagogy, psychology, sociology and ICT development takes more resources than doing a thesis in just one of these areas.
- Your mileage may vary if you plan to do transdisciplinary or cross-disciplinary research. This is something that is usually done by experienced researchers and not in a master thesis.

2.4 Types of research

After our rather abstract discussion about research paradigms and approaches it is now time to look at research in terms of research families that are popular in the social sciences, educational technology included.

Firstly, we should clarify that research tries to explain and to generalize phenomena. According to this principle, we can distinguish ***three levels of theory*** and rate research according to these.

1. Simple description:
    - Don't engage in such a project since it doesn't have much academic value (unless it is led to prepare further research)
2. Classifications and categorizations: put order in concepts or data:
    - The intelligent case study (exploratory research)
    - Typologies (identify characteristics of classes of cases, e.g. uses of technology in schools, types of teachers according to their beliefs in pedagogy, use of ICT, use of new pedagogies, etc.)
    - Ideal-types (theory-based identification of classes of cases)
    - The systems model (shows interactions between elements)
    - ....
3. Research where *theory* plays important role:
    - Theory attempts generalization and demonstrates regularities.
    - Theory tries to understand, to explain, or to predict.

It is generally agreed that research should aspire to level 3. Level 1 is barely considered research and level 2 is appropriate at certain evolutionary status of a research subject, in particular when little is known about a domain.

Research also can be classified according to **scientific ends**, i.e. the general purpose of a project. Most research types in the following summary table, modified from Marshall & Rossmann (1995: 41), are what we called "level 2" research above.

Finalities	Typical questions	Approaches	Methods
exploratory • study of new phenomena • preparation of another research	• What happens in this program? • How does this organization work?	• case study • field study	• participatory observation • in-depth interviews • information interviews
explanatory • explain the forces that constitute a phenomenon	• Which events, behaviors, beliefs result in this phenomenon?	• comparative case study • historical study • field study • ethnography	• (like above) • questionnaires • document analysis • field observations
descriptive/ comprehensive • documentation of a phenomenon • comprehension	• What are the events, structures, processes that constitute this phenomenon?	• field study • case study • ethnography	• (like above) • non-intrusive measures • task observations

predictive • global predictions • predictions of events, behaviors etc.	• What's the result of X? • How does X influence Y?	• experiment • quasi-experiment • statistical • simulation	• questionnaires • quantitative content analysis • quantitative obs.
engineering • delivered product • delivered technical rule • test of a technical rule	• What's the problem? • How to build something? • Does it work? • What are its effects?	• designs (with user, usability studies) • most approaches above before and after engineering	• application of design rules (technical rule) • rather qualitative • most methods above

Table 8: Research according to scientific ends

Järvinen (2004: 10) proposed a similar taxonomy, but it is arranged in a tree that shows how different approaches relate to each other.

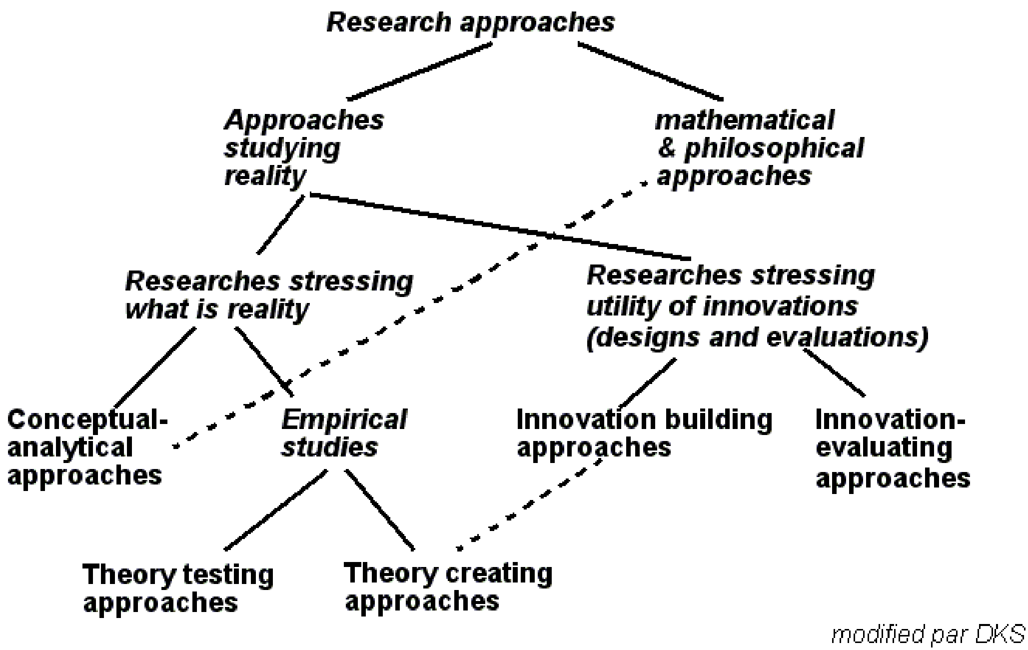


Figure 8: Research approaches (Järvinen)

This typology is interesting because it integrates engineering sciences, something social science methodology texts usually do not. Since part of educational technology is research on technologies and since e-education itself can be called a form of engineering, this Järvinen typology is useful.

So far, we discussed research approaches in general. Each field of research may contribute its own somewhat topic-influenced typologies. We shall look at educational technology research in the following section.

Let us finish this discussion with a very simple typology of research and that we will use to organize chapters on research design: ***explanatory theory testing***, ***theory creation***, and ***design*** research.

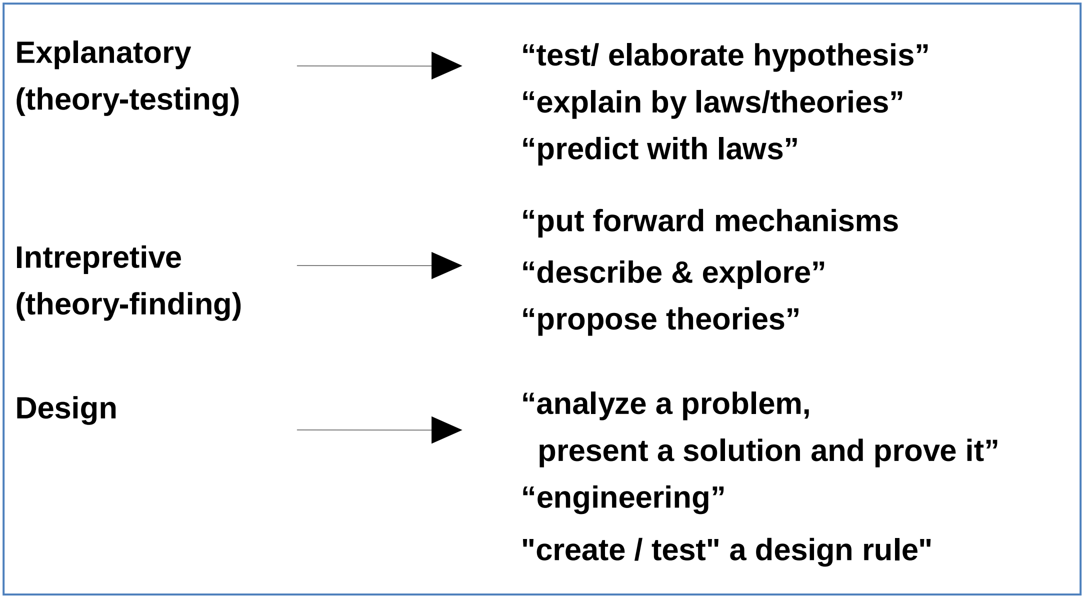


Figure 9: A simple typology of research types

As you may discover later, in educational technology, you often will find hybrid research designs, e.g. a study that both attempts to “engineer” a practical education problem, but also to answer some more fundamental research questions.

2.5 Interesting research in educational technology

Educational technology is a wide field. Therefore, one can find many definitions, some of which are conflicting. Educational technology can be considered either as a **design science** or as a **collection of different research interests** addressing fundamental issues of learning, teaching and social organization. Nevertheless, there are a few features on which most researchers and practitioners might agree:

1. Use of technology is principled: Technology means the systematic application of scientific knowledge to practical tasks. Therefore, **educational** technology is based on theoretical knowledge drawn from different disciplines (communication, education, psychology, sociology, philosophy, artificial intelligence, computer science, etc.) plus experiential knowledge drawn from educational practice.
2. Educational technology aims to **improve education**. Technology should facilitate learning processes and increase performance of the educational system(s) as it regards to effectiveness and/or efficiency.

2.5.1 What is educational technology?

Educational technology is an interdisciplinary **field**. **An** *educational technology* refers to a specific technology that is particularly suited for education. Beyond this distinction and according to research tradition, there are other names for educational technology, for example:

- Instructional technology
- E-education
- E-learning

- Educational communications and technology
- Learning technology

Educational technology is divided into many technical ***sub-fields***. Each refers to many different pedagogical and technical designs. Here is an incomplete list: *cognitive tools for learning, computer-assisted language learning, computer-based assessment systems, computer-based training, computer-mediated communications, computer-supported collaborative learning, distributed learning environments, electronic performance support systems, interactive learning environments, interactive multimedia systems, interactive simulations and games, intelligent agents on the Internet, intelligent tutoring systems, micro-worlds, and virtual reality based learning systems*.

We therefore can quite safely claim that educational technology is not a well-defined field, but rather a collection of sub-fields within which researchers and practitioners may specialize. In addition, researchers adopt different stances of what it means to practice academic research. For our field, we could distinguish a series of levels going from the conceptual to the technical:

1. **Fundamental research**: Many researchers in the field choose to adopt a more fundamental research stance focusing on small well-defined problems such as "under which conditions can multimedia animations be effective".
2. **Technology-supported instructional design** applied to various **domains** of education. Major categories are distance teaching, blended teaching, computer-enhanced classroom teaching, industrial training. Other specializations may concern subject matters (e.g. science or language teaching) or approaches (direct instruction vs. project-oriented learning for example).
3. Research on the **design and application of technologies**: Researcher may specialize on subjects like the use of computer simulations in education or

more technically, how to build authoring and learning environments for simulations.

To further complicate things, some researchers may combine a fundamental research perspective with a particular kind of instructional design and a particular kind of technology. Depending upon these options, research interests and research methodology will not be the same. From these possible combinations, we probably could identify two major strands of thought:

1. Educational technology as part of the **learning sciences**: Research is inspired by and contributes to modern learning theory. This strand includes research communities like computer-supported collaborative learning, intelligent tutoring systems, ubiquitous computing.
2. Educational technology as **instructional technology:** It is inspired by and contributes to **instructional design theory** and methodology. This strand includes research communities on e-learning, distance teaching, and multimedia design.

Educational technology can be considered as a design science and as such, it has developed some specific research methodology like "Design-based research". However, since it addresses also all fundamental issues of learning, teaching and social organization, educational technology ***makes use of the full range of modern social science and life sciences methodology***. Globally speaking, research methodology for educational technology relies on general research methodology, in particular on approaches of the social sciences.

2.5.2 Research topics in educational technology

One way to find out what kind of research is popular and recognized is to study authoring guidelines for good academic journals in the field.

The **Journal of the Learning Sciences** is the official journal of The International Society for Learning Sciences. It defines its aims in the following way (April 2009):

> *The **Journal of the Learning Sciences** provides a multidisciplinary forum for the presentation of research on learning and education. The journal seeks to foster new ways of thinking about learning that will allow our understanding of cognition and social cognition to have impact in education. It publishes research articles that advance our understanding of learning in real-world situations and of promoting learning in such venues, including articles that report on the roles of technology can play in promoting deep and lasting learning. The Journal of the Learning Sciences promotes engaging and thoughtful participation in learning activities, and articles reporting on new methodologies that enable rigorous investigation of learning in real-world situations.*

The **Educational Technology Research and Development** journal is the official journal of the Association for Educational Communications & Technology. It defines itself like this (April 2009):

> *Educational Technology Research and Development is the only scholarly journal in the field focusing entirely on research and development in educational technology.*
>
> *The Research Section assigns highest priority in reviewing manuscripts to rigorous original quantitative, qualitative, or mixed methods studies on topics relating to applications of technology or instructional design in educational settings. Such contexts include K-12, higher education, and adult learning (e.g., in corporate training settings). Analytical papers that evaluate important research issues related to educational technology research and reviews of the literature on similar topics are also published. This section features well documented articles on the practical aspects of research as well as applied theory in educational practice and provides a comprehensive source of current research information in instructional technology.*
>
> *The Development Section publishes research on planning, implementation, evaluation and management of a variety of instructional technologies and learning environments. Empirically-based formative evaluations and theoretically-based instructional design research papers are welcome, as are papers that report outcomes of innovative approaches in applying technology to instructional development. Papers for the Development section may involve a variety of research methods and should focus on one or more aspect of the instructional development process; when relevant and possible, papers should discuss the implications of instructional design decisions and provide evidence linking outcomes to those decisions.*

The ***Journal of Interactive Learning Research*** is edited by Association for the Advancement of Computing in Education. It *publishes papers related to the underlying theory, design, implementation, effectiveness, and impact of interactive learning environments in education and training*. We shall reproduce a longer extract of its definition of scope (May 2009):

> *Many researchers fail to distinguish clearly between the goals of their research and the methods they employ. [Table 9 andTable 10] present a classification scheme intended to distinguish between the goals and the methods of research. Most research studies submitted to JILR should be able to be classified according to the six research goals represented in Figure 1. This scheme reflects the debate about research "paradigms" that has dominated social science research literature for decades. For example, Soltis (1992)*

claims there are currently "three major paradigms, or three different ways of investigating important aspects of education" (p. 620): 1) the positivist or quantitative paradigm, 2) the interpretivist or qualitative paradigm, and 3) the critical theory or neomarxist paradigm. The three categories presented by Soltis (1992) fail to capture the full breadth of research goals in the fields of inquiry relevant to JILR, and therefore the scheme in Figure 1 includes more categories. However, the goals of inquiry represented in Figure 1 are not intended to be a complete and final listing of research goals.

Theoretical	*Research focused on explaining phenomena through the logical analysis and synthesis of theories, principles, and the results of other forms of research such as empirical studies.*
Empirical	*Research focused on determining how education works by testing conclusions related to theories of communication, learning, performance, and technology.*
Interpretivist	*Research focused on portraying how education works by describing and interpreting phenomena related to human communication, learning, performance, and the use of technology.*
Postmodern	*Research focused on examining the assumptions underlying applications of technology in human communication, learning, and performance with the ultimate goal of revealing hidden agendas and empowering disenfranchised minorities.*
Developmental	*Research focused on the invention and improvement of creative approaches to enhancing human communication, learning, and performance through the use of technology and theory.*

Evaluation	*Research focused on a particular program, product, or method, usually in an applied setting, for the purpose of describing it, improving it, or estimating its effectiveness and worth.*

Table 9: Research goal classification scheme

Quantitative	*Experimental, quasi-experimental, correlational, and other methods that primarily involve the collection of quantitative data and its analysis using inferential statistics.*
Qualitative	*Observation, case-studies, diaries, interviews, and other methods that primarily involve the collection of qualitative data and its analysis using grounded theory and ethnographic approaches.*
Critical Theory	*Deconstruction of "texts" and the technologies that deliver them through the search for binary oppositions, hidden agendas, and the disenfranchisement of minorities.*
Literature Review	*Various forms of research synthesis that primarily involve the analysis and integration of other forms of research, e.g., frequency counts and meta-analyses.*
Mixed-methods	*Research approaches that combine a mixture of methods, usually quantitative and qualitative, to triangulate findings.*

Table 10: Research methods classification scheme.

A methodology classification scheme is represented in Figure 2. There are numerous methods available to researchers in areas as diverse as cognitive psychology, instructional technology, and computer science (cf., Driscoll, 1995), but for the sake of simplicity, these five methodological groupings provide sufficient discrimination to represent the major *approaches likely to be used in investigations reported in JILR. This journal will be especially open to submissions that involve alternative methods (e.g., qualitative and critical theory) which seem to be underrepresented in more traditional publications.*

The ***Journal of Interactive Media in Education*** is a good "open access" (free) on-line journal. Its aims are defined as follows (May 2009):

- *To **foster a multidisciplinary and intellectually rigorous debate** on the theoretical and practical aspects of interactive media in education.*
- *To **clarify the cognitive, social and cultural issues** raised by the use of interactive media in education.*
- *To **radically improve teaching and learning through better interactive media**.*
- *To publish leading international research on the theories, practices and experiences in the field.*
- *To l**ink scholars and commercial practitioners***
- *Through its **innovative use of interactive Net-based media,** to be an action research project which explores the changing face of journals, and more broadly, scholarly practice in the age of digital publishing and communication.*

JIME's name is open to multiple interpretations, given the variation in usage of each of the component terms. They are to be interpreted broadly:

- ***Interactive** - refers both to interaction through the media with other people (e.g. teacher-student, student-student, researcher-teacher), and to interaction with the materials embedded in the media (e.g. control of a simulation or educational game).*
- ***Media** - refers to the range of modalities which can be used to support learning. Media may represent educational materials, as well as other people relevant to that learning task. Media embraces text, sound, still and animated graphics, video, model worlds and virtual reality, as applied to the*

delivery of learning materials and communication between relevant communities.

- ***Education*** *- includes all levels and types: schools, colleges, universities, home learning, open and flexible learning, distance learning, personal development, skill learning, work-based learning, and lifelong learning.*

There exist many more academic journals and each of these has a somewhat different view of what kind of research is interesting and acceptable.

Other ways to find out what what kind of research is popular and recognized is to look at conference proceedings and PhD thesis. A third possibility is to refer to meta studies on research topics and methods. A very good source is the free on-line book "*Multidisciplinary Methods in Educational Technology Research and Development*" by Justus J. Randolph. Randolph gives answers to the four following questions:

- What are the methodological factors that need to be taken into consideration when designing and conducting educational technology research?
- What types of research questions do educational technology researchers tend to ask?
- How do educational technology researchers tend to conduct research? – What approaches do they use? What variables do they examine? What types of measures do they use? How do they report their research?
- How can the state of educational technology research be improved?

From his text, we extracted some examples of typical research questions:

Knowledge-based (literature analysis) questions:

- What is known about best practices in user-centered design?

- Across studies, what are the academic effects of tools that help students visualize algorithms?
- What variables are known to influence the effectiveness of educational interventions?

Empirical research questions

- What are the effects of a new technological intervention on the long-term and short-term memory retention of vocabulary words?
- To what degree do students and teachers report that they are satisfied with a new intervention?
- In what ways do teachers and students report that a new intervention can be improved?

Such questions are very general and they just summarize a research subject. As you shall see later, you must learn how to break down a general question into sub-questions: According to Randolph (17). The following question:

- What is the essence of the experience of sense of community in online courses?

This question then could be further specified with these three sub-questions:

- What do teachers experience in terms of the phenomenon of sense of community in online learning?
- What do students experience in terms of the phenomenon of sense of community in online learning?
- What medium-related contexts influence stakeholder's experience of community in online learning?

2.6 Summary

Educational technology makes use of the full range of modern social science and life sciences methodology.

We will distinguish between three main types of research: ***Explanatory theory testing***, ***theory finding***, and ***design research***.

Review questions

1. What are the objectives of educational technology research?
   - Please write down three objectives of educational technology research.
   - Justify for each why you consider it important.
2. Is the there an obvious correspondence between a research question and a research methodology?
   - Explain why or why not.
3. Is educational technology a paradigmatic field? Justify your answer.
4. What are the two definitions of “approach”?

3 Empirical research principles

The purpose of this chapter is to provide an overview of some essential principles that define ***empirical research, i.e. research that looks at data***. Most of the issues will be addressed again throughout the following chapters. Reading this chapter will help you thinking about the research design of a little project. We will explain how to formulate a general research question in terms of operational questions that will help you answering this general question. We also will point out some reasoning pitfalls and reliability and validity problems that may arise.

Learning goals

- Understand the central role of research questions
- Know the elements and the organization of a typical research process
- Understand "operationalization", i.e. the relationship between theoretical concepts and measures (observations, etc.)
- Be able to list some major measurement (data gathering) instruments
- Understand the concepts of reliability and validity and be able to challenge causality claims.

3.1 The typical empirical research cycle

Details of a given research cycle may considerably change within different approaches. However, most research should start by defining precise research questions through a review of the literature and reflections about the objectives.

Figure 10 shows the typical research cycle. We distinguish five major steps: (1) Defining the objectives, reading the theory and formulating questions,; (2) using conceptual and analytical frameworks to make these questions more operational, (3) creating research instruments and/or designs; (4) collecting data and (5) analyzing the data and reporting the results.

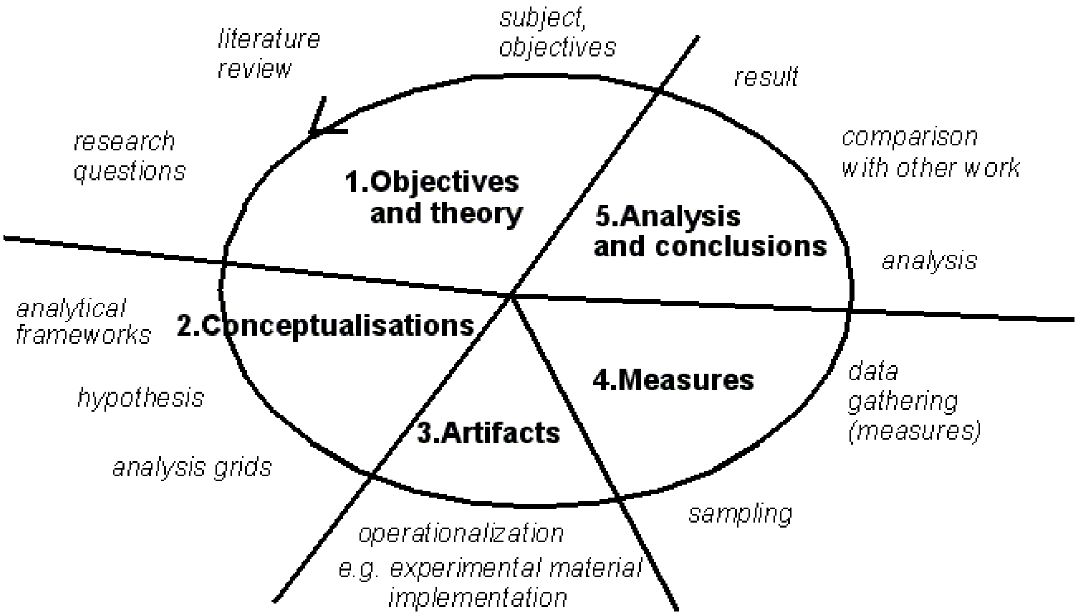


Figure 10: The typical research cycle

For a given **research question**, you usually have to do ***make your question more explicit*** (what we call conceptualizations here), and ***create artifacts*** (e.g. research instruments or designs). Then you will have to ***collect data*** (measures) which you finally have to ***analyze*** in order to answer the research question and sub-questions.

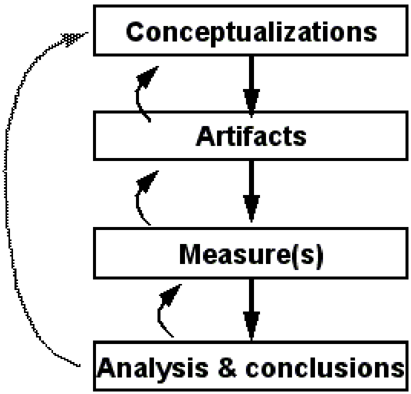


Figure 11: Answering a research question

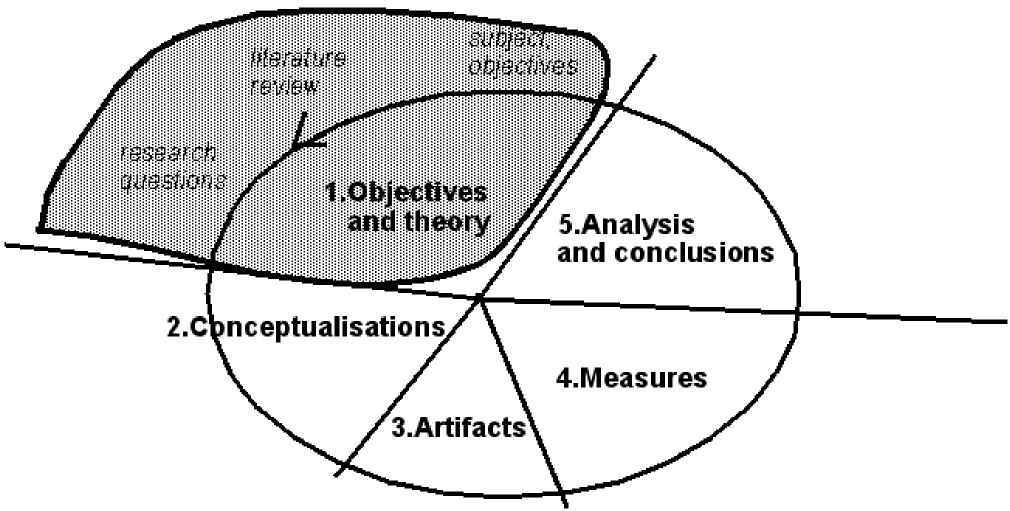
- ***Conceptualizations:*** make questions explicit, identify major concepts (variables), define terms and their dimensions, find analysis grids, define hypothesis, etc,
- ***Artifacts:*** develop research materials (experiments, surveys), implement software, implement designs in the field, etc. Artifacts can be made just for research purposes (e.g. in experimental research) or for "real" purposes (e.g. a computer-supported learning environment for a precise training need)
- ***Measures:*** Observe (measure) in the field or through experiments. *Use* your artifacts in various ways to collect data.

- ***Analysis & conclusions:*** Analyze the data (statistic or qualitative) and link to theoretical statements (e.g. operational research questions and hypothesis).

We now shall look in more detail at each element of the research cycle.

3.2 The research objectives

Research objectives are the starting point of a research project. The **essence** of your research objectives should be formulated in terms of clear research questions.



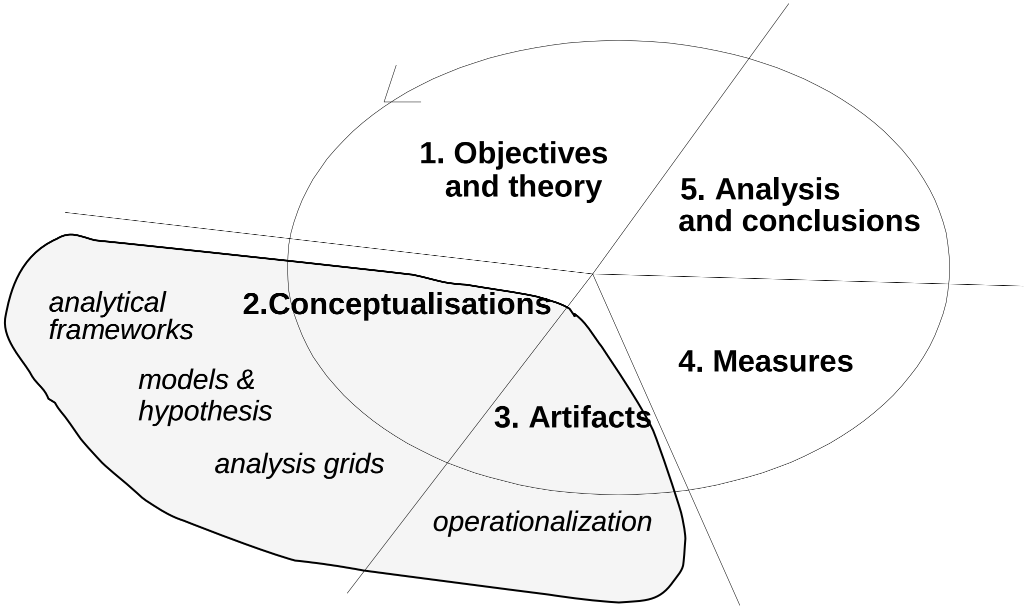
Research questions are the result of:

- your initial objectives (which you may have to revise)
- a (first) review of the literature

Everything you plan to do must be formulated as a research question! See chapter 4 where we will elaborate this question in some more detail.

3.3 Conceptualizations and artifacts

Under the umbrella "conceptualizations" we define a set of intellectual instruments that help you to organize your research questions and the knowledge about a given subject area.



One of your first tasks is to find, elaborate and tailor concepts needed to study observable phenomena. Some of these concepts (analysis frameworks) may globally determine how you look at things; others will add shape to explanatory or explaining variables.

We shall come back to this issue in chapter 7 and we will just provide a few examples here.

Analysis frameworks

Analysis frameworks (analytical frameworks) help you look at things. A popular framework in educational technology research is activity theory, which has its roots in what could be called soviet micro-sociology.

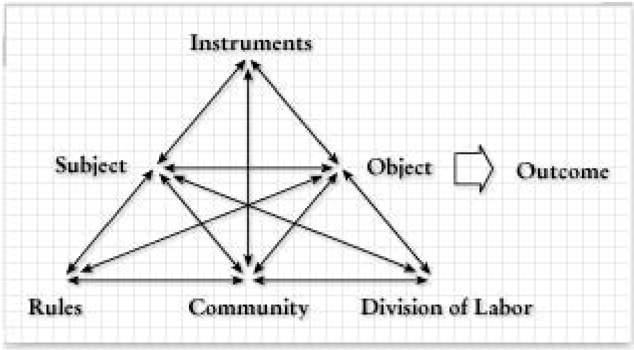


Figure 12: Activity theory triangle

> *The Activity Triangle Model or activity system representationally outlines the various components of an activity system into a unified whole. Participants in an activity are portrayed as subjects interacting with objects to achieve desired outcomes. In the meanwhile, human interactions with each other and with objects of the environment are mediated through the use of tools, rules and division of labor. Mediators represent the nature of relationships that exist within and between participants of an activity in a given community of practices. This approach to modeling various aspects of human activity draws the researcher s attention to factors to consider when developing a learning system. However, activity theory does not include a theory of learning, (Daisy Mwanza & Yrjö Engeström)*

Translation: It helps us thinking about the working of an organization (including its actors, its artifacts and its processes) and therefore how to study it.

Such a framework is not true or false, it is just *useful* (or useless) for a given intellectual task! Finding good analytical frameworks is important and the best method is to identify them during the literature review.

Hypothesis and models

Models and hypothesis are important in theory-driven research, e.g. in experimental learning theory or quasi-experimental implementation or evaluation research.

- Hypotheses (and formal models) link concepts-as-variables and they *postulate causalities* most often expressed in terms of rules.
- Typically, a simple hypothesis postulates that a phenomenon can be explained by another. In more technical terms: ***independent variable X*** explains ***dependent variable Y.***
- Examples: "More X leads to more Y", or "an increase in X leads to a decrease in Y".

Causalities between theoretical variables do not "exist" per se, they only *can be observed indirectly*. Theoretical hypothesis must be operationalized, as we shall see in the following example.

Example 1. Example: Teacher training and quality of teaching

Imagine a research question that aims to know whether there is causality between teacher training and quality of teaching. In empirical research, such a research question would be formulated as a hypothesis that then can be tested.

An often heard hypothesis states the following:

- Continuous teacher training (***cause*** *X*) improves teaching (***effect*** *Y*)

In the picture below, we can show the following principles:

- As a starting point (on top), we need a causal theoretical hypothesis (the postulate).
- We then have to think how to measure each of the two concepts with observable data. E.g., teacher training could be measured by the “amount of training” and quality of teaching by “grades of pupils”.
- However, this operationalization is not enough. At some point, we have to be more precise, e.g. state that "amount of training" will be measured by "days of training received in one year".

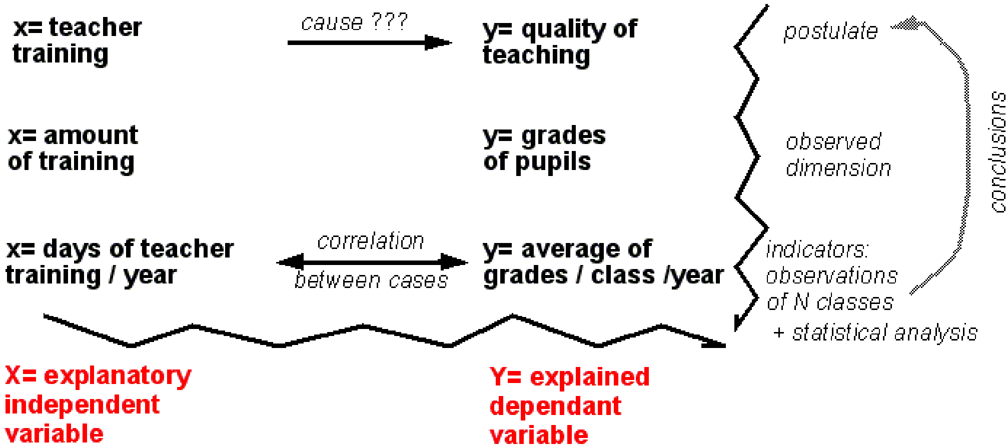


Figure 13: Hypothesis about teaching training

We shall come back later to this central concept of **operationalization**. The point here was to show that hypotheses should be formulated firstly at a conceptual level. They then need to be rephrased to become operational, i.e. applicable to real data.

The importance of difference (variance) for explanations

Before we further look into this operationalization issue, we need to introduce the "***variance***" concept. Variance means that data for a concept can have different values, e.g. teachers can receive {none, little, some, a lot,} of training. At the empirical level, we got a variable "amount of teacher training" that could have different values (none, little, etc.). If we can find this variety of values in observations, then we have variance. If all the teachers receive the same "*some* training" we don't have variance. Research needs variance. Without variance (no differences) we can't explain things.

Furthermore, we need co-variance. Empirical research wants to find out **why things exist**. We must observe ***explaining variables*** that have variance and then measure how they affect variables to be explained that have variance. In other words, without co-variance, we will not be able to explain anything.

Let's explain this principle with two examples

Example 2. Quantitative bivariate example

Let us imagine that we want to test the following hypothesis: "*Longer training makes better teachers*". We shall look at two empirical variables:

- *Training days for teachers* and
- *Average grades* of the classes they teach.

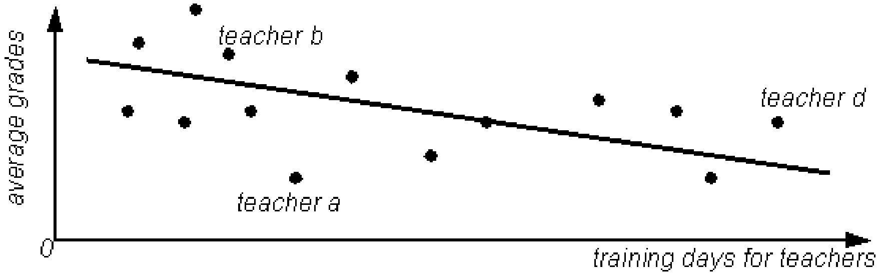


Figure 14: Quantitative variance example

This graphic shows that both variables we looked at have some variance, i.e. we got different grade averages and different training days for different teachers. We now are able to test the hypothesis. According to these hypothetical data, increased training days lead to lower averages. Therefore, the hypothesis should be rejected. Consider this hypothetical example false please!)

Example 3. Qualitative bivariate example

Imagine that we wish to know why certain private schools introduce technology faster than others do. One hypothesis to test could be: "*reforms happen when there is pressure external to the school system*". In this hypothesis, we have two variables (and according values)

- Variable Y = *reforms* (don't happen, somewhat happen, happen)
- Variable X = *pressure* (internal, external)

To operationalize these variables we use written traces for "pressure" and observable strategies adopted by the school for "reforms".

	Strategies of a school (reforms)			
Type of pressure	**strategy 1:no**	**strategy 2:a task force is**	**strategy 3:internal training programs**	**strategy 4:resources are**

	reaction	created	are created	reallocated
Letters written by parents	(N=8) (p=0.8)	(N=2) (p=0.2)		
Letters written by supervisory boards		(N=4) (p=0.4)	(N=5) (p=0.5)	(N=1) (p=0.1)
newspaper articles			(N=1) (p=20%)	(N=4) (p=80%)

N = number of observations, p = probability

The result of (imaginary) research is: Increased pressure leads to increased action. Data for example tells that:

- If letters are written by parents (internal pressure), the probability is 80% that nothing will happen
- If a newspaper article is written, the probability is 80% that resources are reallocated.

We therefore can corroborate our hypothesis. Of course, such results have to be interpreted carefully. We shall come back to these validity issues later.

3.4 The operationalization of general concepts

Now let us address the operationalization issue in more depth, since this is a very important issue in empirical research. A scientific proposition contains concepts (theoretical variables). Typical examples could be: *learner attitude*, *performance*, *efficiency*, or *interactivity*.

An empirical academic research paper ***attempts to find relations between concepts*** (theoretical variables) and grounds these links with ***data***. Firstly, you must find indicators and build indices, Second you will have to detect correlations in these data. Finally, from these analysis you then can make statements at the theory level, for example, corroborate or reject hypothesis.

Example 4. Collaborative learning improves pedagogical outcomes

We have two variables in this example:

1. Explaining (independent) variable: *collaborative learning*
2. Variable to be explained (dependent): *pedagogical effect*

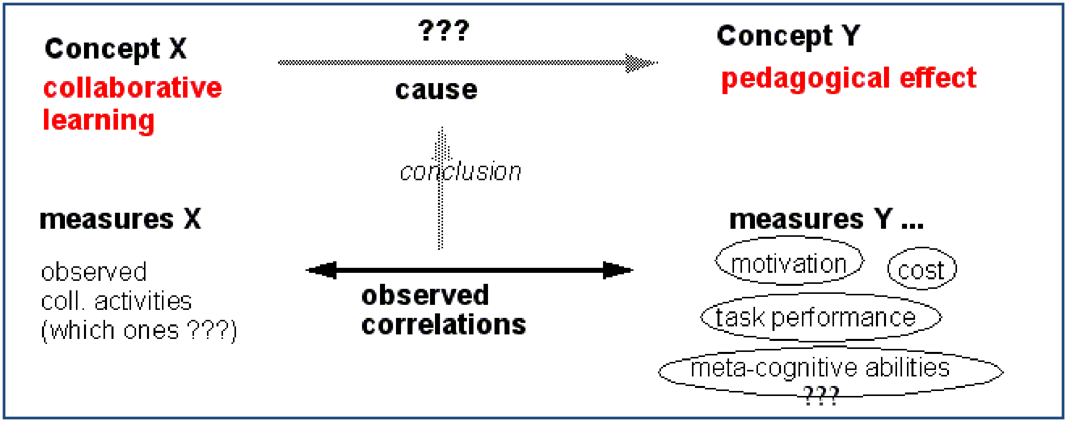


Figure 15: The measure of coll. learning and outcomes

We got a real problem here! How could we measure "pedagogical effect" or "collaborative learning"? Finding good measures is not trivial.

The bridge/gap between a theoretical concept and measures

When you operationalize a concept, there are two issues you must address. You want to minimize two (unavoidable) gaps between theoretical variables and variables that you can observe.

(1) Going from ***abstract*** to the ***concrete***. A theoretical concept cannot be measured directly, only though a series of observables.

Examples:

- You could measure “student participation” with “number of forum messages posted”
- You could measure “pedagogical success” with “grade average of a class in exams»”

(2) Going from the ***whole*** to ***parts.*** Often a concept is quite complex, i.e. it is composed of several ***dimensions.***

Let us illustrate this with a few examples.

1. *Socio-constructivism* refers to a school of pedagogical thought. If you plan to measure the “socio-constructiveness” of a pedagogical design, you should consider several dimensions. The concept «socio-constructivist design» could be decomposed into (1) *active or constructive learning*, (2) *self-directed learning*, (3) *contextual learning* and (4) *collaborative learning*, and (5) *teacher’s interpersonal behavior* (Dolmans et. al). An alternative view is hold by the *5e Learning* cycle socio-constructivist teaching model, "socio-constructivist teaching" is composed of *engagement, exploration, explanation, elaboration* and *evaluation*.

2. In public policy analysis, an important concept is "economic development". This variable is often decomposed in industrialization, urbanization, transports, communications and education.
3. In the Human-Computer Interaction studies, "usability" is an important factor. It can be decomposed in "*usefulness*" (does it serve its purpose) and the related "*cognitive usability*" (what you can achieve with the software) and finally "*simple usability*" (can you navigate, find buttons, etc.)

Review questions

1. Try to decompose a concept you find interesting. Then try to operationalize it.
2. Decompose the concept "teaching skill".
3. Take one of decompositions presented above and write down your opinion about it. Did we forget something? Would it apply to a context you are familiar with?

Let us now examine some examples in some more detail.

Example 5. COLLES questionnaire

Taylor and Maor (2000) developed an instrument to study on-line environments called the "Constructivist On-Line Learning Environment Survey (COLLES) questionnaire and it is available on-line: http://surveylearning.moodle.com/colles/.

This survey instrument allows to "to monitor the extent to which we are able to exploit the interactive capacity of the World Wide Web for engaging students in dynamic learning practices". The key qualities (dimensions) this survey can measure are:

- **Relevance**: How relevant is on-line learning to students' professional practices?
- **Reflection**: Does on-line learning stimulate students' critical reflective thinking?
- **Interactivity**: To what extent do students engage on-line in rich educative dialogue?
- **Tutor Support**: How well do tutors enable students to participate in on-line learning?
- **Peer Support**: Is sensitive and encouraging support provided on-line by fellow students?
- **Interpretation**: Do students and tutors make good sense of each other's on-line communications?

Each of these dimensions is then measured with a few survey questions. Each of these questions has the same response items, e.g.:

Statements	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
Items concerning relevance					
My learning focuses on issues that interest me.	O	O	O	O	O
What I learn is important for my professional practice as a trainer.	O	O	O	O	O
I learn how to improve my professional practice as a trainer.	O	O	O	O	O
What I learn connects well with my professional practice as a trainer.	O	O	O	O	O
Items concerning reflection					

... I think critically about how I learn.	O	O	O	O	O
... I think critically about my own ideas.	O	O	O	O	O
... I think critically about other students' ideas.	O	O	O	O	O
... I think critically about ideas in the readings.	O	O	O	O	O

Table 11: Excerpt of the COLLES questionnaire

We shall reuse the COLLES in further chapters, e.g. to illustrate data collection and data analysis principles.

Example 6. Example: The measure of economic development

In the diagram below we shortly picture how one could envision to measure economic development with official statistics (only part of the diagram is shown).

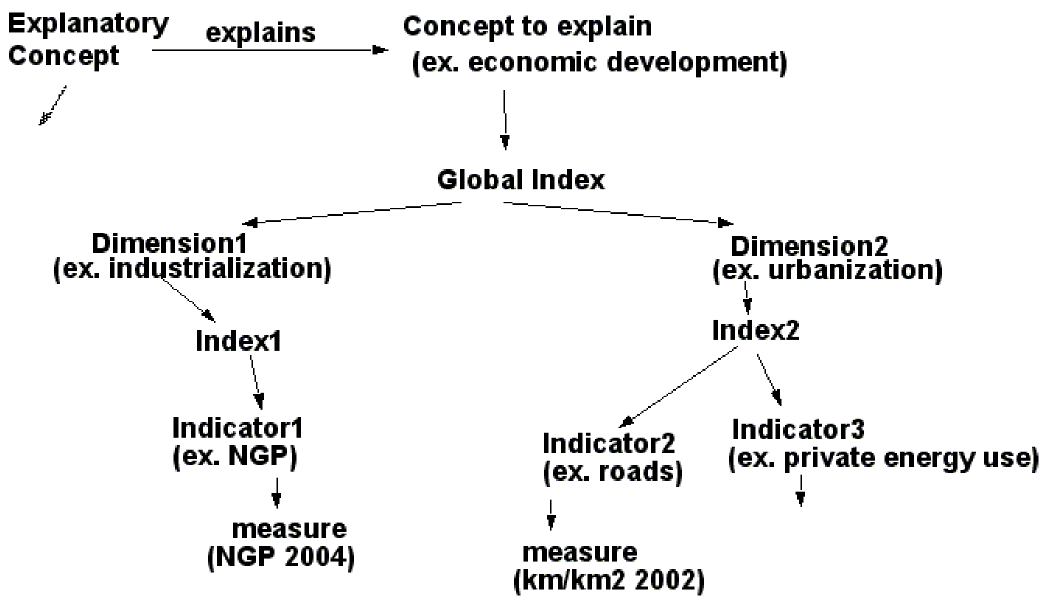


Figure 16: The measure of economic development

Example 7. Strategic efficiency of a commercial school

This example was taken from a French methodology textbook (Thiétard, 1999)

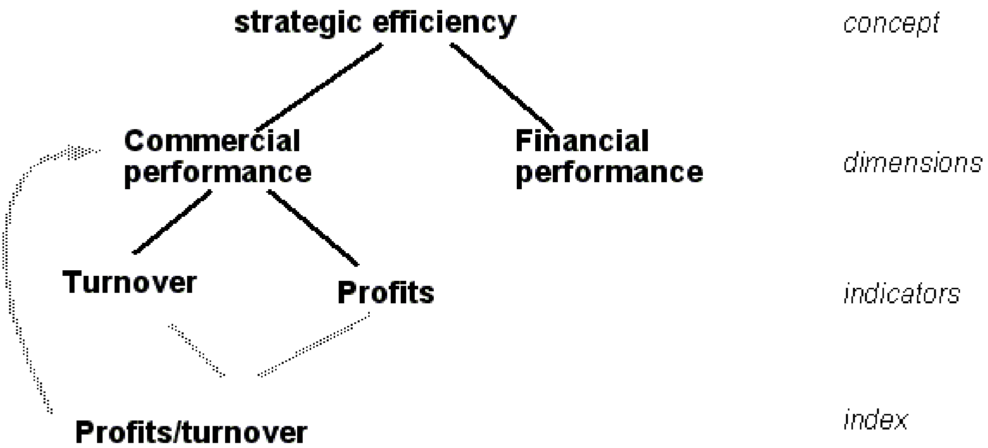


Figure 17: Operationalization of strategic efficiency

Summary - dangers and problems of concept operationalization

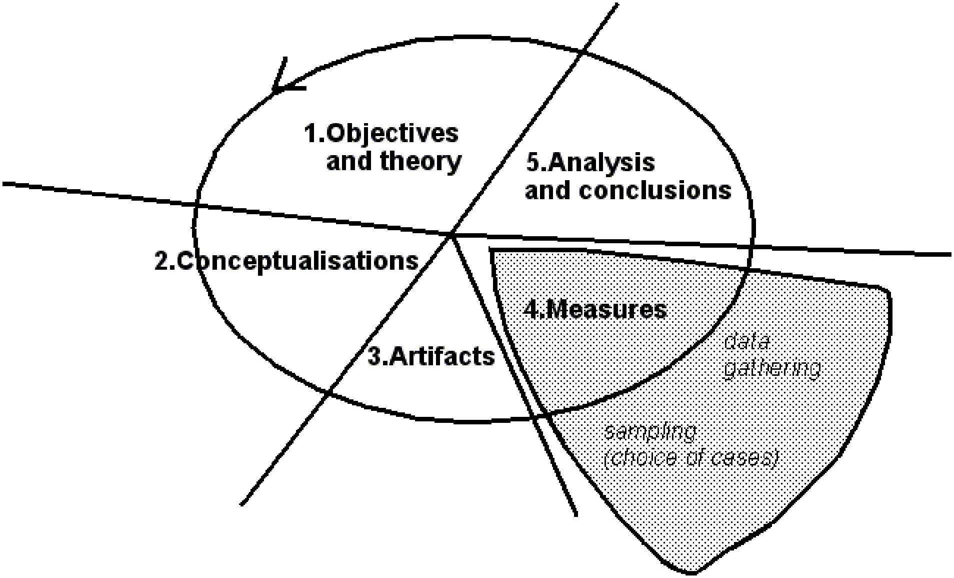
Let us summarize this section on concept operationalization. You critically should think about a few issues:

1. The Gap between data and theory
   - Example: measure communication within a community of practice (e.g. an e-learning group) by the quantity of exchanged forum messages
   - Problem: students may use other channels to communicate!
2. You may have forgotten a dimension
   - Example: measure classroom usage of technology only by looking at the technology the teacher uses e.g. power point, demonstrations with simulation software or math. software
   - Problem: you do not take into account technology enhanced student activities.
3. There could be concept overloading
   - Example: Include «education» in the definition of development (it could be done, but at the same you will lose an important explanatory variable for development, e.g. consider India's strategy that "over-invested" in education with the goal to influence development.
   - Therefore, never ever, collapse explanatory and explainable variables into one concept!
4. Bad measures
   - The kind of data you are looking at may not really measure the concept. We will come back later to this so-called "construct validity" issue.

Table 12: Dangers and problems of concept operationalization

3.5 The measure and data collection

Once you operationalized your research questions (and that may include operational hypothesis) you will have to think carefully about the kinds of data you will collect and at which cases (population) you will look at.



Measuring means:

- (If necessary) create data with artifacts (such as survey questions)
- Observe properties, attributes, behaviors, etc.;
- Select the cases you study (sampling).

According to Randolph (2008), the most popular data gathering techniques in educational technology are:

1. Questionnaires, ideal to collect from many people and to answer clearly defined research questions
2. Log files, to study how users make use of system, i.e. features they use, for how long, with whom they interact
3. Tests, to measure how knowledge changes over time, e.g. after an intervention
4. Interviews

5. Direct observation
6. Exercises
7. Teacher survey
8. Test (standardized)
9. Narrative analysis scheme
10. Number of resubmitted exercises
11. Time on task (electronic)
12. Focus groups
13. Pass rate

We may distinguish between data that is provoked by the researcher (e.g. interviews), data that is found by observation (e.g. classroom observation) and data that already exists (e.g. official statistics or existing log files)

Sampling

Sampling refers to the process of selecting ***cases***, e.g. people, activities, situations etc. you plan to look at. These cases should be representative of the whole "population" you wish to analyze. E.g. in a survey research the 500 persons that will answer the questionnaire should represent the whole group of people you are interested in, e.g. all primary teachers in a country, all students of a university, all voters of a state.

As a rule: **Make sure that operative variables have good variance**, otherwise you cannot make any statements on causality or difference. We define **operative variables** as the set of the **dependant** (to explain) plus the **independent** (explaining) variables.

Sampling in quantitative research is relatively simple. You just select a sufficiently large amount of cases within a given mother population (the one that your theory is about). The best sampling strategy is to randomly select a pool from the mother population, but the difficulty is to identify all the members of the mother population and to have them participate. We will address this issue again in chapter 12.

Sampling can be more complex in qualitative research. Here is a short overview of sampling strategies you might use.

Type of selected cases	**Usage and effect on your research design**
maximal variation	Will give better scope to your result. (But needs more complex models since you have to control more intervening variables)
homogeneous	provides better focus and conclusions; will be "safer" since it will be easier to identify explaining variables and to test relations
critical	exemplify a theory with a "natural" example
according to theory, i.e. your research questions	Will give you better guarantees that you can answer your questions....
extremes and deviant cases	test the boundaries of your explanations, seek new adventures
intense	complete a quantitative study with an in-depth study

Table 13: Short list of sampling strategies

For the moment, we want you to understand that sampling strategies depend a lot on your research questions and that there is no standard answer!

Review question

You are asked to lead a preliminary study of how teachers use an e-learning platform in your university. Since you have a limited budget, you only can interview 6 professors. Please specify, how you would select these and why.

Data collection techniques

Let us now look in more detail at what we mean by “data”. Data are not only numbers, but can be text, log files, photos and videos and so forth.

Below is a table with the principal forms of data collection (also called data acquisition or measures).

	Articulation		
Situation	**non-verbal and verbal**	**verbal**	
		oral	**written**
informal	participatory observation	Information interview	text analysis, log file analysis, etc.
formal and unstructured	systematic observation	open interviews, semi-structured interviews, thinking aloud protocols, etc.	open questionnaires, journals, vignettes, …

formal and structured	Experiment, simulation	standardized interview,	Standardized questionnaires, log files of structured user interactions,

Table 14: Principal forms of data collection

We will re-discuss these techniques in the chapters about data acquisition.

The Reliability of measure

Reliability is the degree of measurement consistency for the same object:

1. by different observers
2. by the same observer at different moments
3. by the same observer with (moderately) different tools

Example 8. The measure of boiling water

- A thermometer always shows 92 C°:
  => it is reliable (but not valid)
- Another gives between 99 and 101 C°:
  =>it is not too reliable (but valid)

Some authors, e.g. Kirk & Miller make a distinction between different types of reliability:

1. ***circumstantial reliability***: even if you always get the same result, it does not mean that answers are reliable (e.g. people may lie)
2. ***diachronic reliability***: the same kinds of measures still work after time
3. ***synchronic reliability***: we obtain similar results by using different techniques, e.g. survey questions and item matching and in depth interviews

In short: can we reproduce and replicate, can we trust data?

Reliability also can be understood in some wider sense. Empirical measures are either directly used as indicators for theoretical variables or they can be used to construct so-called indices. Therefore, “indicator” is just a fancy word for either a simple measure or an index composed of several measures.

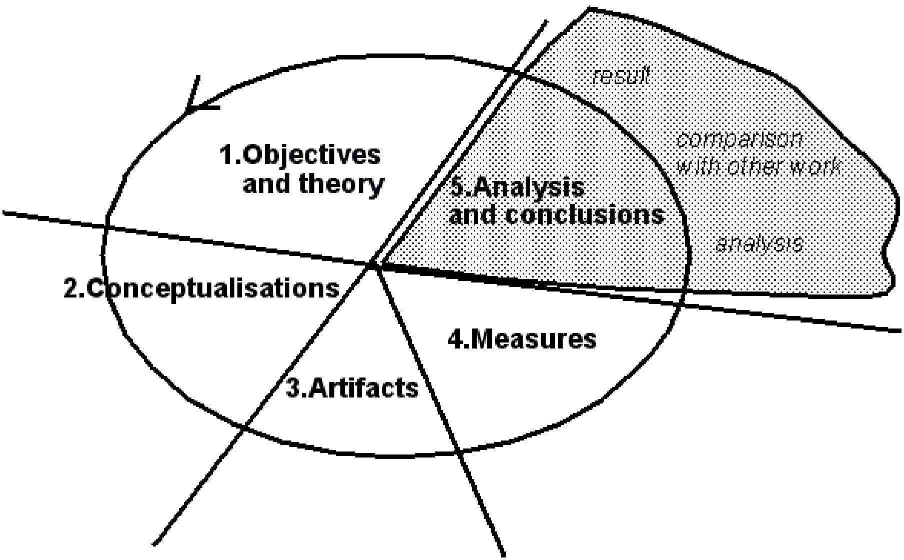
Anyhow, measures (indicators) can be problematic in various ways and you should look out for the “3 Cs”:

1. Are your data *complete?*
   - Problem: Sometimes you lack data for some cases.
   - Solution: Try to find other indicators
2. Are your data *correct?*
   - Problem: The reliability of indicators can be bad.
   - Example: Software ratings may not mean the same in different cultures. In given sub-cultures, organizations, or countries, people are more or less outspoken.
   - Solution: There exists no simple solution for this problem.
3. Are your data *comparable?*
   - The meaning of certain data is not comparable. Examples:
   - (a) School budgets don’t mean the same thing in different countries (different living costs)
   - (b) Percentage of student activities in the classroom don’t measure “socio-constructive” sensitivity of a teacher (since there a huge cultural

differences between various school systems and there exist other activity-based designs that are not socio-constructivist)

3.6 Validity (truth) and causality

Having good and reliable measures doesn't guarantee at all that your research is well done - in the same sense that correctly written sentences will not guarantee that for example a novel is good reading. You analysis must be valid, i.e. respect a series of "logical" requirements.



The kind of fundamental questions you have to ask are:

- Can you really trust your conclusions?
- Did you misinterpret statistical evidence for causality?

Validity is *tricky* and many debates in academia concern validity of findings.

The role of validity

Validity (as well reliability discussed above) determines the formal quality of your research. More specifically, validity of your work (e.g. your theory or model) is determined by the validity of its analysis components.

Ask yourself some critical questions, like:

- Can you justify your interpretations?
- Are you sure that you are not a victim of your natural confirmation bias? (Meaning that people always want their hypothesis to be confirmed at whatever cost)
- Can you really justify causality in a statistical relationship (or should you be more careful and use wordings like "X and Y are related")?

Validity is not the only quality factor of an empirical research, but it is the most important one. In the table below, we show some elements of research projects that can and will be judged. We also show how they are likely to be judged.

Elements of research	Judgments
Theories	usefulness (understanding, explanation, prediction)
Conceptual models (“frameworks”)	Usefulness Construction(relation between theory and data, plus coherence)
Hypotheses and models	validity & logic construction (models)

Methodology ("approach")	usefulness (to theory and conduct of empirical research)
methods	Good relation with theory, hypothesis, methodology etc. Correct use
Data	good relation with hypothesis et models Reliability

Table 15: Judgement of the elements of a research

This table tells that a good piece of work satisfies first an ***objective***, but it also must be valid.

The same message told differently with a figure:

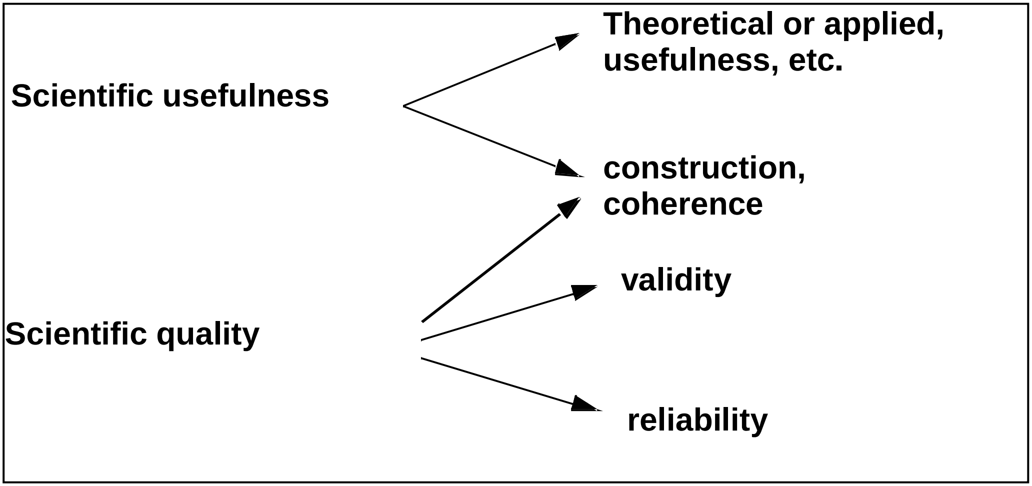


Figure 18: Judgement of research

- The most important usefulness criteria is: "does it increase our knowledge"

- The most important formal criteria are ***validity*** (giving good evidence for causality claims) and ***reliability*** (show that measurement, i.e. data gathering is serious.
- Somewhere in between: Is your work coherent and well constructed?

Some reflections on causality

Let us now have a close look at causality. Causality depends very much on so-called ***internal validity***, a concept that we shall discuss more than once.

A first iron principle is that correlations between data do not prove much by themselves. In particular:

- A correlation between 2 variables (measures) does not prove causality
- Co-occurrence between 2 events does not prove that one leads to the other

The best protection against such errors is theoretical and practical reasoning!

Example: Let us formulate the following conjecture: "*Use of ICT in teaching augments student satisfaction*". A conclusion that could be made from some superficial data analysis could be the following statement: "*We introduced ICT in our school and student satisfaction is much higher*". However, if you think hard, you might want to test the alternative hypothesis that satisfaction is maybe not an effect of media. Increased satisfaction could just be an effect of other reorganization variables that in turn had an impact on various intermediate variables such as teacher-student relationship, teacher investment, etc.

Therefore, remember this:

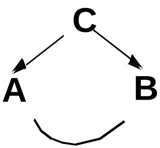
- If you observe correlations in your data and you are not sure, talk about association and not cause!

- Even if can provide sound theoretical evidence for your conclusion, you have the duty to look a rival explanations!

Some examples of bad inference

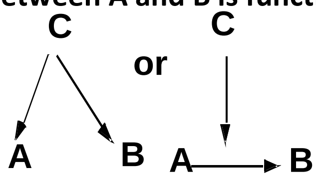
Below we show some examples of simple hidden causalities that one should detect before interpreting an apparent correlation.

Situation 1: Badly interpreted correlation (no real link between A and B)



Example from European folklore:
"Observed storks and birth rate.
Birth rate (A) and storks (B) are both negatively
Correlated with urbanization (C)

Situation 2: Double effect: A and B are explained by C and/or the relation between A and B is function of C



Example:
"more parent meetings increase spending for ICT"
School's organizational culture (C) influences
participation (A) and spending (B)

Situation 3: Causality chain

$A \rightarrow B \rightarrow C$

Example: "Young teachers hate ICT"
Young teachers (A) use less ICT (C)
because they have less resources (time)
left to spend on it (B)

Figure 19: Badly interpreted causality chains

Of course, there exist quantitative and qualitative methods to test for variables that influence correlation… but just start thinking first!

3.7 Summary

We end this short introduction into empirical research principles with a short list of advice:

(1) At every stage of research you have to think and refer to theory

Good analytical frameworks (e.g. instructional design theory or activity theory) will provide structure to your investigation and will allow you to focus on essential things.

(2) Make a list of all concepts that occur in your research questions and operationalize

You cannot answer your research question without a serious operationalization effort. Identify major dimensions of concepts involved and use good analysis grids!

(3) Watch out for validity problems

You cannot prove a hypothesis (you only can test, reinforce, corroborate, etc.). Therefore, also look at anti-hypotheses!

Good informal knowledge of a domain will also help. Don't hesitate to talk about your conclusions with a domain expert

Purely inductive reasoning approaches are difficult and dangerous … unless you master an adapted (costly) methodology, e.g. "grounded theory".

(4) Watch out for your "confirmation bias"!

Humans tend to look for facts that confirm their reasoning and ignore contradictory elements. It is your duty to test rival hypothesis (or at least to think about them)!

(5) Attempt some (but not too much) generalization

Show the others what they can learn from your piece of work; confront your work to other's work!

(6) Use triangulation of methods, i.e. several ways of looking at the same thing

Different viewpoints (and measures) can consolidate or even refine results. E.g. imagine that you (a) led a quantitative study about teacher's motivation to use ICT in school or (b) that you administered an evaluation survey form to measure user satisfaction of a piece of software.

You then could run a cluster analysis through your data and identify major types of users, e.g. 6 types of teachers or 4 types of users). Then you could do in-depth interviews with 2 representatives for each type, "dig" into their attitudes, subjective models, abilities, behaviors, etc., and confront these results with your quantitative study.

(7) Theory creation vs. theory testing

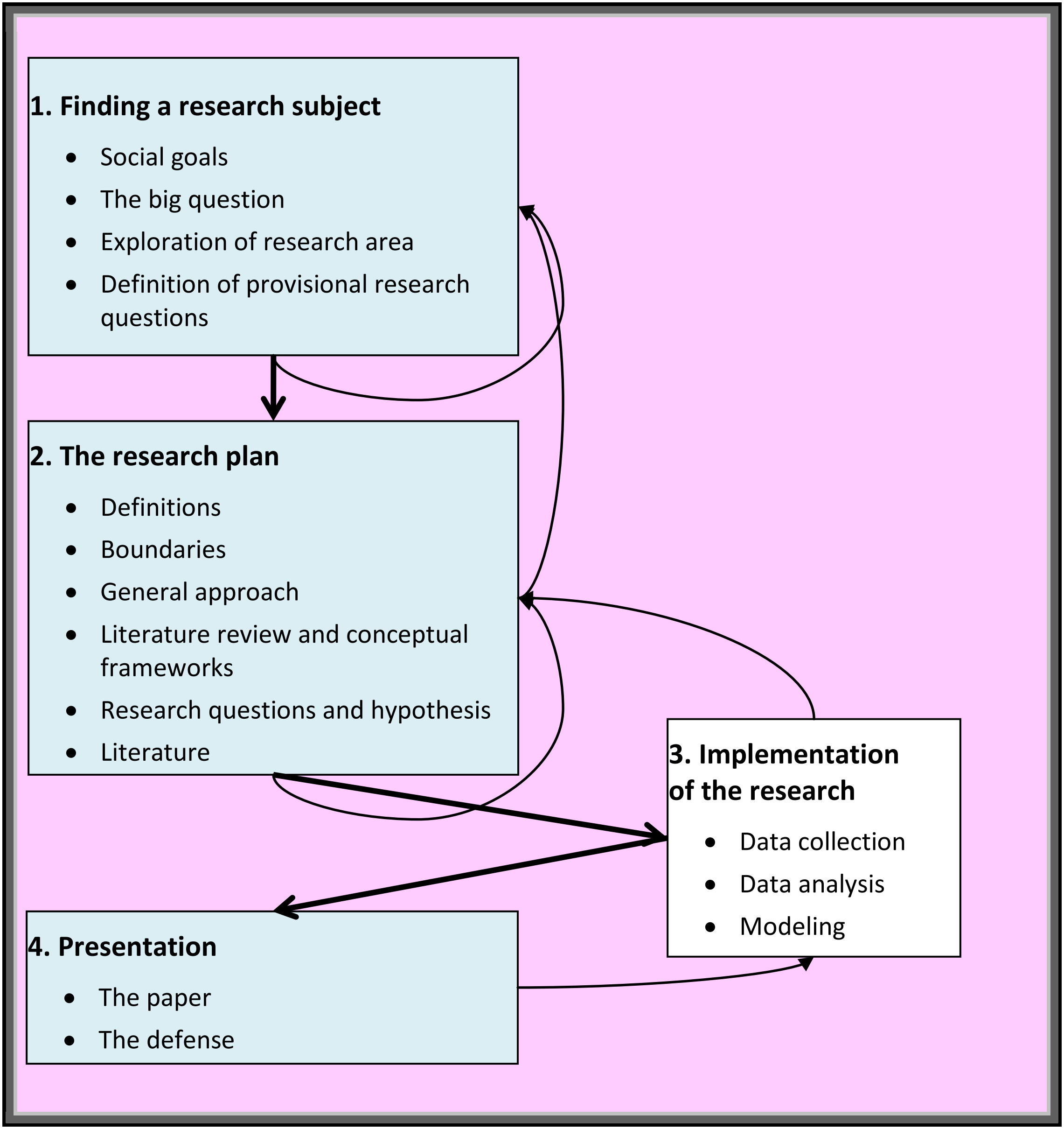
Let us recall that there exist very different research types. Each of these has certain advantages over the other. Qualitative methods are better suited to create new theories (exploration / comprehension). Quantitative methods are better suited to test / refine theories (explication / prediction). Of course, it is possible to use several methodological approaches in one piece of work.

Review questions

- Why is a correlation between two variables not necessarily “proof” of relationship?
- State the four most important stages of an empirical research project.
- What is a hypothesis? Are there different kinds of hypotheses?
- Why is it important to have data with variance?
- What is sampling? Is there a difference between quantitative and qualitative research with respect to sampling?
- What is the difference between validity and reliability?

PART II – PRACTICAL ISSUES

The following chapters deal with more practical issues and that are related to finding a research subject, writing the research plan, writing the research paper and presenting it. The chapters are organized according to the first two and the last phases of the research process


1. Finding a research subject
Social goals
The big question
Exploration of research area
Definition of provisional research questions
2. The research plan
Definitions
Boundaries
General approach
Literature review and conceptual frameworks
Research questions and hypothesis
Literature
3. Implementation of the research
Data collection
Data analysis
Modeling
4. Presentation
The paper
The defense

4 Finding a research subject

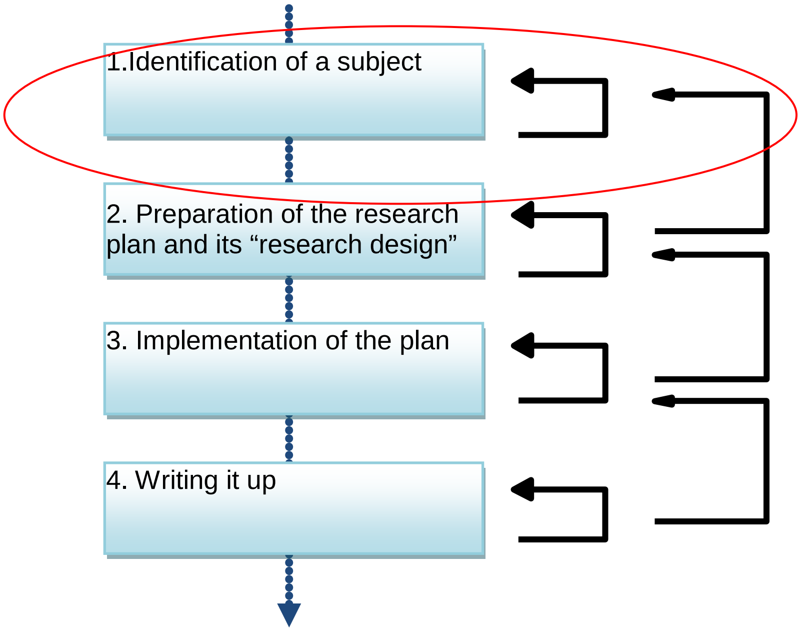
This chapter will help you identifying a research subject, a process that may be more difficult than you might think. Finding a research subject is trivial, if you have to pick it from a list that your professors define. On the other hand, if you have the liberty and the obligation to define your own, you may be surprised at how much time and effort it may take. The purpose of this chapter is to help ***speeding up the subject finding process*** by discussing some tricks and intellectual tools that include for example a recipe on how to conduct a literature review.

Learning goals

- Learn how to explore prior research, i.e. do an exploratory literature review
- Understand how to optimize the subject-finding process with appropriate intellectual tools.
- Understand how important it is to define a "big question". Also, remember that this big question should then decline into a set of research objectives and research questions.
- Understand that you may have to revise the research subject once you start writing the research plan.

Finding a research subject is the first stage of a research project. This may seem obvious, but it is not. Students without tight advising often tend to identify just a research topic, but then fail to formulate a research subject in terms of precise research objects and research questions.

In other words: If you don't watch out, you are unlikely to know what you really are going to do and you will lose a few month or worse, never get started for real ....



Finding a research subject is an ***iterative process*** conducted in several stages. The final formal step happens when you write the research plan and the final non-formal one happens when you really implement your research. E.g., you may find it necessary to add a new question or to downsize the initial project while you conduct your research. Nevertheless, you really should aim to plan as best as you can This way you will get better advice and you will be done earlier.

The most important phases of the subject identification process are roughly the following ones:

1. Identify a few topics / subjects and make a "short list"
2. Make explicit each potential subject
3. Discuss with your professors (if you can)
4. Explore the subjects (new short list), see: Readings and ideas
5. Make a draft of the research plan and negotiate. See Anticipation of the research plan
6. Make it official (consult your local procedure)

Table 16: Finding a research subjects – steps

You should look at several elements, and we shall discuss them in more detail in the following sections.

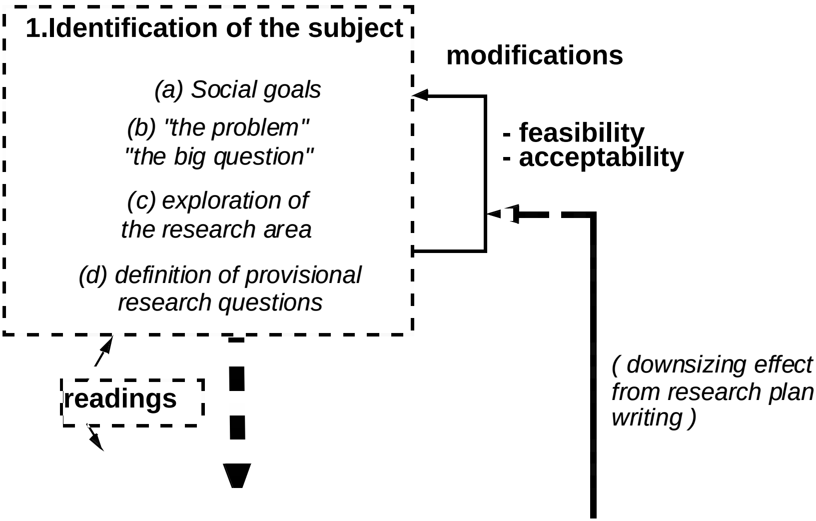


Figure 20: Identification of the subject

4.1 Identification of social goals

You should take some time and think about the larger implications of your projects (besides just getting a degree or publishing a paper). Do you want to learn something? Are there institutional constraints (e.g. does your employer wants you to do something for them)? To you just strive for intellectual fun?

Some questions you might ask:

1. What should your job be in 3-4 years?
    - A thesis is part of your "profile", a "visiting card".
    - A thesis will teach you a lot, what do you wish to learn?
2. And your employer?
    - Is he interested in your master thesis
    - Can you marry academic work with the goals of your organization?
3. What would you consider real “fun”?
    - Are you intrinsically motivated to do this?

Of course, your personal goals or you professional and school context will not be the only factors that will shape your research objectives. As we attempted to explain before, academia has its own ideas about what is an interesting research object and in which ways you could look at it.

4.2 Identification of the central problem

Let us now look at the very core problem, i.e. the identification of a central object, question or problem, whatever you may call it. Firstly you should recall that a research subject is not just a topic! As we argued before, it must be of some academic interest, for example: explain a phenomenon, identify processes, provide scientific arguments for an expertise, prove cognitive ergonomics of some software, demonstrate pedagogic effectiveness, and invent new design rules…

The big question

> **The big central question summarizes your main research objective. It does not necessarily match the title of your project (which just can announcement of a vaguely stated research topic)**

The «grande question» also is a summary of your research questions and it may imply practical goals

Example of research subject that concerns "e-learning":

Very bad: E-learning

Bad: «E-learning» in vocational teacher training

Good (a): *Efficiency* of e-learning in...

Good (b): *Perception* of e-learning....

Maybe: *Analysis of e-learning practice* in university X.

All the good variants need further precision. Usually the big central question is formulated with a single long sentence, but can be longer, i.e. a short paragraph.

Objectives and research questions

Even if you did manage to phrase a good "big question", your intentions are still too vague. You will have to tear your big question apart and make it operational, i.e. make a least a list of research objectives. At some point you probably also will have to rephrase it.

You *absolutely must make all your objectives explicit*; else, you are looking for conflicts and other problems. In particular, it is mandatory that you must formulate *research questions* that cover your objectives. You can write out research questions as “high level hypotheses” or “working hypotheses” if appropriate.

Research questions in any form then ***could*** be further detailed in terms of detailed scientific hypothesis and that are based on theoretical argumentation. It is much easier to deal with hypothesis than with more open research questions. However, formulating hypothesis for theory-finding research projects is pointless.

Finding the right research questions / hypothesis is an *iterative* process.

- Usually you only get them right after having written a draft of **the literature review**. Good research questions are always grounded in prior research
- Therefore, do not start extensive field research, development etc. before you have done some theory!

Let us look now at a master thesis example.

Example 9. Master thesis on the use of ICT in classroom teaching.

This thesis has been conducted by Luis Gonzalez for a master degree in educational technology, University of Geneva, 2004.

Main goal: "Understand the factors that favor teacher’s use of ICT"

The author first defines eight explaining factors found in his literature review and postulates the hypothesis that each will influence the teacher’s use of ICT. He then formulates some hypotheses about relationships among these variables.

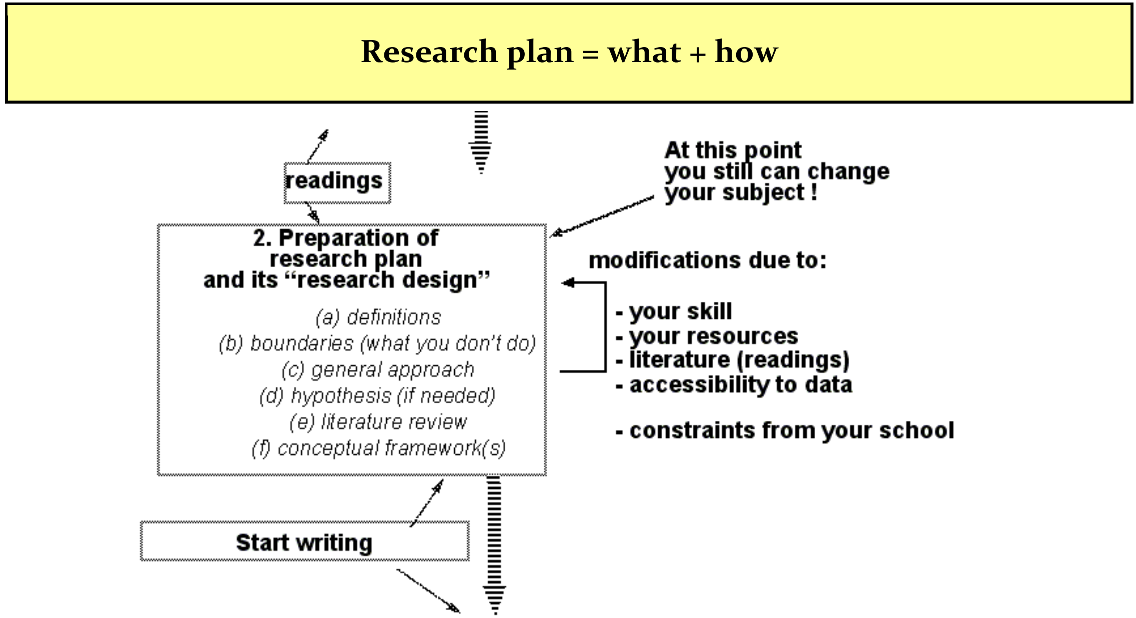
Hypothesis 1: There is a correlation between each of the following factors and teachers’ use of ICT in teaching:

1. Type of support offered by the institution.
2. Teacher's pedagogical competencies.
3. Technical competences of teachers.
4. Training received (initial and continuous).
5. Teacher's feeling of self-efficacy.
6. Teacher's perception of technologies.
7. Teacher's perception ICT's pedagogical use.
8. Teacher's use of ICT to digitalize existing practice.

We shall not present the other hypothesis here, since we shall come back to this example later when we discuss analytical frameworks.

4.3 Anticipation of the research plan

At some point, you will have to start working on a research plan and when you search for a subject, you should anticipate its content. Here is an idea of what will be part of the research plan



We shall introduce the research plan in the next chapter.

4.4 Reading and ideas

Who/what can help you finding a good subject

1. Example dissertations (other theses in the same area)
2. Academic articles (research papers)
3. Academic web sites
4. Interviews with academic experts
5. Interviews with domain experts
6. Your librarian, your library, on-line journals

You may find all these resources on the Internet, in particular on http://scholar.google.com (do not use google.com!). You also should consider becoming a member of a research society like AECT.

Various remarks concerning this phase

Your research topic will be vague in the beginning and you should not be too worried. However, progressively, clear objectives and research questions should emerge from your explorations.

- Be sure to talk to other persons than just your advisor

Be sure to maximize time with your advisor:

- Engage discussion with a written *list of precise questions* and make sure that all questions have been covered at the end of your meeting
- Don't ask questions by mail, ask for an appointment (unless the teacher tells you otherwise)

Do not just "think", start producing at some point, i.e. as soon as you feel sure about the general objective (even if is not yet very clear), start working on the written literature review. In addition, or as an alternative, you also may engage in some intelligent "note taking".

Initial readings

How should you start the literature review and how much should you read? Below is a short "algorithm" that summarizes how you should proceed.

1. Start with 2-3 *articles* or chapters of *standard works* and that contain a survey of your topic or of a related area.
    - ask experts, use the library, use scholar.google.com, use on-line journals

2. If you cannot find anything:
    - Hunt for articles that cover subjects with similar structural properties (e.g. concerning the approach, the "way to look at things", etc.)
    - start to occupy "islands of knowledge" (and enlarge with "circles")
3. Look for further publications
    - follow-up leads from your 2-3 initial articles
    - go through specialized indexes
    - systematically browse through specialized journals
4. Go through the Internet pages of well known researchers in your area of interest
    - do not trust randomly found information (e.g. indirect quotes) on the Internet
    - hunt down home pages (a lot of researchers publish at least a few papers on their site)
5. Do not read too much! Stop when:
    a) the same information comes back,
    b) you found a good central framework, the analysis grids for your concepts, experimental designs that provide you with a good example, etc. (details depend on your approach),
    c) you can relate all your research questions to published work.

6.4 Use of literature and draft of the theory part

We are not in favor of writing summaries of texts, since this very time consuming. We therefore advocate a quicker and smarter form of "note taking":

1. Read texts "diagonally" and just mark the most relevant concepts, theories, models, hypothesis, etc.

2. Create a matrix of the most important concepts like in the table below. You also can add short comments in the cells instead of "x" if you like.

	Concepts				
Articles	**Concept A**	**Concept B**	**Concept C**	**Concept D**	**....**
1		x	x		
2	x		x	x	
...					x

3. Sort the concepts:
   - Mark the most important ones.
   - Look at relations.
   - Throw away the ones you will not need (the theory part must support the empirical part, nothing else). In other words, you only should be interested in concepts that directly relate to your research questions.
4. Write a draft of the literature review:
   - Be synthetic and be critical (!)
   - Do not align one mini-summary after each other, i.e. organize your text by topics and not by authors!
   - End up discussion of each topic (concept) with a conclusion. It could identify its major dimensions (elements), explaining factors or your preferred integrating conceptual frameworks. You also may identify the best analysis grids.
   - End the literature review with a summary of adopted concepts and conceptual models. You also may present a central framework that will guide your research.
5. Look again at your research questions (revise them or add/remove things from your draft)

4.5 Idea generation

At various points you may become stuck and not know how to proceed further. There exist several techniques to generate ideas and you may apply several of these.

Brainstorming

Brainstorming is done in several stages:

1. Write *rapidly* keywords (what you want investigate, know, etc.) on paper
2. Take this list and do it again for each point
3. Sort/clean and go to the next steps (see below)

It is important that brainstorming is done quickly since you want to trigger associations in your brain (and not reflection); else, it is not brainstorming...

Organize your ideas

Create drawings that contain major elements and relationships.

(1) As a first step you can divide a concept or your big research question into its components. To do so, you may use mind-mapping software. However, do not overdo it, since mind mapping may generate too much complexity. All you may get is something like “wow, look it’s complicated!” Doing research means that you should answer precise questions and not just “map out things”.

(2) You then could use concept maps to draw relationships between important concepts.

Alternatively, consider using a wiki (make sure to think about its categories (tagging) and create links between entries. A wiki should not just be a random collection of entries, but an organized whole. Else, you had better use some blogging software.

The outline

Outlines are useful to get your research plan done and to plan difficult chapters like the theory part. An outline will provide support to:

- organize your ideas,
- produce a detailed plan of work to do (e.g. work packages),
- order your ideas in a linear way (your thesis will be linear, not a hypertext nor filled-in concept map).

6.5.4 Trust your brain's creativity

Have something to write on you (always)! Alternatively, as soon as you power up your computer write down any smart idea that popped up earlier.

Good ideas sometimes pop out of nothing at odd times (this is documented in the autobiographies of some outstanding scientists). So make sure not to forget any good inspirations.

4.6 Summary

Below we formulate a list of checkpoints and things to do.

Checklist – finding a research subject

Exploratory discussions and interviews

- Talk to field experts, academic experts (in particular potential advisors)

- Also contact your "victims"

Political feasibility

- Make sure that you will find human subjects willing to participate, that organizations will cooperate (e.g. give you access to documents), etc.
- In some institutions, you will have to submit your research plan to an ethics committee.

Theoretical feasibility

- Do you have a good enough overview of existing relevant research?
- E.g. can you point out theoretical frameworks, analysis grids, propositions (hypothesis)

Methodological feasibility

- Do you have an idea about the general approach you plan to adopt (see below)
- Did you make a list of the concepts found in your research questions?
- Do you have initial definitions for them?
- Do you believe that you can measure each empirical concept? (see below)
- Do you have an idea how to analyze relationships (to answer your research questions)?

Budgetary feasibility

- Time is your enemy!
- Keep your subject as small as possible (but make sure that you address an academic question)

Table 17: Checklist for finding a research subject

The general thrust of research

While you look for a research subject, you always have think about the kind of research you plan to do and in particular, the general approach you would like to use:

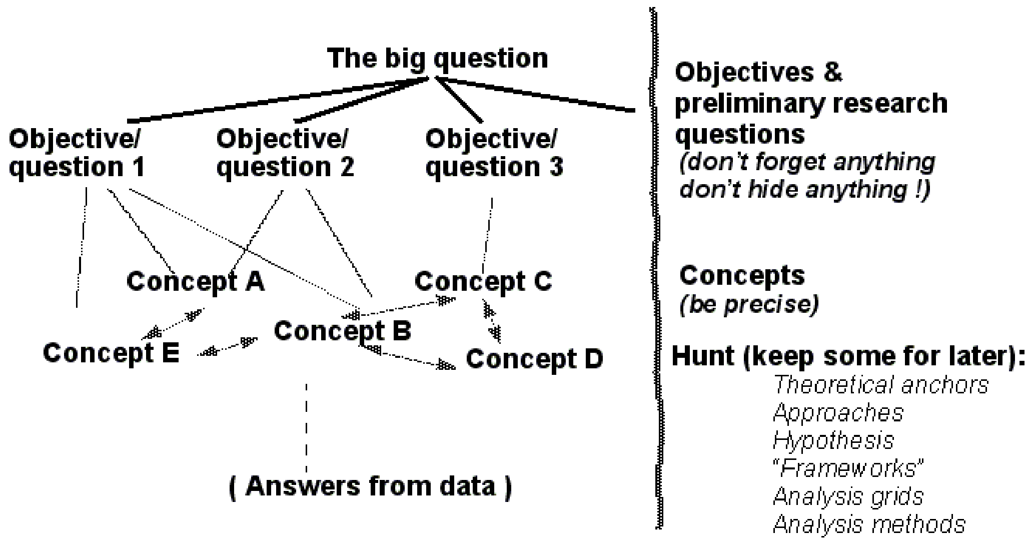
Some possibilities for a master thesis:
Experimental designs that study *how humans behave under certain conditions* (e.g. "Under what conditions does a multimedia animation have a positive effect on learning?").
Quasi-experimental studies (e.g. *test* if one instructional design is better than another).
Sociological studies (e.g. the introduction of ICT to school systems and/or organizations, study of certain population's *attitudes and behaviors* towards ICT or an ICT initiative, e.g. teachers).
Economic studies (e.g. *Return on investment* at the organizational or the national level)
Ethnographic or clinical studies of human subjects, i.e. *in-context behavior* (e.g. usability studies of software, work place analysis to study informal learning, problem-solving behavior related to the use of ICT etc.)
Development of *innovative instructional designs* (either in real world settings or in exploratory studies). All kinds of settings: Formal/informal, distance/blended/classroom, workplace e-learning, just-on-the-spot learning.
Technical development of a system or exploration of new technologies (and that explore/introduce *new ideas (pre-theories)* profitable to education and learning)

Table 18: Examples of master thesis types in educational technology

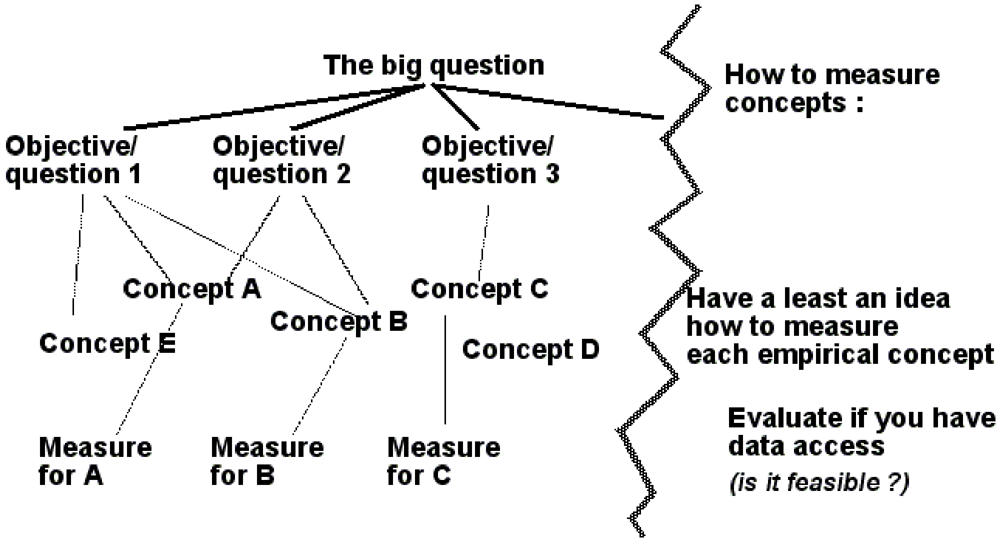
Think hard about the concepts you use

Make sure that you list of research questions is complete, i.e. that they cover **everything** that you plan to do. Then identify **all** major concepts used in your research questions and start thinking a bit on how you are going to collect related data. We discuss some of these issues in PART I and shall come back to it in PART II.

The theoretical face



The empirical face



Review Question

1. State a research subject in 2-3 sentences.
2. Formulate two to four research questions of interest.
3. Identify the central concepts of each question.
4. Write down the major dimension of each concept.
5. Tentatively, write a 2-3 sentences that describe how you would plan to collect data for measuring each concept.
6. Redefine the research subject as a big question that summarizes the research questions.

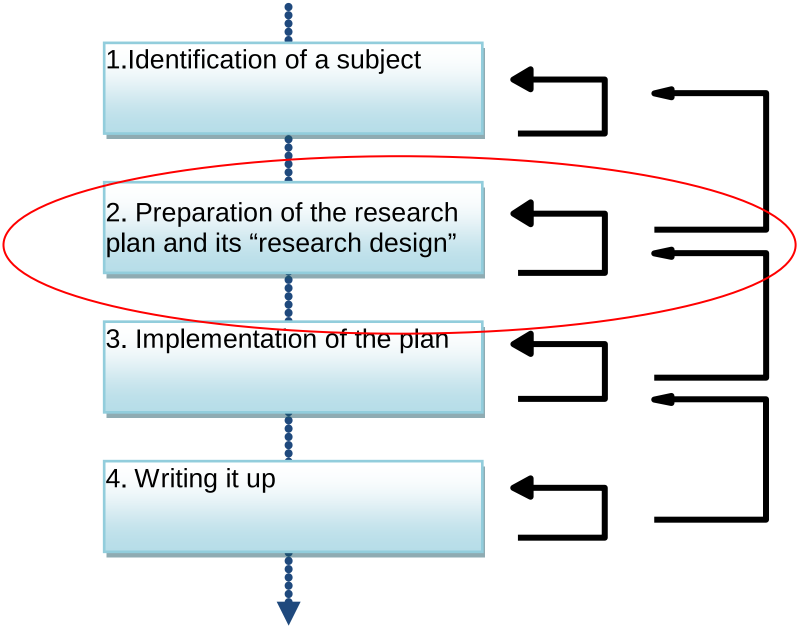
5 The research plan

This chapter provides a short overview of the research plan, i.e. its function and its elements. Reading just this chapter will not help you to prepare a precise research plan. We will define the main elements that should be part of a research plan and you will need to learn more about research methodology and conceptual frameworks in order to produce your own. In any case, you will need advice from a confirmed researcher, e.g. your professor.

Learning goals

- Be able to identify typical elements of a research plan.
- Be able to explain their function.

The research plan has to be defined in an early stage of your research. It explains the "what" and the "how" of your research.



Writing a serious research plan will help you finish your project in time. Nevertheless, we also should warn you that writing a research plan will have a strong impact on your research subject, i.e. you may have to revise your initial intentions. You also have to accept that you cannot come up with a serious research plan in a single go, so be prepared to write/present several revisions that may include quite drastic changes.

A research plan must include a few important elements, like: important definitions, the general approach, a literature review, conceptual frameworks, the research questions and maybe the hypothesis, etc. We shall discuss most of these in this chapter.

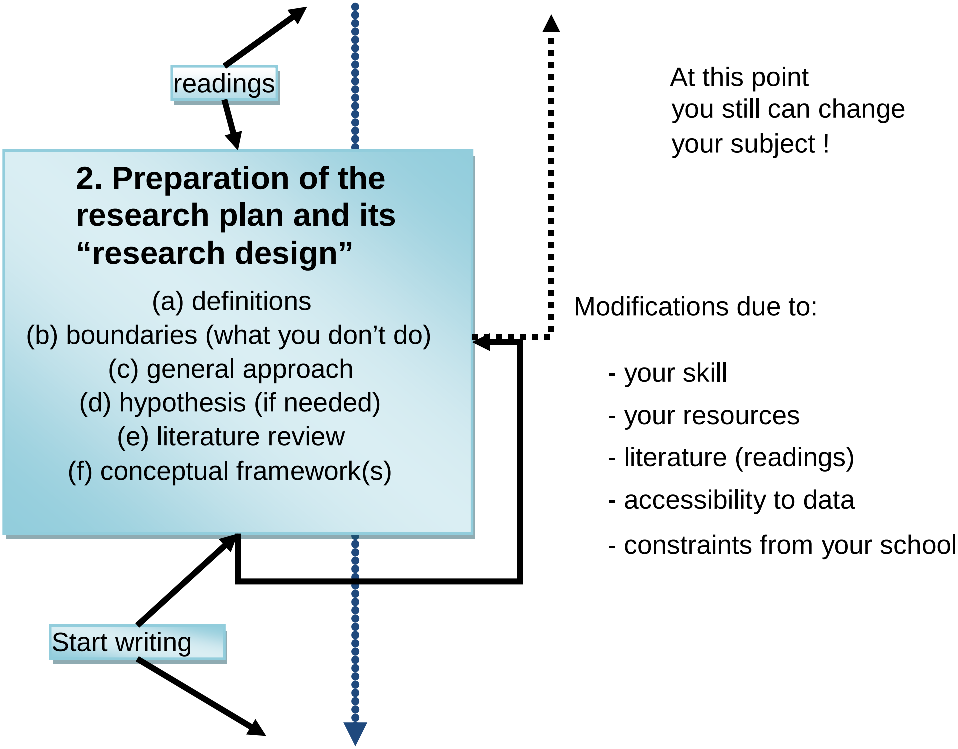


Figure 21: Important elements of the research plan

Review Question

What crucial element is missing in the figure above?

Hint: Think hard about the central element of a research project! If you cannot figure it out, you missed something.

Anticipation of the research activity

You cannot write a research plan without having a clear picture of the kind of work that is needed to implement it, i.e. you may have to read most chapters of this text before you should start doing your plan for real.

However, there are two important rules, if you plan to be successful:

1. Be as explicit as you can (without being too verbose)!
2. Be systematic and honest and leave nothing out! Typically, students cannot formulate a series of good research questions and their real intent will only appear when they start writing about data collection. In other words, if new research question appear when you think about data, then make these explicit! Everything must be connected.

Such a strategy will lower the risk of being stuck and help you to estimate resources (time) you will need!

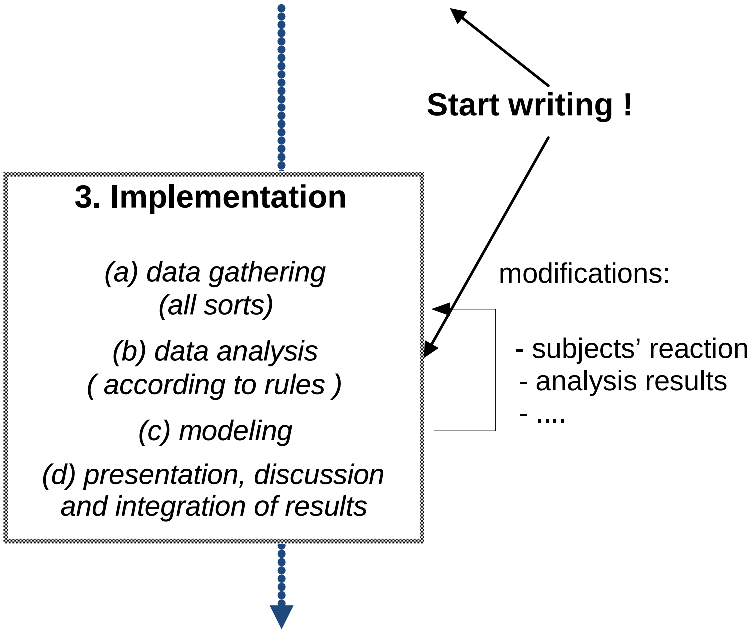


Figure 22: The research activity (anticipation)

The rest of this chapter will look the principal elements of a research plan.

5.1 Elements of a typical research plan

Important remark: You may have to adapt this list to fit formal requirements from your institution. In addition, methodology constraints will tell you how to organize these elements. As you will see later, various research types are implemented using a somewhat different logic and that will translate to a different form of presentation.

Element: Your research subject

At the very beginning, you must state “the big question”, i.e. the general subject in one sentence if possible. In the same paragraph, add a few sentences that demonstrate its theoretical and (eventual) practical interests.

You also can make explicit your motivations and state what you are not going to do.

Element: Objectives of your research

State clearly, what you wish to achieve, because this will determine your research questions and/or hypothesis and that are usually presented after the review of theory.

If appropriate, you can show if/how you plan a valorization activity, e.g. how you plan to transfer results to a "real context".

Element: Theory (review of the literature)

After the introduction that defines the general subject and your main objectives, you should produce a short and synthetic text describing and discussing the “state of the art” in your subject area. This is called a ***literature review***.

Some advice:

- Be sure to mention the major publications concerning your subject. Read the ones you quote!
- You may point out inconsistencies and gaps, which adds additional interest to your project

- Identify theories and conceptual models that you will use to do your empirical research. Maybe add your modifications and present both at the end of the review.
- Make sure that you define all the major concepts that appear in your research question. Many concepts are controversial, e.g. pedagogical effectiveness, efficiency, ...
- Only introduce theory that is relevant for your research.
- As we explained in the previous chapter, make sure to write a synthesis and not just a simple linear collection of uninteresting summaries. Each section of your theory part should end with a conclusion that you later can use to justify your research questions.

See also the advice given in the previous chapter. You will find some additional help in further chapters, in particular the one that deals with conceptual frameworks.

Element: Research questions and/or hypothesis

Research questions will make explicit your research subject and objectives. Research questions ***are the most important element*** in the research plan. You can choose from various styles (or combine them):

- ***Open research questions*** (but make an effort to be as precise as possible).
- Research questions formulated as ***working hypothesis***.
- ***Real hypotheses*** that are based on theory.

In theory-oriented research, formulate hypothesis that postulate causalities

> Bad: "*I postulate that my e-learning design will work*"
>
> Good: "*Conditions for successful implementation of an e-learning design in the context XXX are .....*"

Bad: "*ICT doesn't work in schools*"

Good: "*Critical variables A, B, C for successful implementation of e-learning are ...*". Then, make explicit A, B, C as causal rules.

It is also possible to adopt a ***hierarchical presentation***:

- Formulate between two or seven principal research questions
- Then, for each of these principal questions, create sub-questions or hypothesis.

Element: Approach and methodology

After defining the research questions, you should describe your overall approach (for example "experimental design", "survey study", "usability study", "instructional design evaluation" if hasn't been done in the introduction.

Then you will have to become more specific, e.g. describe all planned data gathering and analysis techniques (for example, semi-directive interviews, content analysis ...)

Remark: Make sure to explain your methodological designs for all levels of analysis!

- at the organizational level (if you are interested in this question),
- at the individual level (e.g. students, teachers)

Basic principle:

- Show convincingly how you are going to answer each research question!
- Obey guidelines dictated by the general approach. In particular be careful with experimental designs, its rules are strict!

1. The Approach
    - Briefly describe the overall approach you are using

- Discuss analysis grids that will measure important concepts
- You also can discuss conceptual frameworks (if not done before)
- For experimental studies: clearly describe the experimental conditions

2. Measures and material
   - Data gathering techniques: (interviews, observations, surveys,)
   - Sampling strategies or justification of singular case selection): For qualitative in-depth studies, describe the sampling of interviews, events, etc. For experimental studies, you have to describe in detail experimental conditions, materials used, sampling conditions etc.
3. Analysis
   - Shortly describe analysis techniques (both qualitative and quantitative)
   - If necessary: point out which methods need development (e.g. analysis of student-student interaction in a CSCW environment)

Element: Information sources

This section usually includes the following elements:

- Bibliography; use a real standard, like APA!
- Documents to analyze
- Information interviews, etc...

Element: Work Agenda

Some planning can help. The minimum you should do is to present a list of the major steps:

- Delivery date - Final research plan
- Delivery date - Good draft of the literature review

- Delivery date - Data gathering I
- Delivery date - Data analysis
- Delivery date - Writing the rest / First draft
- Delivery date – The thesis

If your research includes several case studies, you should modify accordingly.

We shall introduce some planning techniques later, but you should understand an i**mportant principle**: A research plan tells what your research questions are, how they are grounded and how you are going to answer them. It is **not** a chronological listing of activities. The research plan's chronological work agenda should include no more than 1/2 - 1 pages!

5.2 The research plan is a whole

Now let us recall the major principle: All major elements of your research plan must be linked together. In particular, your central big question or problem must be stated in terms of research questions. Each of these research questions must be "grounded in theory". For each question, you must explain how you plan to answer it. This includes both general analysis methods and various techniques as you can see in Figure 23.

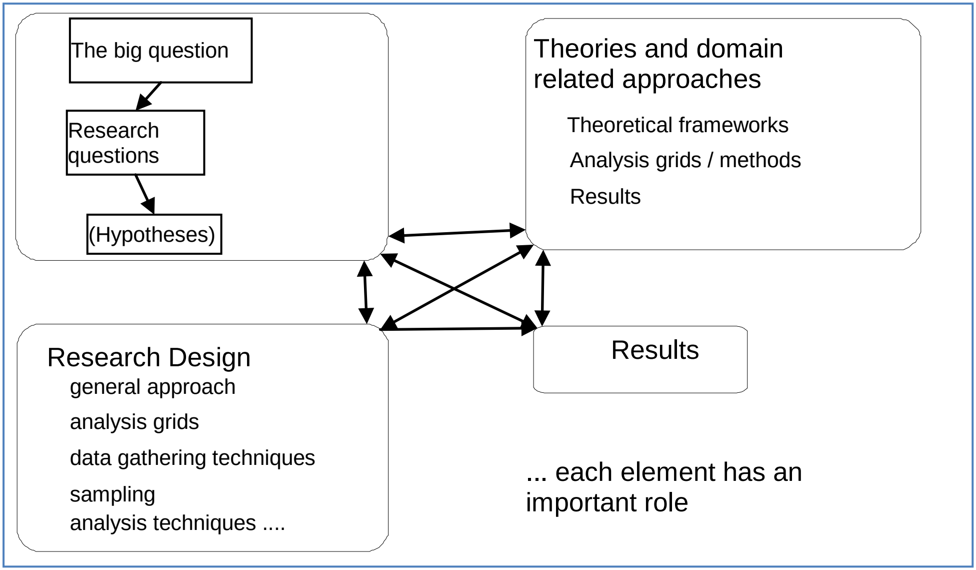


Figure 23: The research plan as an integrated whole

Let us recall the purpose of the research plan. It will tell the "***what*** + ***why*** + ***how***"

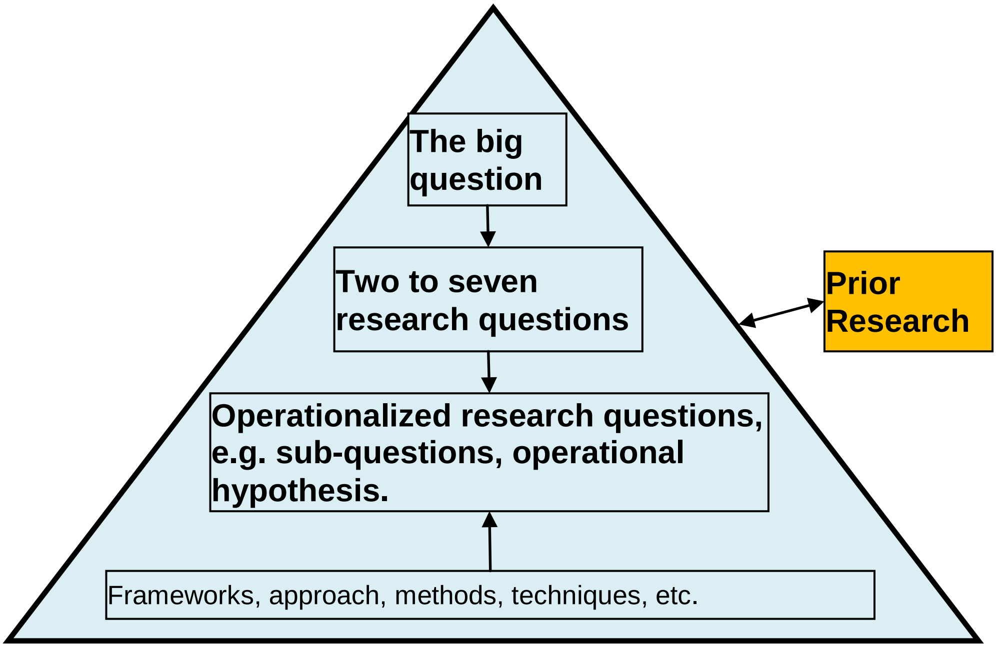
What?	A good big central question or problem !	«So what»? What knowledge do we gain from this research?
	A (or more) good conceptual framework(s) that:	• link your research to a larger identified issue. • structure your phenomenon ; • link your project to a body of existing knowledge; It is preferably available as a nice drawing

How?	Consider that your research plan should be:	• systematic: show that you will study your "big question" and related research questions (and nothing else!) • academic: identify your main approach(s) and major techniques you will use. • somewhat flexible (make sure that you identify priorities also) • In some designs it is required that you show details on how you will answer your questions.
	Be realistic! Prove that you have ...	• the time to do it ? • access to data? • the ability to do it (or to learn how to do it)?
A whole!	Integration!	• A coherent whole! • All your intentions are made explicit. • Your research questions cover your essential planned work.

Table 19: Functions of the research plan

5.3 Summary

You research plan should be an ***integrated whole***. It is important to understand that you will have a "pyramid" at its core. Everything depends on stating your research questions right in a first step. You then have to tell how you will answer these. If new research questions pop up, make sure that these fit the "big question" and that your instruments are still appropriate.



Before you believe that you are done with the research plan, check again the following points:

1. Theoretical feasibility
   - You cannot do it all by yourself, check the literature (if not already done so, find overview and "ground breaking" articles)
   - In particular: theoretical frameworks, analysis grids, theoretical statements.
   - organize an interview with a least an academic and a domain expert
2. Inventory of approaches and methods
   - There exist constraints, you cannot study everything in any way (but you do have

choice, but check with your advisor!)

- finding a good design always is an iterative process (so don't worry if your first version looks bad)

3. Is your main approach appropriate?
   - Look at similar research
   - Remember, if you want to **prove things**, you need comparisons!
   - Use qualitative approaches to explore and to understand, quantitative approaches to confirm, generalize, prove, ...
4. Methodological feasibility
   - Dress a list of all the *concepts* that appear in your research questions (and hypothesis if you have)
   - Take each concept apart for its dimensions,
   - Operationalize each empirical dimension (make it is measurable)
5. Does your theory part really relate to your empirical / practical part?
6. Make sure that you can produce needed data and then analyze them
   - Do you know how to collect data (make observations, design questionnaires, and make interviews?
   - Did you check if you will have access to persons, documents, etc.?
7. Check your analytical skills and resources
   - Can you handle these data? If not, plan to train yourself.
8. Did you do some rough planning?
   - Isn't your project oversized?

Table 20: Checklist research plan

Review questions

1. What are the most important elements of the research plan?
2. Is there a standard model for writing research plans?
3. Do you need to formulate hypotheses ?
4. Are you able to write a good research plan? Why would you think so?

6 Planning techniques

This chapter will introduce elementary planning techniques. Some planning will help you to estimate the workload for a given project and to control your progress later on.

Learning goals

- Learn how to make simple GANTT work plan charts
- Learn about PERT activity charts
- Get some other advice

It is not necessary to use project management techniques for a smaller research project, but doing so could help getting your thesis done in time. The main advantages good planning are:

- Better ***estimation of resources*** (time), i.e. a good planning effort will likely tell you to reduce the scope of your research.
- Planning can be a tool for ***self-control.*** If at some point, you are much behind schedule you can detect this, and have an opportunity to act.

The minimal planning you should do is the following: Create: 1. A list of the major things to do (each item is called a ***work package***) 2. Specify ***deadlines*** for each work package 3. Estimate the ***time*** (e.g. in man/days) needed to complete each work package. Then create a to-do / start / deadline list, e.g. something like: 1. Literature review: start = oct. 2020, end = feb. 2021, volume = 1 man/month 2. Case study 1 field work: start = ____

Table 21: Minimal planning

Let us now discuss some planning techniques in more detail. Knowing about planning may also be useful in other contexts, i.e. later in life.

6.1 Scheduling

Scheduling means to do the following.

- You will have to divide a project into ***tasks***, called ***work packages*** (WPs)
- For each WP, you should provide an estimation in man/days or man/weeks it takes to finish
- A work package usually relates to a stage of the research plan, e.g. “creating the research plan”, “field work”, “development of software”.
- If possible, a work package should depend little on parallel work packages
- Work packages can lead to a ***milestone*** (an important stage in your research plan) and/or to ***deliverables***, e.g. tangible products such as the research plan.

To manage the scheduling process you then can work with two (related kinds of graphics):

- An ***activity diagram*** that shows dependencies of work packages and a critical path.
- A ***bar diagram*** that specifies activities over time.

6.1.1 Activity diagrams

Activity diagrams allow estimating the time it takes to reach an important stage and the global time needed for the whole project.

The most well know methods are:

- PERT (Program Evaluation and Review Technique)
- CPM (Critical Path Method)

Activity diagrams contain at the least the following elements:

- Each project is represented as a directed graph of tasks (the rectangles in Figure 24)
- Some tasks depend on other tasks
- For each task, you must estimate its duration. Often you do this with three figures: expected minimum duration, expected duration and expected worst case.
- Then you also may add milestones, i.e. the completion of a group of tasks and that represent the end of an important stage.

Example 10. A simple PERT example

Here is the start of simple PERT-like graphic.

- *Milestone M1 – Exploration* is done after you completed "becoming familiar with the domain of study" (5 days), after you studied an example (3 days), you found some references (3 days) and you thought hard about finding an appropriate approach (3 days).

- *Milestone M2 - a project draft*" needs an extra 5 days.

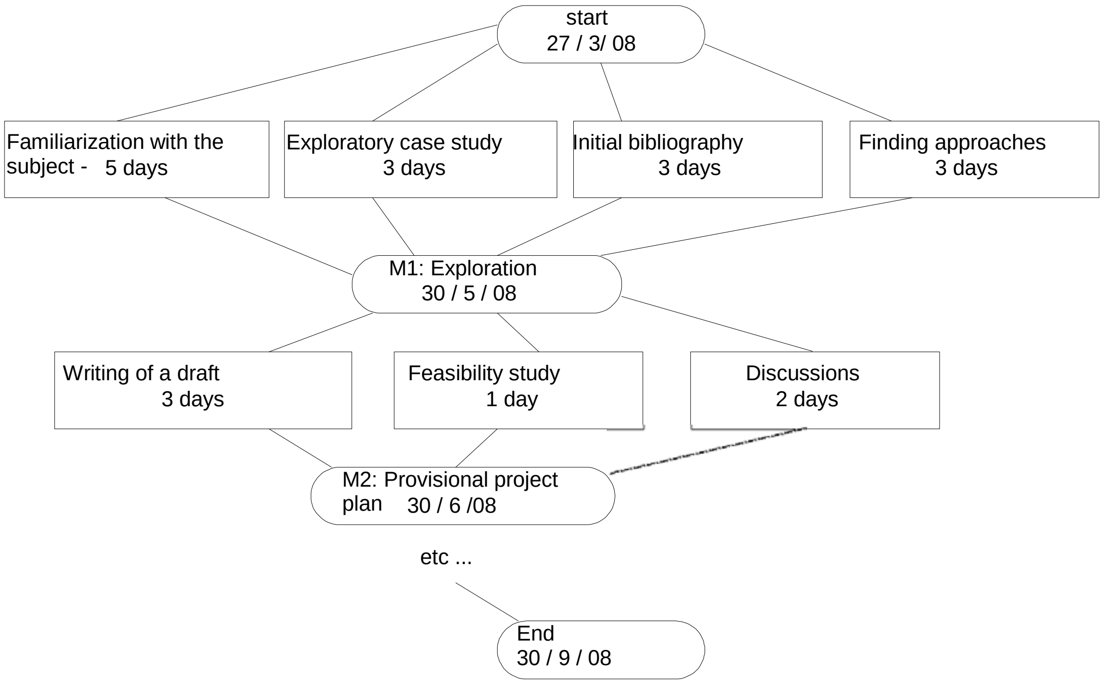


Figure 24: PERT chart example

You have to figure out yourself what elements you need to plan. It is important **to include every single activity that is directly or indirectly related to your thesis work**. This includes taking out your advisor for drinks and revising your English at the end.

Read more about [Program Evaluation and Review Technique]() in Wikipedia if you wish to understand the real thing! Here we just presented a good-enough solution for a master thesis.

6.1.2 Bar Charts

Bar charts, also called GANTT Charts are easier to produce. They represent a sort of calendar that includes time units (e.g. weeks) in one axis and work packages in the other. You can create a simple version with a word processor or spreadsheet software:

- The horizontal axis is organized by either days, or weeks, or month (depending on the size of the project). For a master thesis, we suggest to use weeks or months.
- The vertical axis includes a list of work packages (WPs) and milestones.

You then can fill in the table like this:

- use "XXX" during the weeks you plan to work hard
- use "xxx" during the weeks you plan to work a bit on it

Read more about Gantt chart in Wikipedia. Below is simple bar chart made with an HTML table?

WPs and Milestones	**oct 6 08**	**oct 13 08**	**oct 20 08**	**oct 27 08**	**...**	**...**	**...**	**...**	**...**	**...**	**...**	**jun 1 09**
Exploration of the subject area	xxxxxxxxxx											
.....												
Preliminary case study		XXXxxx										
Research plan			M									
.....												

.....												
Writing it up				x	xxx							XXXXXXXXXX

Figure 25: GANTT chart example

6.1.3 To-do lists

To-do lists are a simple alternative to more complex PERT/GANTT scheduling. Its principle is simple: Just write down all the work packages you have to do and regularly annotate what you did complete in terms of percentages. For example:

Task	**Completion**
Exploration of the subject area	20%
.....	
Preliminary case study	50%
Research plan	10%
.....	
.....	
Writing it up	5%

Table 22: To do list example

There exist simple online task managers, e.g. in WebTops like Pageflakes.

6.2 Controlling

If you create a work plan without planning to use your work plan, forget it and just present a short list in your research plan if your institution wants it. You only will lose your time otherwise.

Arguments against planning are that motivated students work on their thesis as much as they can anyhow, and that very often the research work goes not exactly (or even remotely) as it was presented. As we said before, doing a good research plan is crucial; creating a work plan is less.

Who should / will control your progress?

- In industry, it is the boss or the project group as a whole that does it.
- Depending on the educational institution, it is **you** mostly, but you may give it to your advisor or integrate it into the research proposal.

Progress monitoring and crisis management

We suggest to compare reality with planning about once per month (or once per week if you thesis must be completed in just a few month).

If there are important deviations from schedule, you should understand why and take corrective action. You will have to develop an appropriate crisis management strategy. It may include:

- Asking help from your advisor
- Negotiating to do less, i.e. downsizing you initial plans
- Adapt the approach for another that is less costly

6.3 Duration of a typical master thesis

(Adjust to your institution and type of work)

Below is an example for a qualitative field-study. Estimations are in man/month. So divide by the percentage of time you can spend on the thesis.

Tasks (large WPs)	**By element**	**Total**
Find a subject and do the research plan		1 month
Literature review and initial writing		1 month
Contact each research site	1/2 day	1 month
Site visits	1 day	
Coding of data	2-3 days	1 month
Analysis (matrices and visualizations)		
Draft thesis		1 month
Revisions		1 month
Total		6 month

Table 23: Example planning for a master thesis

Your planning is likely to be over-optimistic! Select as few cases as you can get away with if you do a qualitative study or rather adopt a quantitative approach.

6.4 Conclusion

As we said in the beginning, planning can be really helpful to estimate the size of your project and to control progress. However, do not confound writing of work plan with writing a research plan. The research plan is much more important and it has a logical structure.

Review question

- What is the difference between a work plan and a research plan?
- What are the two most important planning elements?

Review assignment

- Take one larger assignment in one of your courses and produce a GANTT chart that includes several work packages and scheduling information

7 Finding conceptual frameworks

This chapter will introduce conceptual frameworks that help structuring ideas and concepts. Any research project should relate to theory. Conceptual frameworks are key elements of academic thinking. It is important that you manage to identify useful frameworks in early stages of your research, since they help organizing concepts and structuring analysis. We put this chapter in the "practical part", since our purpose is not to introduce theory. Our aim is to get the message across that you should work with some central conceptual artifacts since they help bridging theory to research questions and define relationships among major concepts.

Learning goals

- Understand the potential of conceptual frameworks to help you organize your ideas.
- Get some inspiration from various examples provided.

We may loosely distinguish four types of conceptual frameworks.

1. ***Theoretical frameworks***
    - Provide an overview of the phenomenon (elements and relations)
    - Help to bridge the gap between theory and empirical research
2. ***Analysis frameworks***

- Help with analysis and formulating research questions (e.g. what causalities to look at, what is of interest, etc.)

3. ***Lists of dimensions***
   - Help to determine all aspects of a concept
   - Help finding empirical instruments for measuring a concept
4. ***Analysis and evaluation grids***
   - Help to organize data gathering and collection
   - Will bridge the gap between general concepts at theory level (e.g. your research questions) and measurable indicators

7.1 Theoretical example frameworks

In this section, we shall present and shortly discuss some example frameworks that may be useful in research projects about e-education. Our purpose is not to discuss e-education and similar topics, but simply demonstrate why conceptual frameworks are important and why you should refine your research project and organize your research questions with the help of such intellectual instruments.

Example 11. The inquiry circle in inquiry-based learning doctrine

Inquiry learning combines more radical open-ended constructivist principles (discovery learning) with a model of guidance. As opposed to so-called Learning Design, most inquiry-based models do advocate opportunistic (i.e. adaptive) planning by the teacher. However, there are many different ways to think about inquiry learning. A picture that shows the central concept will make the model explicit. The example below was made by "Chip" Bruce et al.

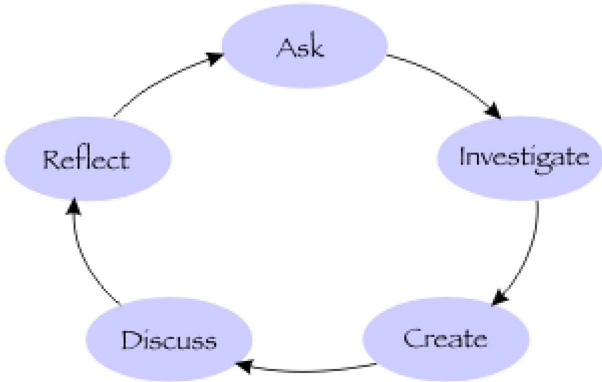


Figure 26: The Cyclic inquiry model (inquiry page, UIUC)

This picture

- clearly identifies the major elements of the inquiry learning model
- claims/shows that inquiry is circular

In other words, such a drawing both identifies important elements of a pedagogical scenario and it shows relations among them, it defines a dynamic, etc. In other words, such a framework guides both implementation of a specific pedagogical design, i.e. inquiry learning, and its study and evaluation.

Example 12. A linear model of research

This study book also relies on an analytical organizing framework. The model presented in the figure below helped organizing the writing of some chapters.

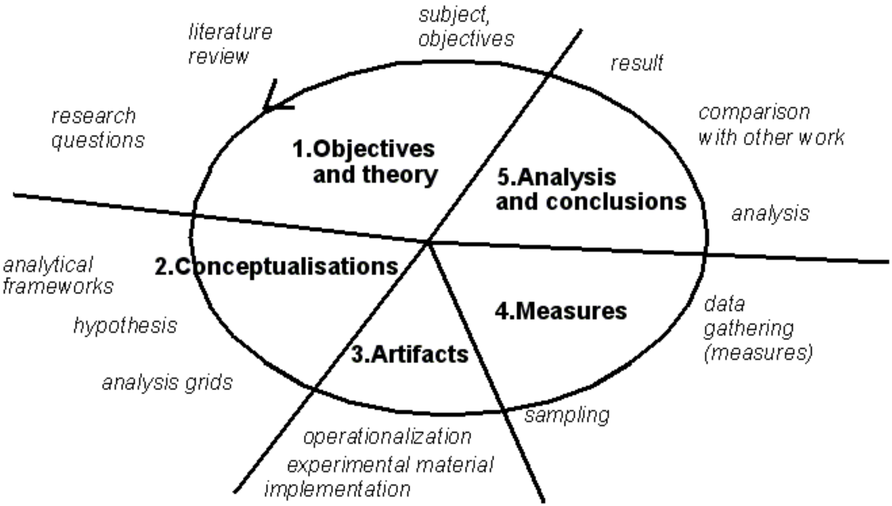


Figure 27: Model of the research cycle

Of course, such a model does not exactly describe reality. A model (in the general sense of a conceptual framework) should rather be considered as a *language that helps to look at a given set of phenomena*. Research is much more disorderly than what we teach it to be. However, we do need ideal-typical models in order to describe it in a systematic way.

Example 13. Implementation research model

This example is drawn from public policy analysis and may be used to organize research about government programs to introduce ICT in education for example. It provides a certain "image" of the policy-making process:

- Actors intervene during the whole process (and not just in their “natural” stage)
- Problem perception, goals and other elements can change over time. Sometimes, the implementers may redefine goals or even set new goals.

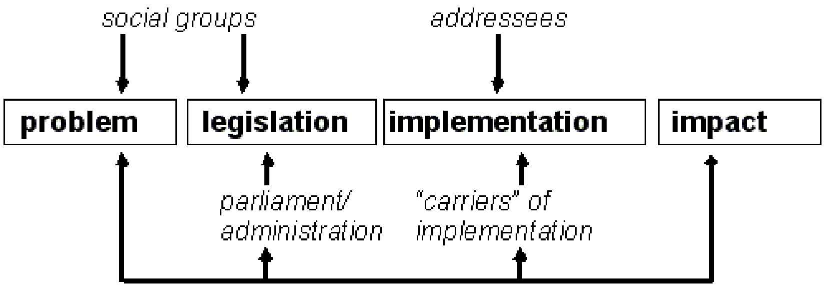


Figure 28: Implementation research model

Such a model does not only identify the stages and feedback loops of the policy implementation process, but it also embodies a theory about policy making: The fact that a government agency has been created to sponsor ICT-based pedagogical reform, does not entail that it will happen as planned. Implementation carriers (e.g. schools) and addressees (e.g. teachers) may redefine goals and will have to establish operational practice.

Example 14. Policy outcomes

This drawing defines how to define the concept of ***policy outcome***. According to this model (Knöpfel, 1996), there are three major kinds of results you can study.

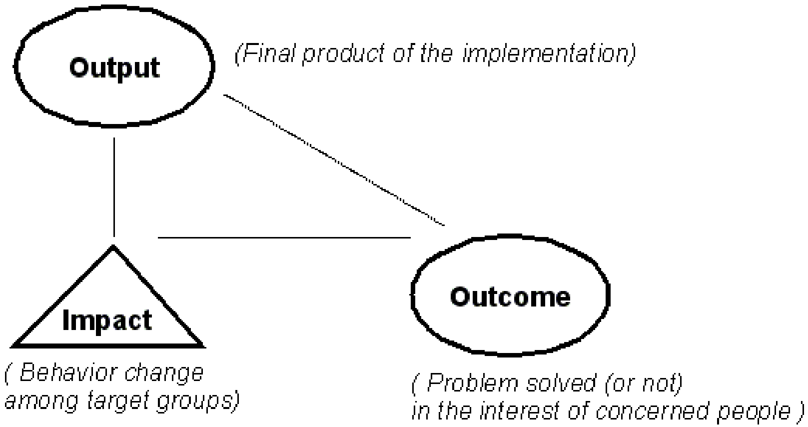


Figure 29: Policy outcomes model

It could be useful to provide a perspective on the analysis of educational reform policies.

Example 15. Functions of a learning environment

Sandberg (1994) presented a general framework that describes functional elements of a learning environment and that we present here in slightly modified form.

- **Teacher component**: Its role is to provide something between loose guidance and direct instruction. It can be a human agent (present or distant), an intelligent agent, instructions like some text books provide, etc. This component provides information from the syllabus to the task level.
- **Monitor component**: Ensures that something is learned. A role taken by either the human teacher, the learner (self-control) or by some program.
- **Fellow learners' component**: Improves the learning process (some research tries to implement artificial ones).

- **Learning material**, often Courseware: Contains what has to be learned in a very broad sense (knowing what, knowing how). It can be computational in various ways (exploratory hypertext, lesson and task oriented hypertext, simulation software, task solving environments, etc.).
- **External information sources**: All kinds of information that is not directly stored in the learning material (e.g. additional material, handbooks, manuals, etc.).
- **Tools**: Everything that may help the learning process other than the learning material (e.g. calculators, communication software, etc.)
- **School** [a category we added]: Something that provides a curriculum and does student administration.

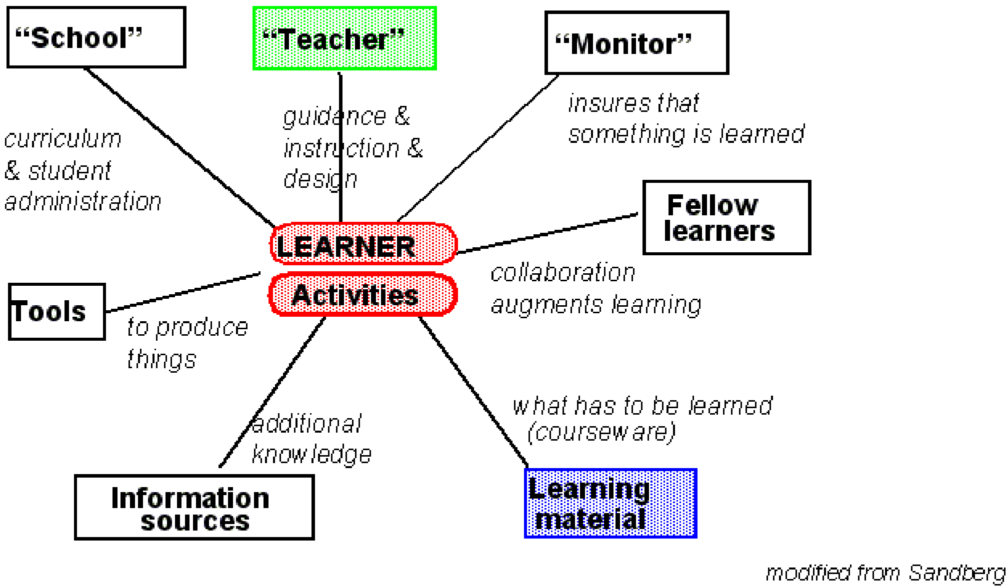


Figure 30: Functions of a learning environment

This model makes you think about functions that a learning environment should provide and therefore about the structure that will instantiate these functions. It also allows deciding on which aspects design or analysis should focus. For example:

- The *teacher's role* would be central in activity-based designs
- The *learning material* is important in e-learning designs for mass-education

Example 16. Types of e-learning designs

Schulmeister (2005) makes a distinction between:

- **E-learning type A**: based on "manageable" contents that easily can be made explicit via standardized learning objects and individual self-learning.
- **E-learning type B**: focusing on a high percentage of complex contents that are based on implicit knowledge and that has to be acquired through learning communities of practice.

In terms of interactivity one also could talk about internal person-to-machine interaction (type A) and external person-to-person interactivity (type B). However, from a learning psychology point of view, most of type A e-learning is not really interactive (selecting contents and answering quizzes is a rather low form of interactivity).

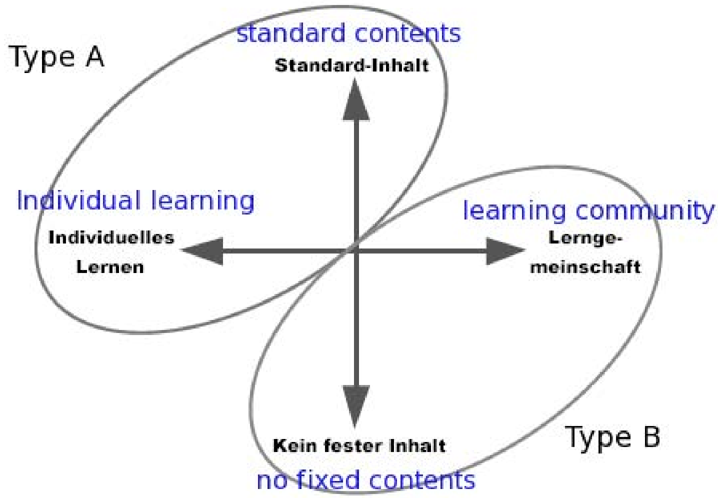


Figure 31: Schulmeister's type A and B e-learning

Such a model defines a simple taxonomy of two kinds of e-learning models using two dimensions. It will help to clearly define what type of e-learning you may implement or study.

Example 17. Euler and Seufert's e-galaxy

Euler and Seufert (2004) present a conceptual framework to describe learning environments. This four component framework allows describing various settings with four dimensions:

- Social forms of learner interaction
- Social communication forms of teaching
- Type of Media
- e-teaching action forms

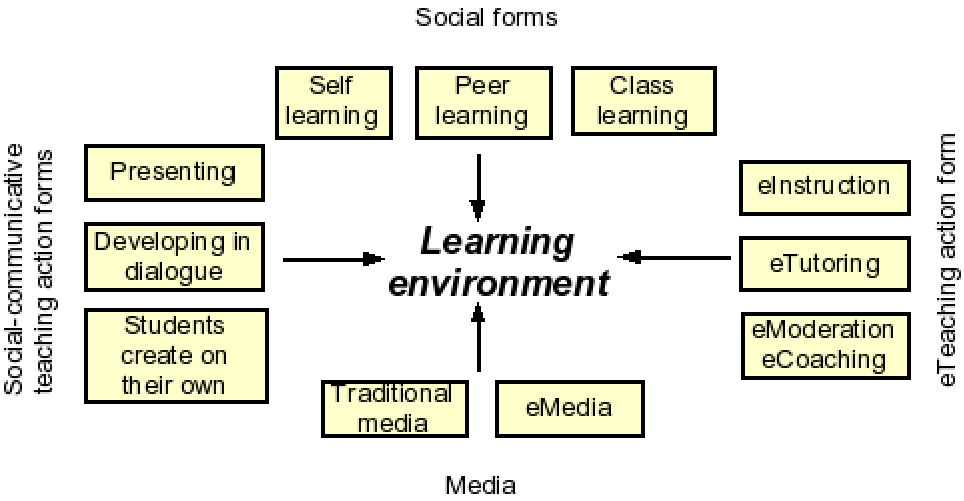


Figure 32: eLearning building bricks framework (SCIL)

The common factors in all such models about e-learning is the idea that there are (1) information tools and (2) communication tools to be used actively (as producers) or more passively. In addition, these models also postulate that environments should provide pedagogical support in one form or another (monitoring, coaching, scaffolding, etc.). Such a model helps you think about the structural components that define a learning environment, and what variants could exist.

Example 18. Key elements of an ICT design

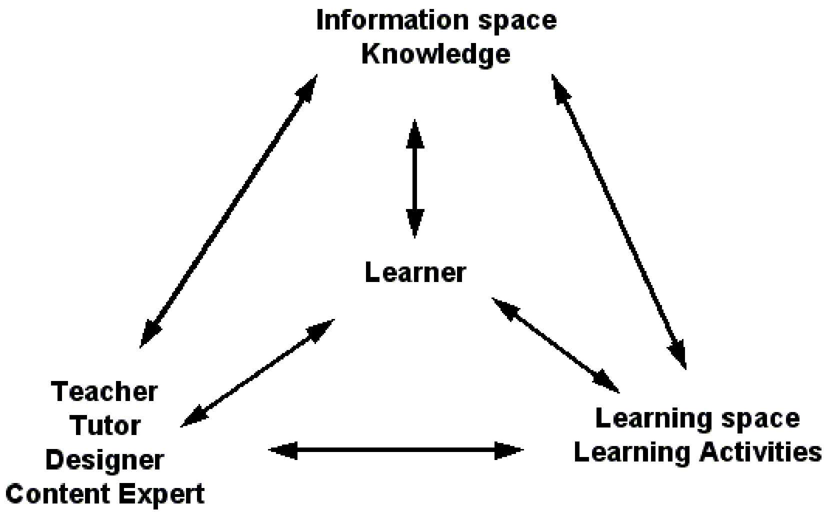


Figure 33: Example 18. Key elements of an ICT design

This is not a complex model, but it makes you think about the distinction between ***learning activities***, information (***learning material***) and ***people*** involved. It expresses an instructional design stance that can be found in the learning design community. As in the two previous examples, you should understand that such models always embody a theory about reality and at a more practical level about how things should be designed.

Example 19. The instructional systems design method

An instructional design method defines how to organize the process of creating a pedagogical design. It may include elements like learning contents, learning activities, learning environments or tools. Frequently, such methods are tied to specific instructional design models that in turn are based on learning and teaching theory. The fundamental principle of systems design is that each component of the model depends on each other.

Edmonds et al. (1994:57) defines the following essential components of the instructional design process (Figure 34).

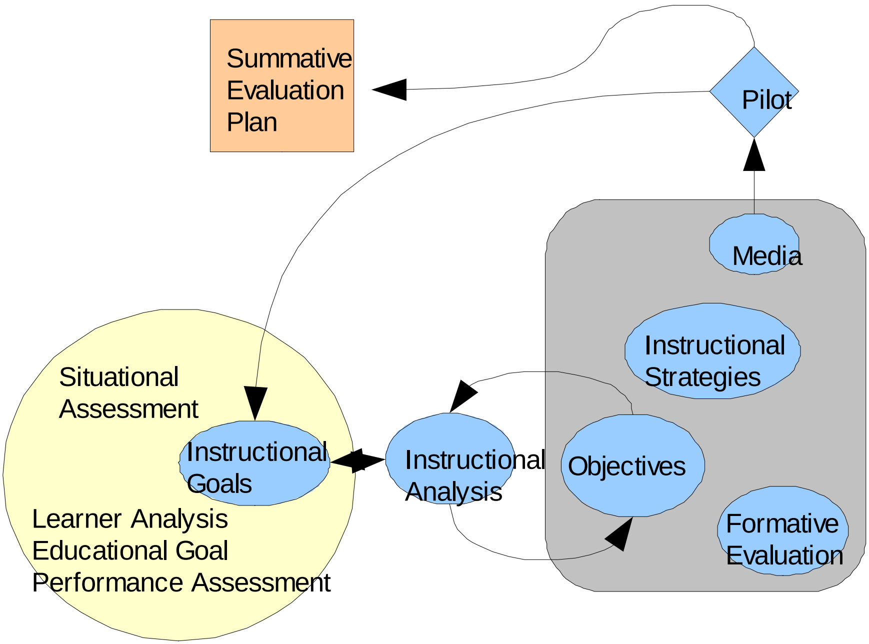


Figure 34: Edmonds' instructional design method

Such a model describes the instructional design process. It identifies the major stages, but also their relationship. In addition, it defines a normative design rule, i.e. how you should plan and implement a course.

Example 20. A "help desk model" for "on-the-spot" life-long learning

This model allows you to think at the same time about system components and actor's roles. It also summarizes a kind of instructional design model

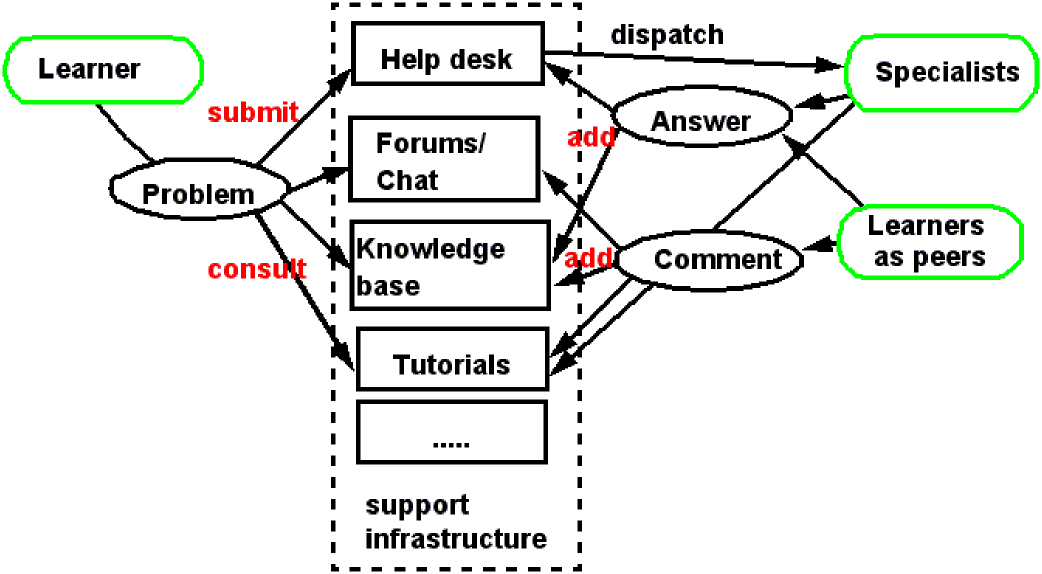


Figure 35: Help desk learning model

Such a model relates activities, roles and tools. Technical infrastructure used could be C3MS portals, groupware, specialized help desk, knowledge management software, but they should support a certain number of content management and communication tools.

Example 21. 2.9 A loop model for activity-based teaching

This figure defines scenarios as *sequences* of *activity phases* within which group members *do tasks* and *play specific roles*. That kind of *orchestration* implies organizing *workflow loops*.

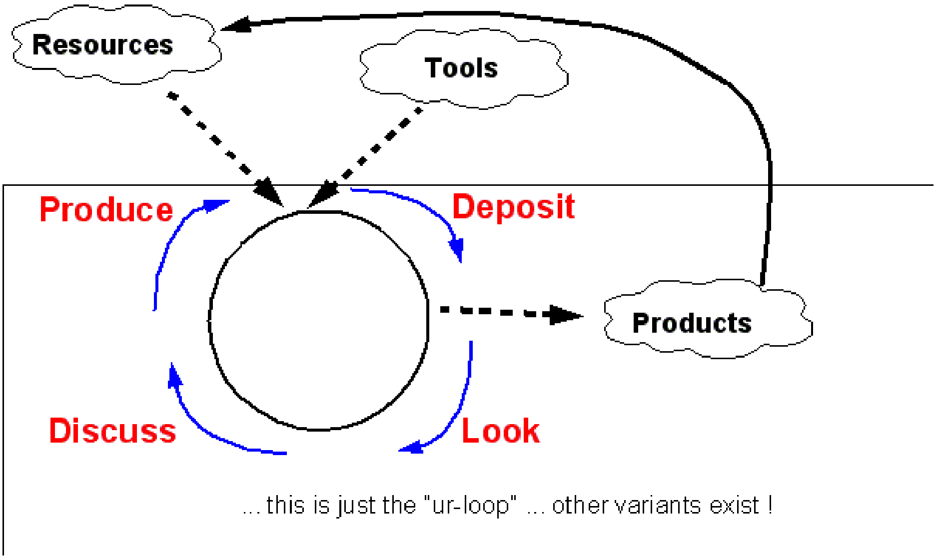


Figure 36:Loop model for activity-based teaching

Such a framework clearly shows that students have to engage in activities, that activities lead to products that can be discussed and reused. It helps you analyzing and design activity-based pedagogies.

Example 22. 2.10 Definition of a C3MS (community) portal

Some models are presented as simple lists of functions. Table 24: Functions and modules of a C3MS" does two things:

- It identifies six major functions that a community portal used in teaching should support with tools.
- It then provides some examples of tools that could support each function

Function	C3MS modules (tools of the portal)

Content management	News engine (including a organization by topics and an annotation mechanism) - Content Management Systems (CMS)Collaborative hypertexts (Wikis) - Image albums (photos, drawings, etc.) - Glossary tool or similar - Individual weblogs (diaries)
Knowledge exchange	News syndication (headlines from other portals)File sharing(all CMS tools above)
Exchange of arguments	Forums and/or new News engine, Chats,
Project support	Project management modules, Calendars ...
Knowledge management	FAQ manager, Links Manager, Search by keywords, Top 10 box, Rating systems for comments, What's new (forum messages, downloads, etc.), ...
Community management	Presence, profile and identification of members, Shoutbox (mini-chat integrated into the portal page), Reputation system, Activity tracing for members, Event calendar, News engine ...

Table 24: Functions and modules of a C3MS

This table provides associations between a list of functions and structure (software modules) that a teacher could use to support a project-based learning design. It could help designing a learning environment and then analyzing its implementation through a study that attempts to find out if all functions have been properly implemented and used. Of course, such a study, then also should look at learning outcomes.

Example 23. Support for creativity and engagement

This figure makes the claim that using portalware, or similar web 2.0 software like webtops, are good at supporting creativity and engagement.

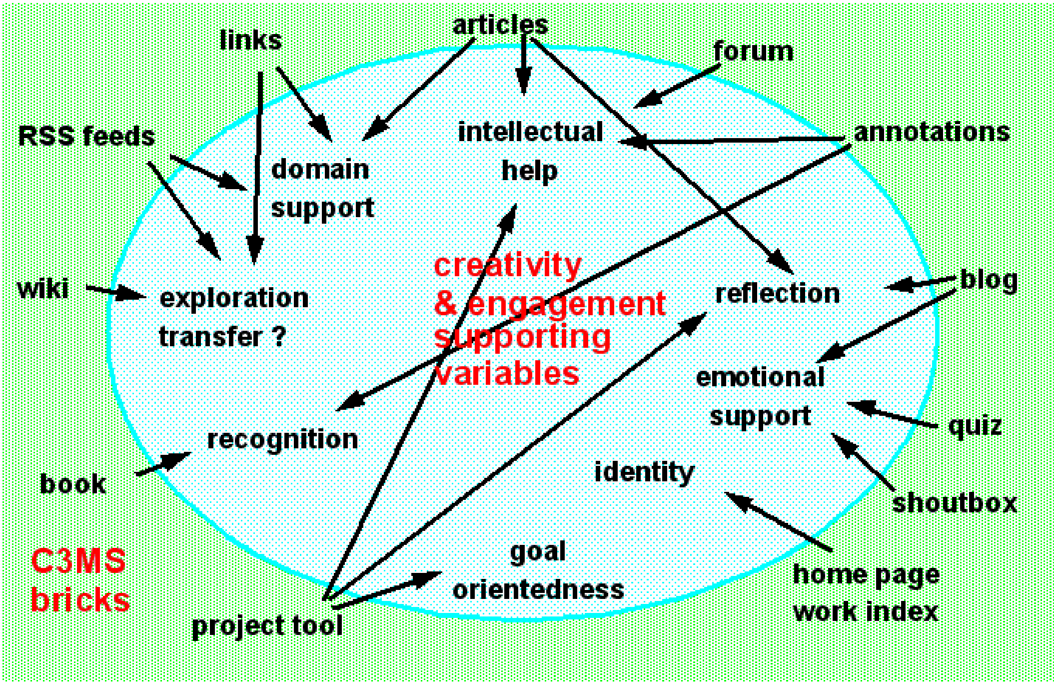


Figure 37: Technological support for creativity and engagement

This map links structure (software elements outside the blue oval) to functions inside the oval (creativity and engagement enhancing variables).

7.2 Analysis example frameworks

Analysis frameworks help to model things like relationships between variables or present components and activities of a system. We shall come back to this topic in the chapters about data analysis and shall just present a few examples here.

Example 24. Gonzalez 8-factor model for ICT usage in schools

We already introduced this master thesis research in section 4.2 *Identification of the central problem*. The author defines eight explaining factors found in a literature review and postulates the hypothesis that each will influence the teacher's use of ICT. He then formulates a series of hypothesis that postulate a few relationships among these variables. As whole, these hypotheses form a model that is pictured in Figure 38 below.

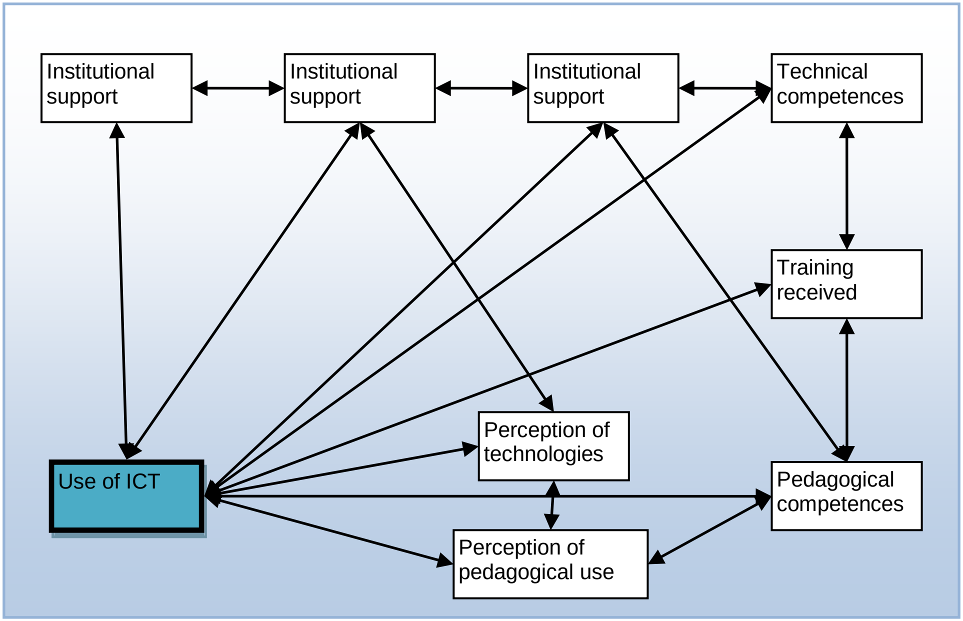


Figure 38: Eight factor model to explain teacher's use of ICT

Such models can be often found in studies on teacher development or transformative pedagogy. It clearly identifies variables and postulates relationships that you later can test with statistical analysis of survey and other data.

Example 25. Visualization of activities

Activity diagrams can be used to describe workflows, processes and other procedures. In information technology, a popular language to describe activities is UML. UML activity diagrams include the following concepts:

- Actions, represented by a rectangle with rounded corners
- Decision and merge control nodes represented with a diamond
- Fork and join control node represented with a fat line
- “Swim lanes” to represent what different actors do

The following example taken from a European UNFOLD project document contains the following elements: a start node, an end node, two joins/breaks (the fat lines) and three activities (the ovals). A learner will enter an opinion about a subject and then discuss the other’s opinions. This activity is monitored by a facilitator.

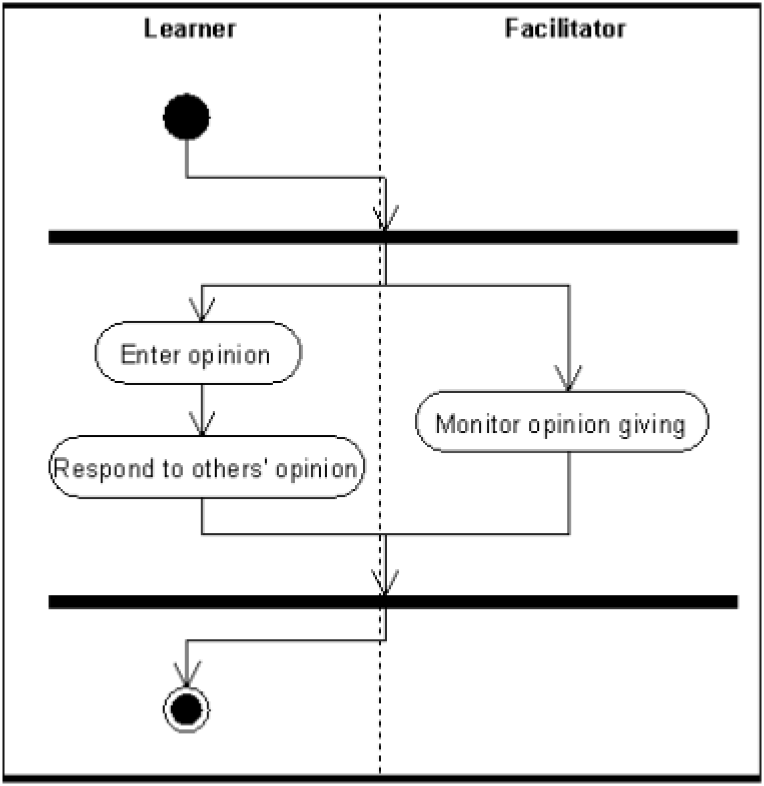


Figure 39: Activity diagram of a simple activity flow

Such activity diagrams can be both normative, i.e. define what a given activity structure should look like, and an analysis tool that allows to capture the essence of some observed behavior.

Example 26. Conjecture maps

Design-based research approaches, which we will introduce later, may formulate wholistic models of a phenomenon. According to Sandoval (2004a:2), "*designed learning environments embody conjectures about learning and instruction, and the* *empirical study of learning environments allows such conjectures to be refined over time. The construct of embodied conjecture is introduced as a way to demonstrate the theoretical nature of learning environment design, and to frame methodological issues in studying such conjectures*". An **embodied** conjecture is a conjecture about how theoretical propositions might be reified within designed environments to support learning. Designed environments include **tools** (like software), **materials**, and **activity structures** (defined as the combination of task structure, how a task is organized, and social participation structures.

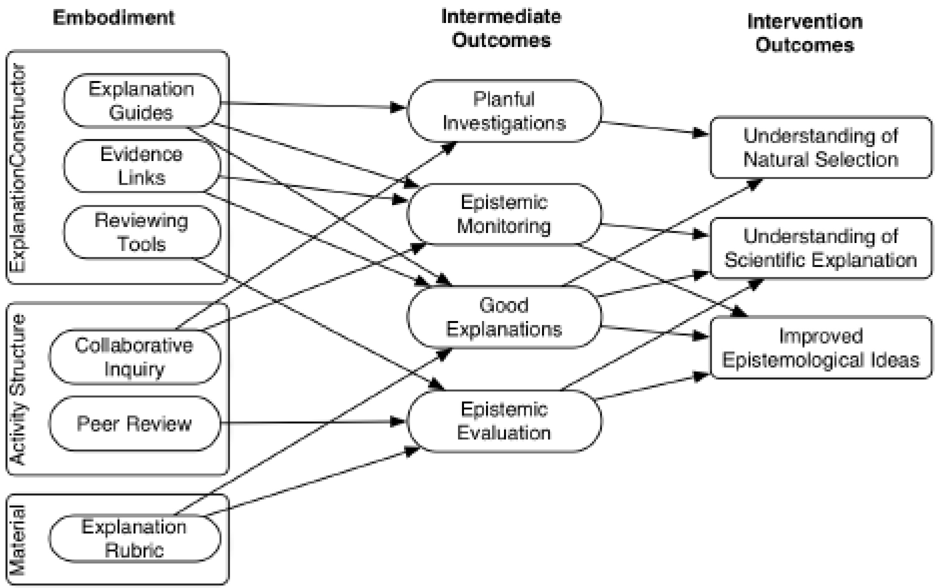


Figure 1: Map of embodied conjecture and predicted outcomes.

Sandoval, William A. (2004). Developing Learning Theory by Refining Conjectures Embodied in Educational Designs. PREPRINT (published later in Educational Psychologist, Vol. 39, No. 4)

Figure 40: Sandoval's conjecture map of the BGUILE Project

7.3 Examples of dimensions list and typologies

As you (hopefully) learned in the chapter on empirical research principles, it is important that you split high-level concepts into components, i.e. their dimensions. You will find many such lists of dimensions in the research literature as well as on web sites that are maintained by researchers.

Example 27. Types of Learning

We can categorize kinds of learning in terms of "learning domains" or "learning types". Such categories can be described both in terms of learning (the kind of knowledge involved) and teaching (what the learner must be able to do). Below we present a typology made by Greg Kearsely. (***http://tip.psychology.org/***)

Learning domain/type	**Description**	**Learner's behavior**
1. Attitudes	Disposition or tendency to respond positively or negatively....	Learners must make an appropriate *choice*
2. Facts learning (Factual Information, memorization):	Processing of factual information and remembering.....	Learners must *recite*, summarize, etc.
3. Concept learning (Discrimination):	Discriminate and categorize things. It is not related to simple recall and must be constructed.	Learners must *identify* (according to features), also be able to *discriminate* and *classify*

4. Reasoning (Inference, Deduction):	Thinking activities that involve making or testing inferences	Learners must *demonstrate* something
5. Procedure learning:	Being able to solve a certain task by applying a procedure.	Learners must *demonstrate* being able to select/apply a procedure
6. Problem solving:	Identification of sub goals, use of methods to satisfy sub goals.	Learners must *generate* a solution
7. Learning Strategies (related to metacognition)	Can hardly be taught and only be learned and to some extent only!	Learners must select appropriate *self-regulation* strategies.
8. Motor skills	Being able to physically perform something	(Like driving a car).

Table 25: Table of learning types

Example 28. Levels of learning

Instructional designers also are interested in learning levels, although they may formulate these in terms of increasingly complex learning types or learning outcomes. E.g. Gagné (1985), on the basis of Bloom defined the following taxonomy of learning outcomes:

1. Verbal information: reciting something from memory, e.g. recall a definition, tell a poem.

2. Intellectual skills:
   a) Discrimination: Recognizing that two classes of things differ e.g. be able to identify objects, features, symbols, etc. as not being the same.
   b) Concrete concept: Classifying things by their physical features alone, e.g. identify blue paintings, a symbol.
   c) Defined concept: Classifying new examples by their abstract (and possibly physical) features, e.g. identify an assignment in a computer program.
   d) Rule: Applying a simple procedure (a single relationship) to solve a problem or accomplish a task, e.g. add two numbers.
   e) Higher-order rule: Applying a complex procedure (multiple rules) to solve a problem or accomplish a task, e.g. write a computer program
3. Cognitive strategies: Inventing or selecting a particular mental process to solve a problem or accomplish a task
4. Attitudes: Choosing to behave in a way that reflects a newly-acquired value or belief
5. Motor skills: Performing a physical task to some specified standard

Other instructional designers or educational technologists formulated combined taxonomies of levels of instruction which we shall introduce in the conclusion of this chapter.

Example 29. Major pedagogical approaches (strategies)

A table of pedagogical approaches may help you to decide what sort of teaching and learning you want to study or favor with an ICT-based environment

Transfer	Tutor	Coach

Factual knowledge, *know-that*	Procedural knowledge, *know-how*	Social practice, *knowing-in-action*
Transfer of propositional knowledge	Presentation of predetermined problems	Action in (complex and social) situations
to know, to remember	to do, to practice	to cope, to master
Production of correct answers	Selection of correct methods and its use	Realization of adequate action strategies
Verbal knowledge, Memorization	Skill, Ability	Social Responsibility
to teach, to explain	to observe, to help, to demonstrate	to cooperate, to support
Teaching I	**Teaching II**	**Teaching III**

Table 26: Taxonomy of pedagogical approaches

Source: *Baumgartner & Kalz*, modifications by Schneider

Example 30. Khan's (2000) list of pedagogical methods and strategies

Presentation	Exhibits
Demonstration	Drill and Practice

Tutorials	Games
Story Telling	Simulations
Role-playing	Discussion
Interaction	Modeling
Facilitation	Collaboration
Debate	Field Trips
Apprenticeship	Case Studies
Generative Development	Motivation

Table 27: list of pedagogical methods and strategies

You may ask yourself the question, which pedagogical strategies work better *for what types* of learning (not included) ?

Example 31. 3.4 Intrinsically motivating elements of gaming ...

The following table almost represents a theory: What could we learn from gaming? Why do kids spend many hours playing games without getting bored or tired?

Element	**Explanation**

fantasy	triggers *imagination* and implies freedom (make believe + voluntary activity)
challenge &curiosity	games aim at a *level of difficulty* that triggers curiosity presence of goals uncertainty (surprise)
feedback	is *immediate* and clear (i.e. useful)
self-esteem	is achieved through adapted tasks provides encouragement to learn & augment scores
control	is implement through levels to play, *user selection* of goals, strategies & tactics

Table 28: Intrinsically motivating elements of gaming

Such a table defines constituent elements of a phenomenon. You may use it to think about the features of an educational game.

Example 32. Typology and typical functions of virtual environments

This figure makes explicit what someone means by "virtual environment"

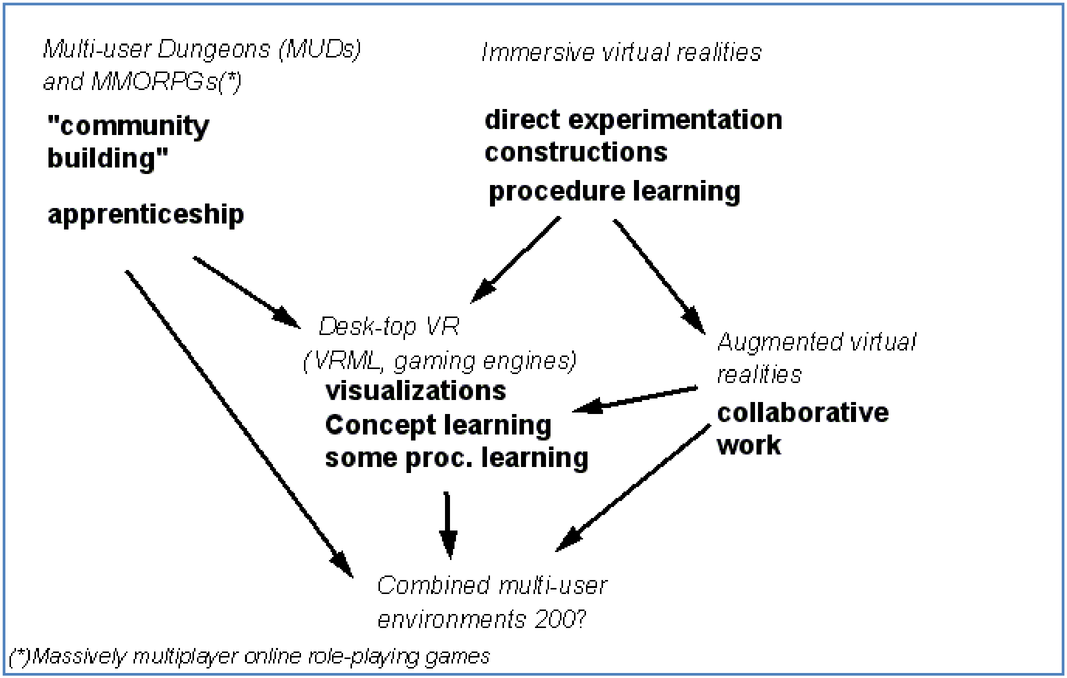


Figure 41:Typology and typical functions of virtual environments

We would argue that it is not safe to use the word "virtual environment" when you talk about an e-learning platform. We rather would quality these learning management systems as a form of portalware, i.e. a computer-mediated communication and content-delivery tool.

Example 33. Computer supported collaborative learning

This picture makes the claim that collaborative learning can be very powerful because its properties engage students in various meta-cognitive activities.

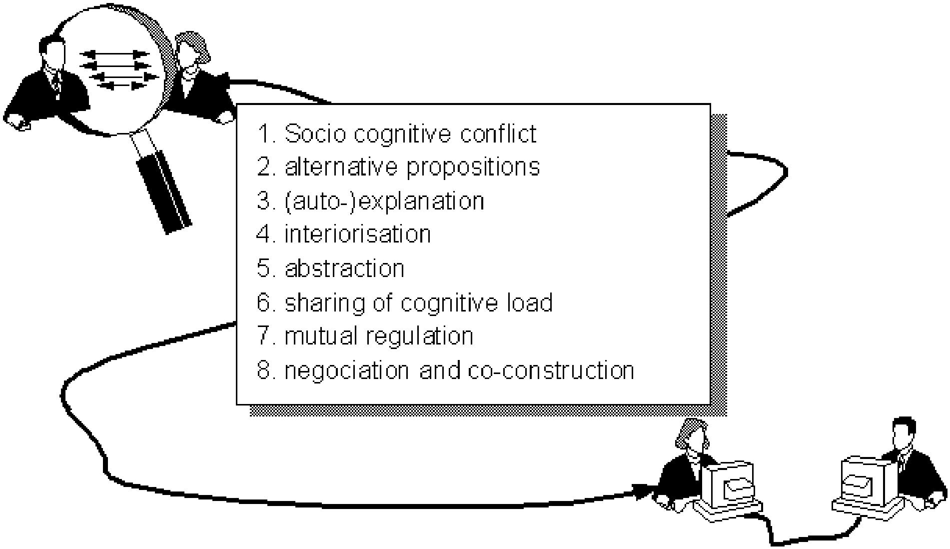


Figure 42: Effects of computer-supported collaborative learning

Source: Pierre Dillenbourg. Remark: Most researchers would argue that efficient collaborative learning needs scenario-building (story-boarding), i.e. so-called CSCL scripts or learning designs.

7.4 Example analysis grids

More grids (scales) are shown in quantitative design and analysis modules

Example 34. Ergonomics criteria of Bastien

This is a checklist for studying the ergonomics of software or another artifact.

1. Guidance	3. Explicit control
1.1 Incitation	3.1 Explicit actions
1.2 Grouping/Distinction between items	3.2 User control
1.2.1 … for localization	4. Adaptability
1.2.2 … for the format	4.1 Flexibility
1.3 Immediate feed-back	4.2 Taking into account user experience
1.4 Readability	5.Error management
2. Cognitive load	5.1 Protection against errors
2.1 Briefness	5.2 Quality of error messages
2.1.1 Concision	5.3 Correction of errors
2.1.2 minimal actions	6. Homogeneity/Coherence
2.2 Info density	7. Meaning of codes and labels
	8. Compatibility

Source: *http://www.lergonome.org/*

Example 35. Competence profile of a manager (dimensions)

Source : Emery, Y. (1997) Le centre d'évaluation pour managers publics, Cahier de l'IDHEAP 166, p9.

1. Personal competences
    a) introspection and permanent learning
    b) tensions resistance, energy and willfulness
2. Intellectual competences
    a) Systemic thinking, analysis and synthesis capacity
3. Relational competences

   a) leadership and group management
   b) listening and communication capacity
4. Managerial competences
   a) environment awareness et pro-activity
   b) entrepreneurship and decision spirit
   c) planning and controlling capacities

Again, such a list defines the dimensions of a complex concept and it can help both in design and analysis.

Example 36. Socio-constructivist features of on-line teaching

Taylor and Maor defined the COLLES grid we already introduced to study teacher education environments over the Internet. The authors identified six dimensions:

1. Relevance	How relevant is on-line learning to students' professional practices?
2. Reflection	Does on-line learning stimulate students' critical reflective thinking?
3. Interactivity	To what extent do students engage on-line in rich educative dialogue?
4. Tutor Support	How well do tutors enable students to participate in on-line learning?
5. Peer Support	Is sensitive and encouraging support provided on-line by fellow students?
6. Interpretation	Do students and tutors make good sense of each other's on-line communications?

Table 29: COLLES grid

This grid clearly identifies six dimensions of socio-constructivism (there are many other grids). We will see in the data gathering and analysis modules how to make it operational

7.5 Conclusion

It is important that you remember that this chapter did ***not aim to introduce various theories***, but we wanted to demonstrate that there exist a number of “intellectual tools” that will help you talk about your domain of research, that will help organizing research questions, define the dimensions of important concepts, etc. You can find more such frameworks in http://edutechwiki.unige.ch/en/ .

It is not very likely, that you can directly use one of these frameworks in your research project. Your task is to find appropriate frameworks during your ***literature review***!

Review question

- What is the role of a conceptual framework?
- Can you differentiate between different kinds of conceptual frameworks?

Review assignment

- On scholar.google.com, try to find two models for problem-based learning. Compare the two, select the best one, and explain why.

8 Structure of a master thesis

In this chapter, we will provide some advice about the structure of a master thesis. The word “thesis” has several meanings. One is “*proposition that is maintained by argument*”. A thesis-as-dissertation is just that: an **argument**, as we will argue.

Learning goals

- Understand that a master thesis is an argument
- Understand which elements are crucial for the read
- Learn about the function of each element
- Learn how to sequence the chapters of a thesis
- Learn some formal rules and understand that you may have to respect certain standards

A thesis or a research article is an argument

The organization of the written text presenting the research has nothing to do with the organization of the research plan or its little section on planning. In particular:

- A research plan (i.e. the research design) defines and organizes your work according to logical criteria. Do not write the research plan as a list of planned chapters.
- The research planning (i.e. the little section at the end of your research plan) organizes your time according to work packages and deliverables.
- Research is just done and not told, i.e. you do not tell people your personal experience with this. The thesis is ***not*** the tale of this research experience.
- The ***thesis*** or ***research article*** therefore presents the results of your research (including a literature review and methodological explanation on how you did it).

The structure of your thesis if defined by three elements:

1. The ***research type,*** i.e. the focus of thesis.
1. The chosen methodological ***approach(es)*** and related methodological criteria.
1. Some ***rhetorical principles***, i.e. your thesis should be readable. A reader must understand your objectives, the theoretical background, the research questions, how you did it, your results and your interpretation of the results.

8.1 Presentation and typographic structure

Let us first have a look at some technical and superficial presentation issues.

8.1.1 The word processor

Start admitting that you do not know how to use a word processor. Do not feel ashamed. Most people do not. The most important idea is not to lose days of work with repetitive re-formatting.

Here is a list of “must know” things:

- Define styles (and make sure to configure your word processor so that will inhibit modifications on the fly and automatic addition of new styles).
- Automatically create tables of contents and figures
- Create indexes
- Automatically number titles
- Create stable numbered lists

There exist two “formatting” strategies

- Either learn how to create a good list of styles (you may need between 15 and 30 for a master thesis depending on your research type
- Ignore my advice, but then only spend your last day with manual formatting.

Professionals do it this way

- Each type of paragraph has its own style
- **Never** use TABS or empty lines. For example, paragraphs are separated by space, not an empty line, therefore, add horizontal space to the paragraph style element definition.

You need at least the following style elements:

- Numbered Chapter, numbered section, numbered sub-section and unnumbered sub-section. If you use MS Word, just define styles for heading 1 to heading 4.

- List elements (bullet list items and enumerated items). You may, but usually don't have to define these at two levels
- Normal paragraphs
- Citation paragraphs (indented)
- A style for fixed formats if you plan to present code
- One or more good table styles
- Figure captions

8.1.2 Titles, sections and the table of contents

The table of contents not only is a navigation tool but it indirectly defines your argumentation flow. This is why wording of titles and structure is important.

Do not use too many section levels (like 12.3.4.1.a). Your thesis is not an administrative operations manual, but a flow of connected ideas.

- Too many levels will make orientation difficult for the reader. He will not understand where he is located in the text.
- You may add unnumbered titles at the section or the sub-section level or maybe use something like (a) .... (1) ....
- Each numbered sub-section represents an important topic
- Titles should summarize a topic (without being too long)

You have to find a compromise between:

- flow of argumentation (avoid sub-titles because the "cut" intro a text)
- structure (use sub-titles to separate topics)
- readability (use un-numbered sub-titles to structure contents that stretch over several pages)

8.1.3 Layout

There exist several schools of thought. Make sure to consult official guidelines too!

Page numbering

Either just number from 1 to N or use the more sophisticate following scheme:

- Roman numbers for preface, table of contents etc.
- Normal numbers for the main part
- Something like A-1, etc. for annexes.

Headers and footers

- On top of left pages you should put the current chapter title
- On top of right pages you should put the current section title
- On bottom right (and if you use left/right pages, also on bottom left) include the page number. Make sure to do this for early drafts too. Advisers do not like students presenting drafts without table of contents and numbered pages.

Remarks: Adapt this rule to other languages that do not adopt the western left-to-right scheme. In MS Word,adding chapter headings is painstaking labor since you have to do this for each section, so you may skip this. However, any real word processor can do this easily.

Line length

- Do not produce long lines, since readers will have troubling tracking a line, may lose it, and get lost on the page. Simply use decent margins and don't use small fonts (10pt is too small)
- You may indent titles to the left (certainly not to the right as some Word default styles will do)

Some modern additions

- You can use boxes to present "special information" like case summaries or important conclusions. That is what we do in this text.
- Use side headers (also very difficult to do in Word 2003).

Figures and tables

- Label and number each of these. If you work with a real word processor, let them float to the top or the bottom of the page. If you use Word, you can do this manually (but only the day before you turn in the dissertation).

Fonts

- Use a font with serifs, e.g. an "old" font like Garamond or a modern font like Constantia that has been designed for both print and online reading.
- Non-serif fonts may look prettier to you, but most of these diminish readability since serif fonts add some "invisible line" that the reader's brain will use to keep track. However, you may use fonts like Univers, Frutiger or Calibri.

8.2 The organization of a thesis

Organization of the thesis is of utmost importance. We shall discuss the most important parts of an academic thesis. You also should be aware that many institutions define their own guidelines, at least presentation rules. In addition, there exist conventions within given research approaches that you must respect. Table 30 summarizes the elements we shall discuss. As you can see, in terms of rhetoric, the introduction and the conclusion are the most critical elements.

Elements	**Importance**	**Main functions**
Foreword	*	Personal Context
Table of contents	**	Navigation
Abstract	*	Main objective, result and scope
Introduction	***	Objectives, global approach
Principal part	**	(depends on your research type)
Conclusion	***	Summary of results, further work and scope
List of sources	*	Data anchoring
Indexes	*	Navigation

Bibliography	**	Theoretical anchoring
Annexes	*	Presentation of detailed data, materials, etc.

Table 30: Most important elements of a thesis

8.2.1 Foreword

The foreword (also called preface) is ***not*** part of your thesis. Things that relate to your work belong to the introduction. You may use the preface to:

- thank people (e.g. your parents, your partner, your advisor),
- explain why you have chosen this subject,
- (maybe) excuse yourself for things to didn't do,
- announce some follow-up.

Tip: Give some thanks to your advisor. He/she probably deserves it and even if he/she does not, it's good policy.

8.2.2 Table of contents of tables and figures

Tables of contents and figures are mandatory

- Position: At start and after the foreword
- Items in the table of contents match chapter and section titles in the text (this should be obvious). Even Word can generate this easily.
- You also should add tables for the figures and the tables. This will allow people finding synthetic information.

Do not forget that you do not just write the dissertation for the jury. Other people may read it and they want to do this fast and maybe just find some bits of information as quickly as possible.

8.2.3 The Abstract

- An abstract is often mandatory and should summarize all aspects of your work, in particular the big research question, the approach and the results.
- If it is not, you also may summarize your thesis as a paragraph in the introduction

8.2.4 The Introduction

The introduction (as well as the conclusion) is the most important chapter of your thesis in terms of impact on the reader. Some people will decide to read or not to read your thesis after looking at the first page.

Even serious readers like the jury, will read the introduction first and they should clearly understand what you did. Also, make sure that they find your subject interesting. You have to **frame** readers. A reader must quickly understand the following components of your piece:

Elements	**Details**
The big question	.... Summarizes your subject, i.e. what you wanted to find out.
	.... implicitly or explicitly defines a scope
The "language"	.... which major *concepts* you use, word definitions you use, etc.
The general	.... research type, global approach, principal *methods* used

approach	.... the *structure* of your thesis

In general, the introduction includes:

1. A description of your *research subject* (including the big question).
2. A *short discussion* of the *interest* of your work and its *scope* (including what you will not do).
3. A synthetic list of research questions and/or working hypothesis (if your research is rather theory-finding). Alternatively, they may appear after the literature review part.
4. A list of some important definitions, e.g. an explanation of the words you use in the title of thesis or the big question. You also can do this in the literature review.
5. A presentation/discussion of the global approach, unless you dedicate a special section to this. In the latter case, you should just briefly describe the approach in a single short paragraph.
6. A short guide for the reader. It will help the reader finding things and show that you can provide a rationale for the adopted structure.
7. An introduction of the object(s) you study. E.g. if you do some policy implementation research, you may present the context and the legal basis.

Remark: A working hypothesis is not a scientific hypothesis that can be tested. It is just a more aggressively formulated general research question. “Real” hypothesis exist in theory-testing approaches. They are grounded in theory and can be properly tested with data. Such hypothesis are always presented after the theory part and then even further operationalized after or in the methods chapter.

8.2.5 Principal chapters

It is difficult to provide short and useful advice regarding the principal chapters for the large variety of different research types. Certain of these research types / approaches have strong guidelines for content structuring and they all may be quite different. However, we can try to formulate some general principles.

In all empirical studies, you should:

- present and discuss **existing work**
- **present** data and results
- **discuss** results
- **link** results with the questions and hypothesis
- **confront** results with **existing** knowledge

However, the order is not necessarily the same for a given research type...

A remark on writing style

Avoid including lots of statistical indices in your sentences, rather use tables for this task (except in experimental psychology, where text is supposed to be unreadable)

8.2.6 The literature review chapter

Usually, the review is done in chapter two. However, there exist exceptions (e.g. in history). In any case, the literature review chapter(s) should be **used**. Research questions are presented in detail after the review and they must be grounded in the literature review. Research results have to be confronted to the theory later on (e.g. after or during presentation and discussion of the results). This is an often-observed problem in master theses. This principle also works the other way round. If you do not use a theory, do not present it.

8.2.7 The Conclusion

Recall the *principal results* of your research

Discuss the scope of your results and provide an outlook

- You may discuss the *external validity* (i.e. attempt some generalization)
- Discuss questions for which you don't have answers or things you didn't implement (and why)
- You could *formulate a new theory* that could be refined/tested in further work
- You can formulate new interesting research questions. Often the value of a master thesis is to generate new research ideas that your adviser could pick up or that you could turn into a Ph.D. thesis ☺.
- You could globally compare your work to other empirical studies (if not already done so)
- You may discuss the practical usefulness of your work (in particular if your thesis does not have a practical aim)
- If you produced an applied and/or design-oriented thesis, you should recall major recommendations (e.g. present a set of design rules for practitioners)

8.2.8 List of sources

If necessary, this chapter will include a list of all your primary sources, e.g.

- laws and other legal or paralegal documents, or
- historical sources.

You also may include these in the bibliography.

8.2.9 Indexes

You may (but usually must not) produce an index of concepts and authors. It will help the quick reader to find interesting "spots" and also provide an idea about the way you tackled your research.

Most word processors can do this fairly easily (even Word)

8.2.10 Annexes

Annexes are important and include everything that is not strictly necessary for the presentation and the discussion of empirical results.

Typically, the annex(es) may include:

- All research artifacts (such experimental materials, survey questions, etc.),
- some raw data (e.g. stories told by individuals), most often just excerpts,
- Intermediate analysis data like descriptive statistics, qualitative summary tables, etc.).

The annex allows a critical reader to find how you conducted your data analysis. You also may include some data, but you should be careful not to include confidential data. In the same spirit, annexes also will help other persons to replicate some or your empirical research, e.g. apply your questionnaire to a different population.

8.2.11 The bibliography and citations

It must include each reference you directly or indirectly used. You do not need to include any other references, i.e. texts you did not use.

You must respect a certain **standard** for the bibliography (and be coherent)

Tip: Start doing the bibliography right from the start. As soon as you use a text, include it! You may learn how to use a reference manager, although for a typical master thesis you also can do it "by hand".

For your citations, you also will have to respect a given norm.

In some institutions, you can choose bibliographic and citation style, in others you will have to comply. A popular norm in educational technology for bibliographies and citations is APA (http://en.wikipedia.org/wiki/APA_style).

8.3 Ethical issues

Your institution likely created guidelines for conducting research. Respect these! In particular, you should pay attention to the following issues:

- When you work with a population (e.g. children in a school or students) the children themselves and their institution or/and their parents must consent. There exist considerable policy differences between countries.
- In qualitative studies, you should anonymize names. E.g. instead of quoting student “Monica”, you should use “Student D”.
- In the annex, you should not include data tables that include names.

8.4 The presentation

Do not forget to prepare your presentation. A good presentation can make a little difference. Often the jury is divided and has to decide between a somewhat lower and a somewhat higher grade. Time is usually very limited, so stick to the essential!

(1) Make sure to present the essential elements only

- Your introduction should be as short as possible (no mumbling about how you found your subject and how your thesis changed your life and the one of your dog or cat). Just state the objective (main goal and big question) of your thesis
- Then present the research questions and the results. Make sure to arrange this part according to standards observed for your research type. E.g. in experimental psychology you would present hypothesis, materials, results, discussion.
- If there is time, you can present some outlook.
- End with a stunning conclusion, do not finish mumbling...

(2) Plan a test run with some friends. Ask them to tell you what was not clear.

(3) Prepare the delivery. Once you feel that the contents are ok, you will have to deliver ***in time*** (e.g. 30 minutes) and with a minimum of style. The **only** way to get this right is to repeat the presentation using your voice at least 3 times (just looking at the slides and mumbling will not help).

Here is a typical "talk menu". It is in French since its food has a good reputation.

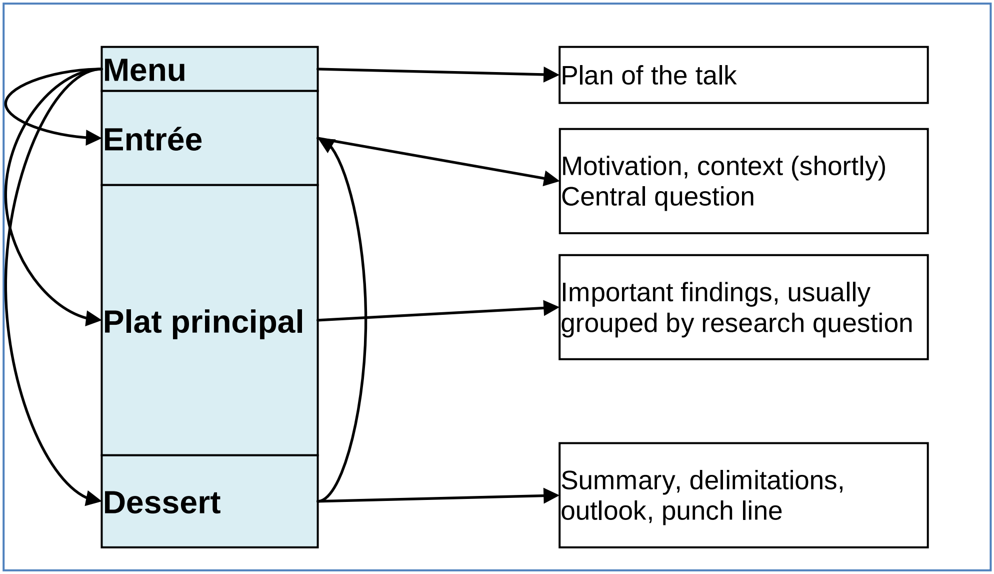


Figure 43: Menu plan for the presentation

8.5 After you are done

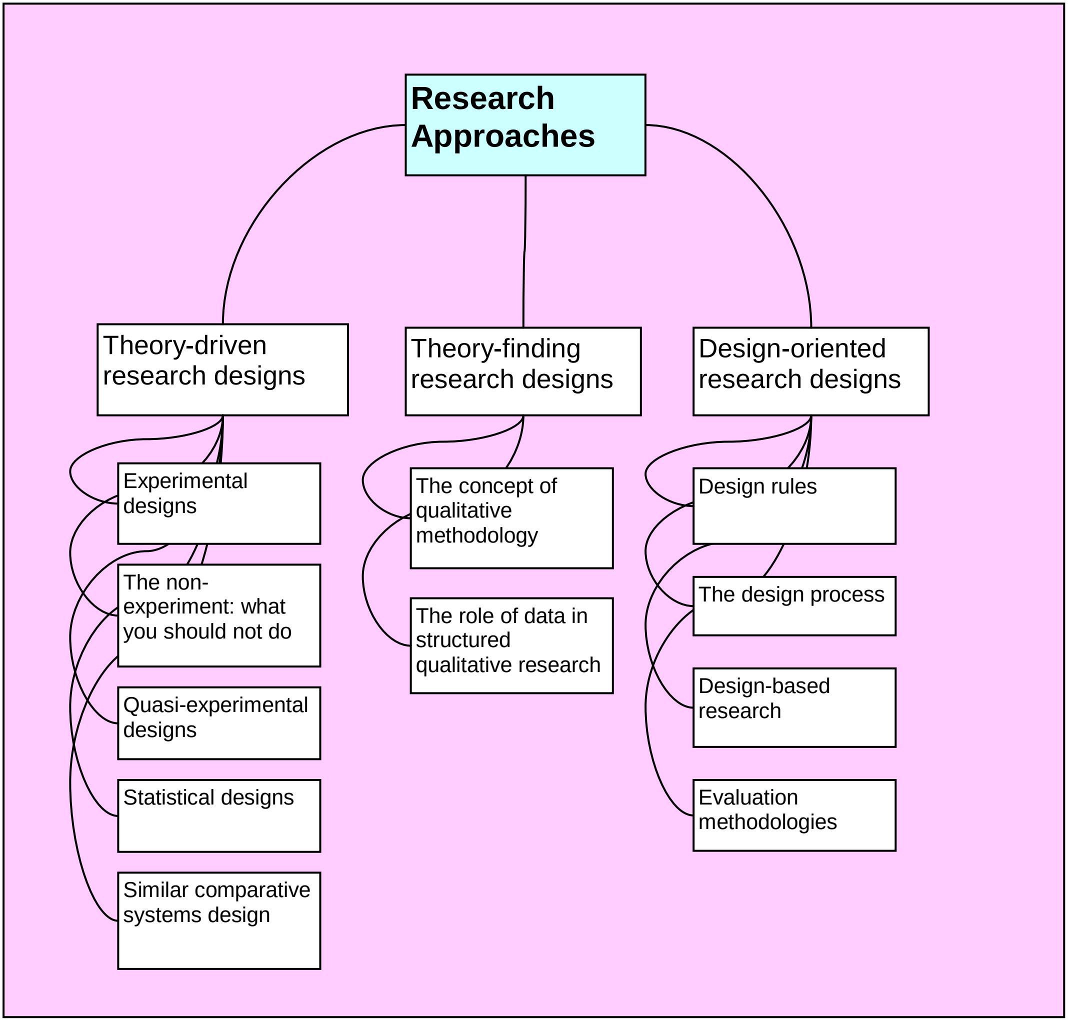
Suggest to your advisor to present your work as a conference paper with him as second co-author. This is a fairly standard procedure in the US but not necessarily in other countries. Both will profit if he/she does his/her share.

> A research paper or a thesis is an argument ! Do not tell the story of your experience, but organize it according to logical criteria.

Review question

- What are the two most important elements in a dissertation in terms of rhetoric?
- Is there a standard structure for dissertations in academia? Explain!
- What is the most important bibliography and citation style in educational technology?
- What is the role of the literature review chapters?

PART III – INTRODUCTION TO RESEARCH APPROACHES



9 Theory-driven research designs

In the conclusion of chapter 2, i.e. in the Types of research section, we presented three big families of research approaches: explanatory theory testing, interpretive theory finding, and design research. This chapter will present explanatory theory-driven research designs, i.e. mainstream social science. Most research in educational technology published in high quality journals will adopt this approach. Many evaluation studies also rather use a top-down approach that is driven by theoretical constructs.

Learning goals

- Understand the fundamental principles of theory-driven research
- Become familiar with some major approaches and be able to discriminate among these.

The most important elements of an empirical theory-driven design are theory, hypothesis, measures and causal (statistical) analysis.

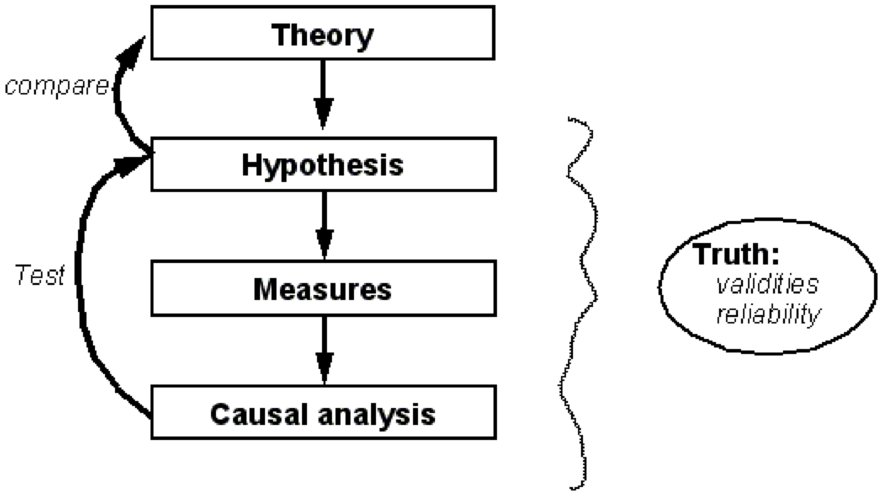


Figure 44: Important elements of empirical research

- *Conceptualizations*: Each research question is further specified in terms of one or more hypothesis. Hypotheses are grounded in theory.
- *Measures* : are usually quantitative (e.g. experimental data, survey data, organizational or public "statistics", etc.) and make use of artifacts like surveys or experimental materials
- *Analyses & conclusion* : Hypothesis are tested with statistical methods, for example experimental designs or correlational (statistical) designs

There exist several variants of theory-testing research approaches and we shall shortly discuss a few of these in the following sections. These various approaches share various assumptions and methodological constructs and we shall introduce them when most appropriate.

9.1 Experimental designs

Experimental research represents the ideal (best) paradigm for empirical research in most natural science disciplines. The experiment aims to *control physical interactions between variables*.

Typical research questions that one might ask in educational psychology are:

- What are the effects of a new technological intervention on the long-term and short-term memory retention of simple concepts?
- What is the influence of the continuity of a presentation flow on memory retention?

The experimentation principle in science fields is quite simple:

1. The study object is completely isolated from **any** environmental influence and observed (O_1)
2. A stimulus is applied to the object (X_1)
3. The object's reactions are observed (O_2).

We may draw a picture for this:

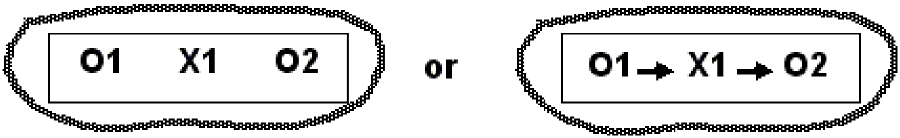


Figure 45: The experiment principle

O1 = observation of the non-manipulated object's state

X = treatment (stimulus, intervention)

O2 = observation of the manipulated object's state?

The effect of the treatment (X) is measured by the difference between O_1 and O_2. In other words, an experiment can provide evidence (corroborate) that an ***intervention X*** will have ***an effect Y***. X and Y are theoretical variables that are operationalized in the following way. X is the treatment (intervention) and Y represents quantified measures of the effect in terms of $O_2 - O_1$.

In human sciences (as well as in the life sciences) it is not possible to totally isolate a subject from its environment. Therefore, we have to make sure that effects of the environment are either controlled or at least equally distributed over the control group. Let us now look at a few strategies for conducting experiments in the learning sciences.

9.1.1 Simple experimentation using a control group

A simple control group design looks like this:

Figure 46: Experimental control group design with randomized groups

The principle of this methodological design is the following.

1. Two groups of subjects are chosen randomly (R) within a mother population. This ought to eliminate systematic influence of unknown variables on one group. I.e. we postulate that both groups will be under the same influence of the same uncontrolled variables.
2. The independent variable (X) is manipulated by the researcher. He will put one group in an experimental condition, i.e. apply a treatment.
3. Ideally, subjects should not be aware of the research goals since they might consciously or unconsciously want to influence the results.

In order to analysis the effects, we compare effects of treatment (stimulus) vs. non-treatment of the two groups. The measure "O" is also called a **post-test** since we apply it ***after*** the treatment.

Example 37. Simple randomized control group posttest experiment

Treatment	**effect (O)**	**non-effect (O)**	**Total effect for a group**	
treatment: (group X)	bigger	smaller	100 %	We do a "vertical" comparison
non-treatment: (group non-X)	smaller	bigger	100 %	

Analysis questions are formulated in this spirit: What is the probability that treatment X leads to effect O? In the table above, we can observe an experimentation effect. We can see that the effect in the experimental (treated) group is bigger than in the non-experimental group and the other way round.

9.1.2 Simple experiment with multiple treatments

The **Simple experiment with different treatments** is a slightly different design alternative, but similar in spirit. We would like to observe the effects of various kinds of treatments.

R	X1	O1	experimental group 1
R	X2	O2	experimental group 2
R	X3	O3	experimental group 3
R	X..	O..	

Figure 47: Simple experiment with different treatments

Example: First students are assigned randomly to different lab sessions using a different pedagogy (X) and we would like to know if there are different effects at the end (O). Remark: O1 to O3 all use the same tests.

9.1.3 Problems with simple experimentation

Such "post-test" only designs are not optimal and for various reasons.

- **Selection**: Subjects may not be the same in the different groups. Since samples are typically very small (12-20 / group), random selection of subjects may not work.
- **Reactivity of subjects**: Individuals ask themselves questions about the experiment and this leads to compensatory effects or they may otherwise change between observations
- Difficulty to **control certain variables** in a real context: Example: A new ICT-supported pedagogy may work better, because it stimulates the teacher, because students may increase their attention and amount of work, or simply because experimental groups may be smaller than in real conditions and individual student therefore get more attention.

In principle, one could test such intervening variables with new experimental conditions. But for each new variable, one would have to add at least two more experimental groups, something that is very costly. Let us now look at a more popular design that includes pre-tests.

9.1.4 The simple experiment with pre-tests

The following design attempts to control the difference that may exist between two experimental groups, i.e. we don't trust randomization or we can't randomly assign subjects to a group. This is typically the case when we select for example two classes in a school setting, which we subject to two different treatments.

Here is the design "formula":

R	O1	X	O2	experimental group
R	O3		O4	control group

Figure 48: Experimental control group design with pre/posttest

Analysis of results is done in slightly different way than in the randomized without pretest design. To control the potential difference between groups we compare the difference between O_2 and O_1 with the difference between O_4 - O_3. O1 to O4 are identical tests.

Effect = $(O_2$-$O_1)$ versus $(O_4$-O_3.

There are also disadvantages of this design; in particular, the effect of the first measure (the pre-test) can influence the outcome. Example: (a) If X is supposed to increase a pedagogical effect, the O_1 and O_3 tests could have an effect (students learn by doing the test), so the pure effect of X may be overestimated.

This **experimentation effect** can be controlled by the **Solomon design**, which is similar in spirit. This method requires two extra control groups and is therefore more costly.

R	O1	X	O2
R	O3		O4
R		X	O5
R			O6

Figure 49: The Solomon design

The Solomon design combines the simple experiment design with the pretest design. We can test for example if

O2>O1, O2>O4, O5>O6 and O5>O3

Simply comparing two different situations is ***not*** an experiment! The treatment variable X must be simple and unidimensional (else, you don't know the precise cause of an effect). We shall come back to this problem below when we discuss quasi-experimental research designs. Let us just state a simple principle: Experimental designs that involve humans exposed to meaningful tasks just provide positive or negative evidence for a hypothesis. We never should use the word "proof" or "verification", but just "corroboration" or "evidence".

9.1.5 Factorial designs

In this introduction, we only presented simple experimental designs, i.e. the kind one would expect in master thesis conducted by novices in experimental research. We shall not elaborate factorial designs in detail, but just outline the principles.

In educational technology research and related fields, researchers often attempt to study the influence of more than one factor X and how, for instance, the two factors X_A and X_B will interact. Controlling interactions between two independent variables requires at least four groups.

Example 38. A simple two factor design

Let us imagine a most simple two factor design: "*What is the impact of a training length (1 hour vs. 4 hours) and the setting (presential vs. distance) on learner achievement?*" Factor A is the *level of training* and factor B is the *setting* (presential vs. distance").

		Factor A	
		1 hour condition	**4 hours condition**
Factor B	**Presence condition**	Group 1	Group 3
	Distance condition	Group 2	Group 4

Table 31: A simple two factor design

We also could use a notation similar to the one we presented above. This notation should be interpreted in a different way than above. X_{11} for examples means that the group is in Condition A=1 and condition B=1, X_{21} means that a group is in condition A=2 and B=1.

R	O	X_{11}	O		Group 1 is in condition A=1 and B=1
R	O	X_{12}	O		experimental group 2
R	O	X_{21}	O		experimental group3
R	O	X_{22}	O		experimental group3

Firstly, we could analyze the effects of each factor (like in the previous example). However, it is more interesting to test how these factors interact. E.g. there may be no difference between group 1 and group 3 (meaning that one hour of training is enough in the presence condition), but there could be a difference between group 2 and group 4, meaning that time of instruction has an effect in the distance condition.

As we wrote before, explanation of factorial designs is outside the scope of this introduction. You may read Bill Trochim's on-line text on Factorial Designs to learn more (http://www.socialresearchmethods.net/kb/expfact.php)

9.2 The non-experiment: what you should not do

Let us now look at bad designs, since they often can be found in the discourse of policy makers or within early drafts of research proposals. Avoid these at all costs since experts will not accept evidence based on faulty logic.

9.2.1 The (non)experiment without control group nor pre-test

This first bad design looks like this:

X O	experimental group

Figure 50: Bad experiment (1)

We just look at data (O) after some event (X).

Example 39. A faulty discourse on ICT competence of pupils:

Let us look at the following claim: *Since we introduced ICT in the curriculum, most of the school's pupils are good at finding things on the Internet*.

In such a claim, there is a lack of real comparison!

- We do not compare what happens in other schools that offer no ICT training. Maybe it is a general trend that pupils have become better at finding things on the Internet, since most households how have computers and Internet access.
- We do not even know what happened before!

A statement like "*Most of the students are good at X!*" ... means that you do not compare to what happens in other settings that do not include ICT in their curriculum. It is therefore worthless as proof that introduction of ICT on schools had any effect.

The variable to be explained (O)	**x= ICT in school**	**x= no ICT in school**	
bad at web search	10 students	???	Horizontal

good at web search	20 students	???	comparison of % can't be done

Things have changed ... means that you are not aware of the situation before the change.

The variable to be explained (O)	**before**	**after**	
bad at web search	???	10 students	Horizontal comparison of % can't be done
good at web search	???	20 students	

Now let us look at another bad design.

9.2.2 Experiments without randomization nor pre-test

In the following design, we have the problem that ***there is no control over the conditions and the evolution of the control group***.

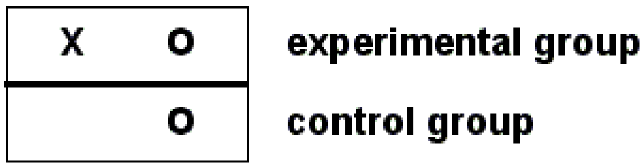


Figure 51: Bad experiment (2)

A typical faulty example would look like this: *Schools that make use of computer animations have better average grades.* School A using computer animations may have better grade averages than in school B for totally different reasons. School A simply may attract pupils from different socio-economic conditions and they usually have better grades. In addition, richer schools have to money to introduce computer animations and at the same time, they attract better learners.

Finally, let us look at the experiment without control group, yet another bad design.

9.2.3 The experiment without control group

Figure 52: Bad experiment (3)

In this design, we do not know if X is the real cause

Example: *Since I bought my daughter a lot of video games, she is much better at word processing*". You don't know if this evolution is "natural" (kids always get better at word processing after using it a few times) or if she learnt it somewhere else. This is called "natural evolution" or "statistical regression" of the population.

9.2.4 Experimental example studies

We shall present here a typical master thesis that uses an experimental design to study the effects of multimedia learning materials on learning.

Example 40. Effect of multimedia animation on learning

The author actually presented two related thesis, one in educational technology (in French) and one in experimental psychology (in English). Below we summarize the thesis submitted in educational technology.

> Rebetez, C. (2004). Sous quelles conditions l'animation améliore-t-elle l'apprentissage ? Master Thesis (145p.). Master Thesis, MSc MALTT (Master of Science in Learning and

Teaching Technologies), TECFA, University of Geneva.
http://tecfa.unige.ch/perso/staf/rebetez/papers/memoire_staf.pdf

The big research question

> *Our research has the objective to show the influence of the continuity of a presentation flow, of collaboration and previous states in memory and to verify the influence of individual variables like visual span and capacities to do mental rotations.*

Explanatory (independent) variables, i.e. conditions

1. **Animation**, *static vs. dynamic condition*: allows visualizing transition between states. Static presentation forces a student to imagine the movement of elements.
2. **Permanence**, *present or absent condition*: If older states of the animation are shown, students have better recall and therefore can more easily build up their model.
3. **Collaboration**, *present or absent condition*: Working together should allow students to create representations that are more sophisticated.

In order to test effect of these conditions, 3 x 3 = 9 experimental groups had to be tested.

Operational hypothesis

1. Animation
    - Inference scores and retention scores are higher in the dynamic condition than in the static condition
    - Perceived cognitive load is higher in the dynamic condition than in the static condition.

- Time for discussion and certitude levels remain the same in all conditions.

2. Permanence
    - Participants in the permanent condition will show better results in the post-test questions then the participants in the not permanent condition. In particular, we expect better inference scores.
    - Perceived cognitive load should not differ between the two conditions. Time for discussion and certitude levels should be higher in the permanent condition.
    - Influence of permanence should be more important in the dynamic presentation condition.
3. Collaboration
    - Collaboration has a positive effect on learning, regarding both retention and inference. In addition, due to the "grounding effect" we expect a stronger impact on inference.
    - Perceived cognitive load should be lower in the collaboration condition.
    - Time for discussion should be higher in the collaboration condition.
    - Certitude levels should be higher in the collaboration condition.

Method (short summary)

Population: 160 students. All have been tested to check if they were novices (show lack of domain knowledge used in the material)

1. Material:
    - Pedagogical material is two different multimedia contents (geology and astronomy), each one in two versions. For the dynamic condition there are 12 animations, for the static conditions 12 static pictures

- Contents of pedagogical material: "Transit of Venus" made with VRML, "Ocean and mountain building" made with Flash
- These media were integrated in Authorware (to take measures and to ensure a consistent interface)

2. Procedure (summary)
    - Pretest (5 questions)
    - Introduction (briefing)
    - For solo condition: paper folding and Corsi visio-spatial tests
    - Test with material
    - Cognitive load test (NASA-TLX)
    - Post-test (17 questions)
3. Measured dependant variables:
    - Number of correct answers in a retention questionnaire.
    - Number of correct answers in an inference questionnaire.
    - Level of response certitudes in both questionnaires.
    - Subject cognitive load scores (measures with the NASA-TLX test)
    - Paper-folding test score
    - Visual span test score (Corsi)
    - Time (seconds) and number of vignette use in the "permanent condition" permanence.
    - Reflection time between presentations (seconds).

Review question

- What is the relation between ***independent variable*** and ***condition***?
- Why is randomization important?

- Define the experimentation effect.

Case study assignment

1. Please download:

   Rebetez, C. (2006). Control and collaboration in multimedia learning: is there a split-interaction? Master Thesis, School of Psychology and Education, University of Geneva.

   http://tecfa.unige.ch/perso/staf/rebetez/blog/wp-content/files/ThesisProject_Rebetez.pdf

2. Write a summary of this master thesis like in the example presented above

9.3 Quasi-experimental designs

It is difficult to carry out experiments in real settings, e.g. in schools. However, there exist so-called **quasi-experimental** designs. These are inspired by experimental design principles (pre- and post tests, and control groups). The advantage of these designs is that they can be led in non-experimental situations, i.e. in "real" contexts and they can be used when true experimental treatments may become too “heavy”, i.e. involve more than 2-3 well defined treatment variables.

The disadvantages of quasi-experimental situations relate to the lack of control:

- You don’t know all possible stimuli (i.e. causes not due to experimental conditions)
- You cannot randomize (distribute evenly other intervening unknown stimuli over the groups)
- You may lack enough subjects

Nevertheless, quasi-experimental research can help to test all sorts of “threats” from variables that you cannot control. These are called **threats to internal validity** (see below)

In education, quasi-experimental designs are particularly popular in evaluation research and in organizational innovation studies. Knowledge about this design also can help to improve questionnaire design for survey research (think about control variables to test alternative hypothesis)

As in experimental research, there also exist several different quasi-experimental research designs. Some are easier to conduct, but they will lead to less solid (valid) results. Let's now examine a few.

9.3.1 Interrupted time series design

Here is a schema of the interrupted time series design that attempts to control the effect of possible other events (treatments) on a single experimental group.

O1	O2	O3	O4	X	O5	O6	O7	O8

Figure 53: Interrupted time series design

The advantages of this design are that you can control (natural) trends somewhat. I.e. when you observe or introduce a treatment, e.g. a pedagogical reform, you may not really be sure that reform features themselves had any effect or if it was something else, like a general trend in the abilities of the student population.

The problems with this design are the following: You can't control external simultaneous events (X2 that happen at the same time as X_1).

Example concerning the effect of ICT-based pedagogies in the classroom: ICT-based pedagogies that you study may have been introduced together with other pedagogical innovations. So which one does have an effect on overall performance, ICT or the other innovations?

There exist also some practical difficulties: Sometimes it is not possible to obtain data for past years. Sometimes you don't have the time wait for long enough (your research ends too early and decision makers never want wait for long-term results).

Example: ICT-based pedagogies often claim to improve meta-cognitive skills. Do you have tests for year-1, year-2, year-3? Can you wait for year+3? Could you test the same population when they reach university or jobs where meta-cognitive skills matter more?

Examples of time series

Now let us have an informal look at some **time series patterns**, i.e. measures that evolve over time and that can corroborate or invalidate hypothesis about an intervention **X**.

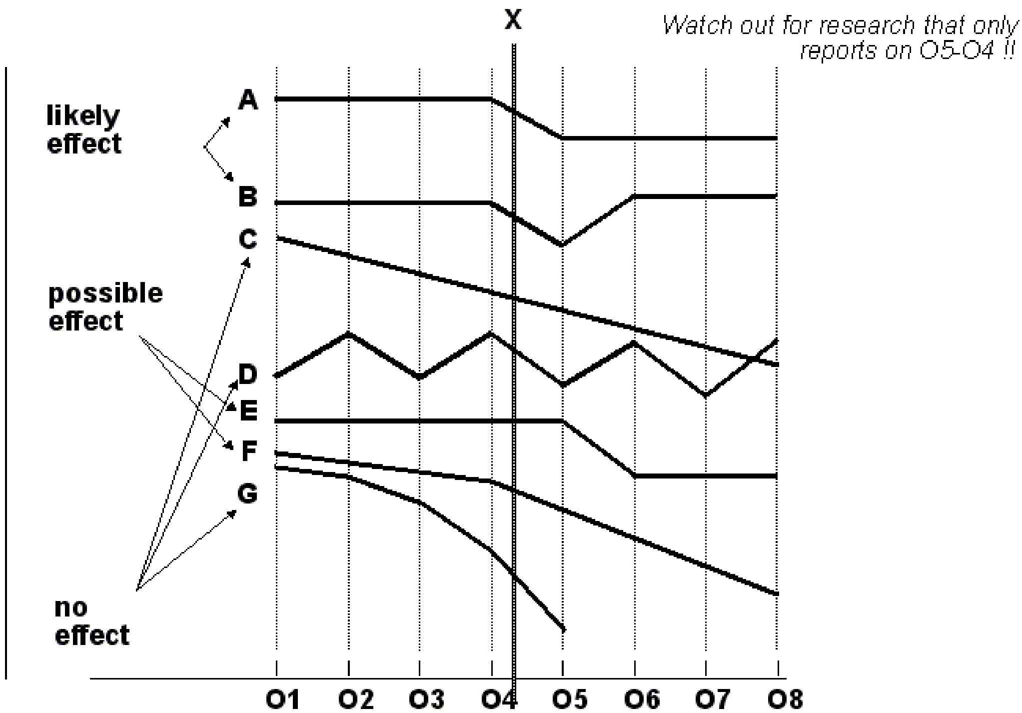


Figure 54:Interrupted time series examples

O1, O2, etc. are observation data (e.g. yearly). X is the treatment (intervention)

1. A. a statistical effect is likely
   - Example: *Student's dropout rates are lower since we added forums to the e-learning content server.*
   - However, you still have to be careful when interpreting: you do not know if there was ***another intervention*** at the same time.
2. B. Likely Straw fire effect
   - Example: *Teaching has improved after we introduced X. But then, things went back to normal*

- Therefore, there is an effect, but after a while, the cause "wears out". E.g. the typical motivation boost from ICT introduction in the curriculum may not last

3. C. Natural trend (unlikely effect)
    - You can control this error by looking beyond O4 and O5!
4. D. Confusion between cycle effects and intervention
    - Example: *Government introduced measures to fight unemployment, but you do not know if they only "surf" on a natural business cycle. Control this by looking at the whole time series.*
5. E. Delay effect
    - Example: *High investments in education and its effect on economic growth* (may take decades to take effect)
6. F. Trend acceleration effect,
    - Difficult to discriminate from G. I.e. there is some change in the curve, but it may just be a variant of exponential natural evolution.
7. G. Natural exponential evolution
    - Same as (C).

9.3.2 Threats to internal validity

The big question you should ask yourself repeatedly: ***What other variables could influence our experiments***? Campbell and Stanley (1963) created an initial typology of threats for which you have to watch out:

Type of threat	Definition and example

history	Another event than X happens between measures. Example: ICT introduction happened at the same time as introduction of project-based teaching.
maturation	The object changed “naturally” between measures Example: Did this course change your awareness of methodology or was it simply the fact that you started working on your master thesis.
testing	The measure had an effect on the object Example: Your pre-intervention interviews had an effect on people (e.g. teachers changed behavior before you invited them to training sessions)
instrumentation	Method use to measure has changed Example: Reading skills are defined differently. E.g. newer tests favor text understanding.
statistical regression	Differences would have evened out naturally Example: School introduces new disciplinary measures after kids beat up a teacher. Maybe next year such events wouldn’t have happened without any intervention.
(auto) selection	Subjects auto-select for treatment Example: You introduce ICT-based new pedagogies and results are really good (Maybe only good teachers did participate in these experiments).

mortality	Subjects are not the same Example: A school introduces special measures to motivate "difficult kids". After 2-3 years drop-out rates improve. Maybe the school is situated in an area that shows rapid socio-demographic change (different people).
interaction with selection	Combinatory effects example: the control group shows a different maturation
directional ambiguity	Is the effect due to the treatment or to different subjects? Example: Do workers show better output in "flat-hierarchy" / participatory / ICT-supported organization or do such organizations attract more active and efficient people?
Diffusion or treatment imitation	Example: An academic unit promotes modern blended learning and attracts good students from a wide geographic area. A control unit also may profit from this effect.
Compensatory egalization	The control groups observes the experimental group Example: Subjects who don’t receive treatment, react by changing their behavior

Table 32: Threats to internal validity

A good rule is always to think and to look for alternative explanations that could explain a phenomenon. However, good research designs also can help producing valid research. Let us now have a look at some designs that attempt to control such threats to internal validity.

9.3.3 Non-equivalent control group design

This design adopts comparisons between two similar (but not equivalent) control groups. The advantage of this design is that it is good at detecting possible influence of other causes

O_1	X	O_2	**experimental group**
O_3		O_4	**control group**

Figure 55: Non-equivalent control group design

If O_2 - O_1 is similar to O_4 - O_3,
we can reject the hypothesis that O_2 - O*1* is due to X, else we can corroborate the experimental effect of X.

Possible problems and disadvantages of this design:

- Bad control of natural tendencies as discussed in the interrupted time-series design.
- Finding equivalent groups is not easy in some “real” contexts.
- You also may encounter interaction effects between groups, e.g. imitation. We shall discuss this just below.

This non-equivalent-control group design is just one kind of control design. Sometimes it is possible to use randomized control designs (as discussed in the section on experiments). We also can create two or three factor designs that can test interaction of independent variables (factors). Design and analysis of such more complex designs is outside the scope of this introduction.

9.3.4 Experimentation and imitation effects

Here is an example of an imitation effect. In a degree program, we introduce a learning management system in one course. We then look at three effects: cost, student satisfaction and respect of deadlines by comparing them to a similar course taught by another teacher.

	Course A introduces ICT in the classroom	**Course B doesn't**	
Effect 1:costs	augment	stable	compare results horizontally
E 2: student satisfaction	augments	augments	
E 3: deadlines respected	better	stable	

Review question

Why could student satisfaction improve also for students of course B?

9.3.5 Comparative time series

One of the most powerful quasi-experimental research designs uses comparative time series. This design is a combination of the interrupted time series design with the non-equivalent control group design we presented above.

O	O	O	O	X	O	O	O	O
O	O	O	O		O	O	O	O

Figure 56: Comparative time series

This is design is good at controlling many validity threats.

1. Compare between groups (situations) to control for other inventing variables.
2. Make series of pre- and post observations (tests) to control for natural trends and straw fire effects.

The difficulties of this design are practical. It is not easy (and sometimes impossible) to:

1. find comparable groups,
2. find groups with more than just one or a few cases,
3. find data (in particular past and future data),
4. control simultaneous interventions at point X.

9.3.6 Validity in quasi-experimental design

Let's now generalize a little bit our discussion and discuss the causality issue we already addressed somewhat in the chapter on empirical research principles.

There exist four kinds of validity according to Stanley et al.:

Validity type	

Internal validity	concerns your research design • You have to show that postulated causes are "real" (as discussed before) and that alternative explanations are wrong. This is the most important validity type.
External validity	Can you generalize? • This is not easy because you may not be aware of "helpful" variables, e.g. the "good teacher" you worked with or the fact that things were much easier in your private school.... • How can you provide evidence that your successful ICT experiment will be successful in other similar situations, or situations not that similar?
Statistical validity	... are your statistical relations significant ? • This not too difficult for simple analysis. Make sure to use the right statistics and to believe them (see the chapter on quantitative data analysis)
Construction validity	...are your operationalizations sound? • Did you get your dimensions right? • Do your indicators really measure what you want to know?

Table 33: Typology of validity (Stanley et al.)

Important: This typology is also useful for other settings, e.g. structured qualitative analysis or statistical designs. In most other empirical research designs, you also **must** address these issues.

9.3.7 Quasi-experimental thesis example

We shall again present a typical master thesis in educational technology here.

Example 41. Scripting Strategies In CSCL Environments

> Notari, Michele (2003). Scripting Strategies In Computer Supported Collaborative (CSCL) Learning Environments, Master Thesis, MSc MALTT (Master of Science in Learning and Teaching Technologies), TECFA, University of Geneva. http://tecfa.unige.ch/perso/staf/notari/thesispage.html

This master thesis studies the design and the effects of ICT-supported activity-based pedagogies in a normal classroom setting. The population was biology classes at high-school level and various subject matters.

Three research questions were formulated as 'working hypotheses':

1. The use of a *Swiki* as collaborative editing tool *causes no technical* and comprehensive problems (after a short introduction) for high school students without experience in collaborative editing but with some knowledge of the use of a common text-editing software and the research of information in the Web.
2. *[Pedagogical] scripting which induces students to compare and comment on the work of the whole learning community* (using a collaborative editing tool) *leads to better learning performance* (as assessed by pre- and post-testing) *than a script leading students to work without such a tool and with little advice or / and opportunity to make comments and compare* their work with the learning community.
3. The *quality* of the product of the working groups is *better* (longer and more detailed) when students are induced to compare and comment on their work (with a collaborative editing tool) during the learning unit.

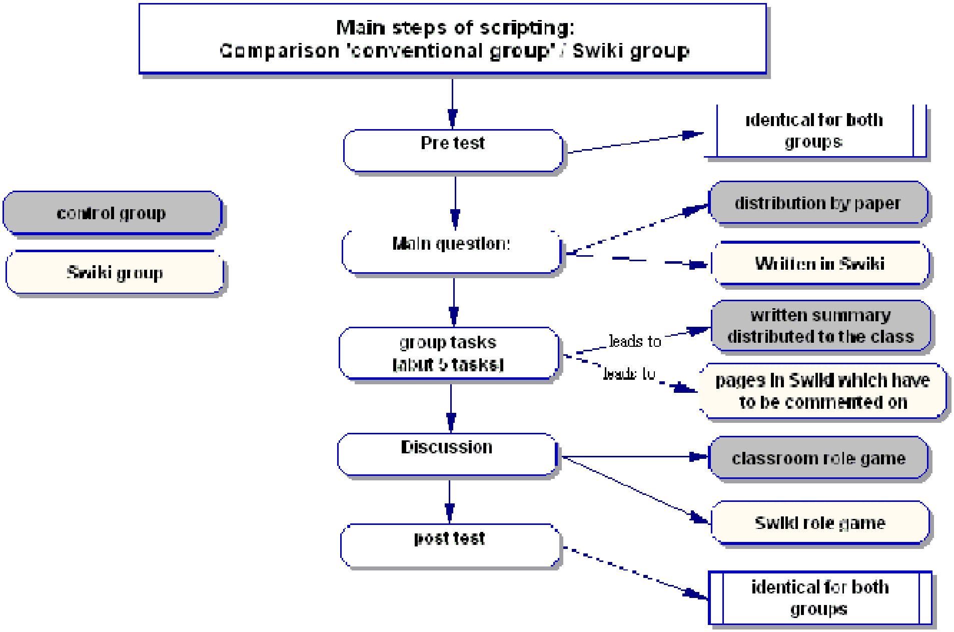
Method (extracts from the thesis)

- The whole research took place in a normal curricular class environment. The classes were not aware of a special learning situation and a deeper evaluation of the output they produced.
- We tried to embed the scenarios in an everyday teaching situation and supposed students to have the same motivational state as in other lessons.
- To collect data we used questionnaires, observed students while working, and for one set-up we asked students to write three tests.
- Of course, the students asked about the purposes of the tests. We tried to motivate them to perform as well as they could without telling them the real reason of the tests.

Remarks:

- This master thesis concerns several quasi-experiments, all in real-world settings. Below we will show and example.
- Several explaining variables intervene in the example below (the procedure as whole was evaluated, and not variables as defined by experimentalism).

A sample experiment from Notari's thesis:



In this design experiment, the teacher used two different classes. In one class, the Swiki too was used, in the other it wasn't. Different measures to compare the effects were used: Objective data (student productions), grades and questionnaires.

Let us now look into so-called statistical designs, an approach that is typically used in survey research.

9.4 Statistical designs

Statistical designs are conceptually related to experimental designs in some ways. Statistical designs formulate laws, i.e. there is no interest in individual cases (unless something goes wrong). The advantage of this design is that one can test quite a lot of laws (hypothesis) with statistical data. Such analysis is often called ***correlational***, since you attempt to show statistical relationships between variables.

Such designs are based on prior theoretical reasoning, because

1. Measures, i.e. questionnaires in most cases, are not all that reliable,
   - what people tell may not be what they do,
   - what you ask may not measure what you want to observe ...
2. There is a statistical over-determination,
   - You can find correlations between a lot of things, but correlations do not necessarily causality as we did discuss before
3. You cannot get an "inductive picture" by asking a few dozen closed questions.

The dominant research design is conducted in a top-down fashion, including a dose of Popper’s doctrine of critical rationalism, also called falsificationism:

1. You start by formulating hypothesis (models that contain measurable variables and relations)
2. You measure the variables (e.g. with a questionnaire and/or a test)
3. You then test relations with statistical tools
4. You then test alternative hypothesis according to the same principle, i.e. you also should provide evidence that your hypothesis cannot be falsified.

The most popular statistical design in educational technology is so-called survey research and we shall introduce it now.

9.4.1 Introduction to survey research

We shall come back to survey research in chapter 12 and we just shortly present the structure of typical research plan here. A typical research plan looks like this:

1. Literature review leading to general research questions and/or analysis frameworks 2. You may use qualitative methodology in a pilot study to investigate new areas of study and cite it here. 3. Definition of hypothesis 4. Operationalization of hypothesis, e.g. definition of scales and related questionnaire items 5. Definition of the mother population 6. Sampling strategies 7. Identification of analysis methods

Table 34: Research plan elements for survey research

Implementation of this kind of research (besides the writing) is conducted in five steps:

1. Questionnaire building (preferably with input from published scales) 2. Test of the questionnaire with 2-3 subjects 3. Survey (interviews, either face to face, on-line or written) 4. Coding and data verification + scale construction 5. Statistical analysis of the data

Table 35: Implementation of survey research

Advise for writing it up:

1. Separate presentation of results from discussion.

2. Always compare your results to theory
3. Make sure to keep your text readable, .e.g. put results in tables.

9.4.2 Levels of reasoning and threats to validity

Let us recall from chapter 3, that there is a gap between theoretical reasoning and empirical data. As a researcher you must be able to formulate general research questions at a general level and link them trough operationalization to precise indicators and indices at the data level. You also must understand that interpretation of statistical data is tricky. It requires reasoning and knowledge about threats to internal validity.

Reasoning level	**Variables**	**Cases**	**Relations (causes)**
theoretical	concept /category	depends on the scope of your theory	Are expressed verbally in a high level language
hypothesis	variables and values (attributes)	mother population(students, schools,)	Are clearly stated causalities or co-occurrences
operationalization	dimensions and indicators	good enough sampling	Are statistical relations between statistical variables (e.g. composite scales, socio-demographic
measure	observed indicators (e.g. survey questions)	subjects in the sample	

statistics	measures (e.g. response items to questions)scales (composite measures)	Data (numeric variables)	variables)

Table 36: Level of reasoning in a statistical approach

Typology of internal validity errors

Error of type 1: You believe that a statistical relation is meaningful, because there is a good correlation between two variables, but "in reality" it doesn't exist. Maybe the real cause is a variable that influences both. See the section on *Validity (truth) and causality* on page 89 again.

- In complicated words : You wrongly reject the null hypothesis (no link between variables)

Error of type 2: you believe that a relation does not exist ... but "in reality" it does.

- E.g., you compute a correlation coefficient, results show that is very weak or not significant. The relation may still exist. Maybe the relation was non-linear, or maybe another variable caused an interaction effect ...
- With more complicated words: Your wrongly accept the null hypothesis

With statistical methods, you can test alternative hypothesis and therefore diminish the risks of internal validity errors. In addition, as always: Think!

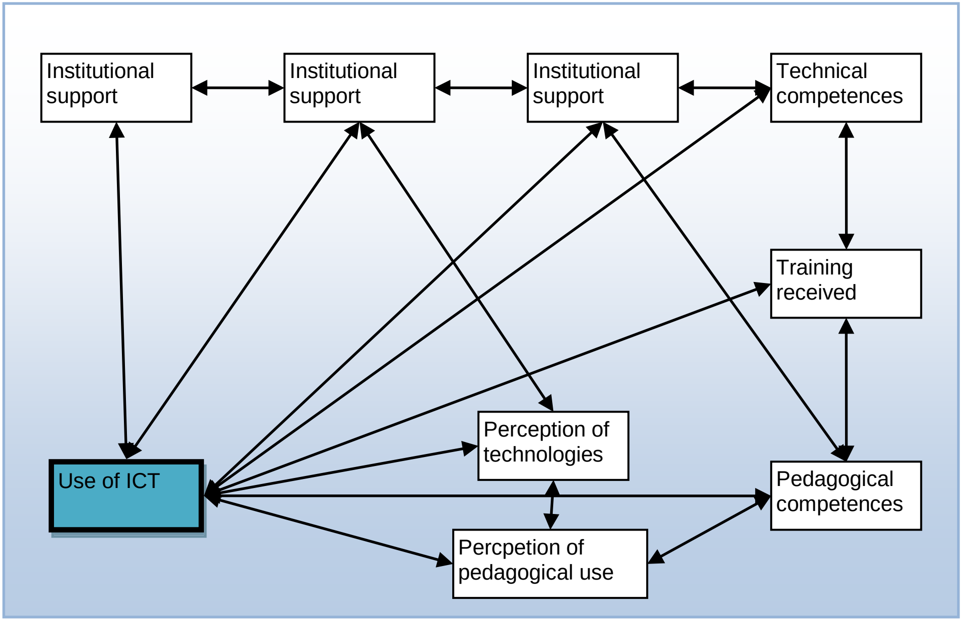
9.4.3 Survey research examples

See also the chapters on quantitative data acquisition and analysis for additional examples.

Example 42. Factors that favor teacher's use of ICT

Source: Luis Gonzalez, Master thesis in educational technology (2004):

Main goal of this thesis that we already introduced earlier was to "Study factors that favor teacher's use of ICT". The author defines 8 factors and also postulates a few relationships among them:



Below we quote from the thesis (translated):

My principal hypothesis postulates the existence of a correlation between the following factors and teacher's use of ICT

- The *type of support* offered by the institutions
- Teacher's *pedagogical competences*
- Teacher's *technical competences*
- *ICT training* received by teachers

- Teacher's feeling of self-efficacy
- Teacher's *perception of technology*
- Teacher's *perception of ICT's pedagogical usefulness*
- Teacher's *digitalization* (rationalization) practices with ICT

Secondary hypothesis are:

- Teacher's perception of ICT's pedagogical usefulness is correlated with pedagogical competences
- Teacher's perception of technology is correlated with perception of ICT's pedagogical usefulness
- Teacher's digitalization (rationalization) practices with ICT is correlated perception of technology
- ICT training received by teachers is correlation with teacher's pedagogical competences and technical competences
- Teacher's feeling of self-efficacy is correlated with teacher's pedagogical competences and technical competences
- Teacher's digitalization (rationalization) practices with ICT is correlated with feeling of self-efficacy

Sampling method

- Representative sample of future primary teachers (students), N = 48
- Non-representative sample of primary teacher's, N = 38
  - All teachers with an email address in Geneva were contacted, auto-selection (!)
  - Note: the questionnaire was very long, some teachers who started doing it, dropped out after a while
- This sort of sampling is ok for a pilot study or a little master thesis.

Questionnaire design

Definition of each "conceptual domain" (see above) as well as the question sets and scales have been adapted from the literature if possible.

Data collection

Data was collected with an on-line questionnaire tool (using the ESP program)

Purification of the instrument

For each item set, a factor analysis was performed and indicators were constructed according to auto-correlation of items (typically the first 2-3 factors were used). Notice: If you used fully tested published scales, you don't need to do this!

Example 43. perception of pedagogical ICT use

In the questionnaire, this concept is measured by two *question sets* (scales).

Perception of pedagogical use of ICT is measures with two series of questions: a first one asks their attitudes with respect to "official statements" about the use of computational resources in education. A second series measures usefulness attributed to various kinds of computer-supported resources.

Both question sets use the same kind of response items: 1=totally disagree, 2=mostly disagree, 3=mostly agree, and 4= fully agree.

From these questions, three indices were produced:

- Var_PUP1 – Degree of importance attributed to collaboration tools
- Var_PUP2 - Degree of importance attributed to student-student communication tools

- Var_PUP3 – Agreement on usefulness of ICT for socio-constructivist teaching designs.

9.5 Similar comparative systems design

This design is popular in comparative public policy analysis. It can be used to compare educational systems of a few districts, states or countries. This design usually uses only very simple descriptive statistics, and often official aggregate data.

Principle:

1. Make sure to have good variance within ***operative variables,*** i.e. the set of all dependant and independent variables.
2. Make sure that no other variable shows variance (i.e. that there are no hidden control variables that may produce effects)

$$\frac{\text{variance of operative variables}}{\text{variance of control variables}} = \text{maximum}$$

Figure 57: similar comparative systems design

In more simple words, select cases that are different with respect to the variables that are of interest to your research, but otherwise similar in all other respects.

Example: Do not select a prestige school that does ICT and a normal school that does not use ICT if you want to measure the effect of ICT. Stick to either prestige schools or "normal" schools, otherwise, you cannot tell if it was use of ICT that made the difference.

Advantages and inconvenient of this method:

- Less reliability and construction validity problems

- Better control of unknown variables with respect to most different systems design.
- Worse external validity (impossibility to generalize)
- Weak or no statistical testing. Most often researchers just compare descriptive data and cannot provide statistically significant results, since cases are too few.

9.6 Summary of theory-driven designs discussed

In this chapter, we presented some important theory-driven research designs, which we summarize in the table below with a few typical use cases. There exist other theory-driven designs, e.g. simulations, that we did not discuss.

approach	some use cases
Experimental designs	• Psycho-pedagogical investigations • User-interface design
Quasi-experimental designs	• Instructional designs (as a whole) • Social psychology • Public policy analysis • Educational reform • Organizational reform
Statistical designs	• Teaching practice • Usage patterns

Similar comparative systems designs	• Public policy analysis • Comparative education

Of course, you can combine these approaches within a research project. You also may use different designs to look at the same question in order triangulate answers.

Review questions

1. What is the main difference between an experimental and quasi-experimental design?
2. How does the quasi-experimental design relate to survey research?
3. List the important steps in survey research.

Review assignment

1. Please sketch out a quasi-experimental design that could answer the following question:
    - In a distance-teaching program, does good tutoring support diminish satisfaction with the study program and the dropout rate of students?
2. Formulate a research hypothesis that relates on-line student participation to tutoring support. For each of the two variables, design a set of four survey questions. Justify each question and the response items.
    - Tip: You may try to find survey instruments in the literature.

Review case study

1. Download Maarten van Wesel, Anouk Prop (2008). Comparing students' perceptions of paper-based and electronic portfolios, Canadian Journal of Learning and Technology, 34 (3). http://www.cjlt.ca/index.php/cjlt/article/view/505
2. Identify the central research question (Tip: Read the abstract)
3. Explain how "self-reflection" was measured.
4. Summarize the results.

10 Theory-finding research designs

This chapter will address general issues about theory-finding research designs. We will not discuss precise approaches in detail here for space reasons. We also should mention that some principles that apply to theory-testing approaches also could apply in theory-finding research designs. E.g., validity is always an issue.

Learning goals

1. Familiarize with names of different kinds of qualitative methodology
2. Understand the typical research process (which is very different from a theory-testing approach)
3. Be able to differentiate use of qualitative methods within a rather quantitative design and within a fully qualitative design

Most often (but not exclusively) theory-finding research designs use a ***qualitative approach*** whereas theory-testing designs are quantitative. However, this is just a general observation, not a necessity. You also could design an exploratory quantitative research design or conduct qualitative research that is strongly theory driven. However, in this text, we only introduce ***qualitative*** theory-finding approaches and this is why shall focus on qualitative research methodology in the following sections.

Design science most often uses a rather qualitative research approach, but since its purpose is different, we will introduce it in a different chapter.

10.1 The concept of qualitative methodology

What is qualitative research and qualitative methodology? There exist two frequent stereotypes: “Qualitative methodology” is often synonym of “simple description” or “interview analysis”. Such a view is held by people who don't understand the difference between a method-as-technique and a method-as-approach.

In reality, there exists a huge pool of design approaches and methods. Qualitative research designs are usually more difficult to create than quantitative designs. Since a typical humanities student is afraid of statistics, he/she may think that qualitative research is easier, but it is not as we shall see later.

In the table below, we present a few examples of qualitative approaches (there are more!)

Families of approaches	**Names of particular approaches**	**Description**
investigative journalism	case description	explanatory story
collaborative research	action research	practical experimentation with a social goal
	participatory observation	analytic immersion

	collaborative research	participatory design of something
Design sciences	See the chapter on design-oriented research designs	
language	text analysis	analysis of relations between elements (grammars)
	dialogue analysis	organization and structure of dialogue
observation in context	anthropology	structured and non-structured observation
	«field research»	(same, but less in depth, more formal)
interpretism	hermeneutics	human activity as "text"
	phenomenology	empathy of «Lebenswelt»
	symbolic interactionism	symbolic interactions between actors

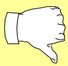
Table 37: Schools of qualitative research approaches

In this chapter, we shall not try to provide you with an overview of various schools of thought, but rather focus on some general principles that are shared by most of these approaches. Qualitative research is usually carried out in cycles as we shall see below. Its most common features are the following:

1. Research must be *anchored* in «rich» descriptions
2. Each theoretical *proposition* must be anchored in *observations*
3. The researcher plays a *delicate role*. He (most) always is visible and even can play an active role, i.e. attempt to transform reality.
4. Most modern research approaches also insist on reliability and validity issues.

Table 38: Characteristics of qualitative research

Regarding the role of theory, there exist two very different doctrines. Each has advantages and drawbacks.

Little theory (no theoretical grounding of research questions and analysis grids)		**A lot of theory (theoretical grounding of research questions and concepts)**	
	openness of mind		linking to other research
			closeness of mind
	allows to tackle new subjects		integration of your results with other knowledge
	tendency to collect too much data		tendency to ignore phenomena

	difficult comparison with other work		easier generalization
	non-explicit preconceptions		explicit preconceptions (therefore controllable

Table 39: Role of theory in qualitative research: little vs. a lot

Unless you are as a student exposed to good training in ethnography, we strongly suggest that you base your research on a **lot of theory**. It is safer and simpler. The general logic of a theory-driven qualitative is design is quite similar to a quantitative one as you can see in the figure below.

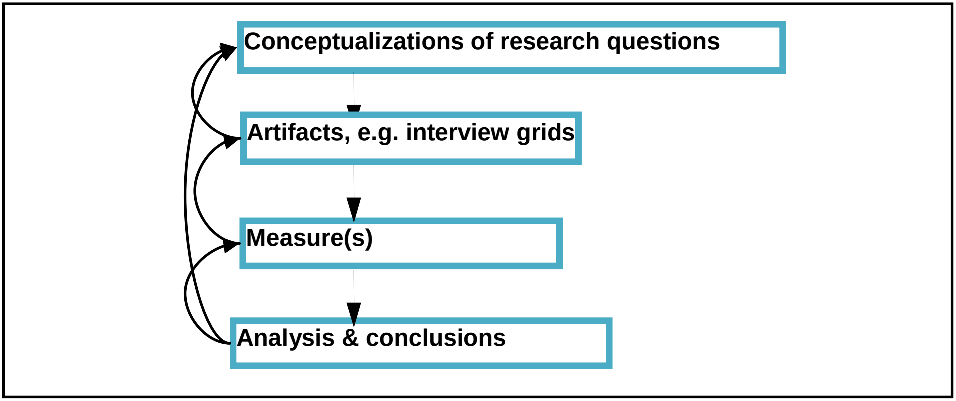


Figure 58 The qualitative research process

For each research question that is usually formulated as an open question, you firstly should identify its major concepts and then think hard how you could observe data to measure these. To do so, you may have to use or create analysis grids and develop instruments like semi-structured interviews guides.

Let us now introduce some very general principles about qualitative data analysis.

10.2 The role of data in structured qualitative research

In this text, we present a modern, structured view of qualitative data analysis designs. Dey (1993:31) formulates the **description - classification - connection** principle that you will find in most modern qualitative designs. For ***each research question***, the qualitative researcher attempts to find "rich" and "deep" data, .e.g. through interviews, field observations or the study of documents. These are called ***descriptions***. These data then need to be structured, i.e. major "variables" must be identified. This is called ***classification*** or ***coding***. Once data is coded, it then can be analyzed in a more systematic way. This step is sometimes called "***connection***" since data must be connected to other data and to theory.

Remark: We are aware that some historical and hermeneutical approaches do not work that way, but we will not discuss these since they are not very popular in educational technology research.

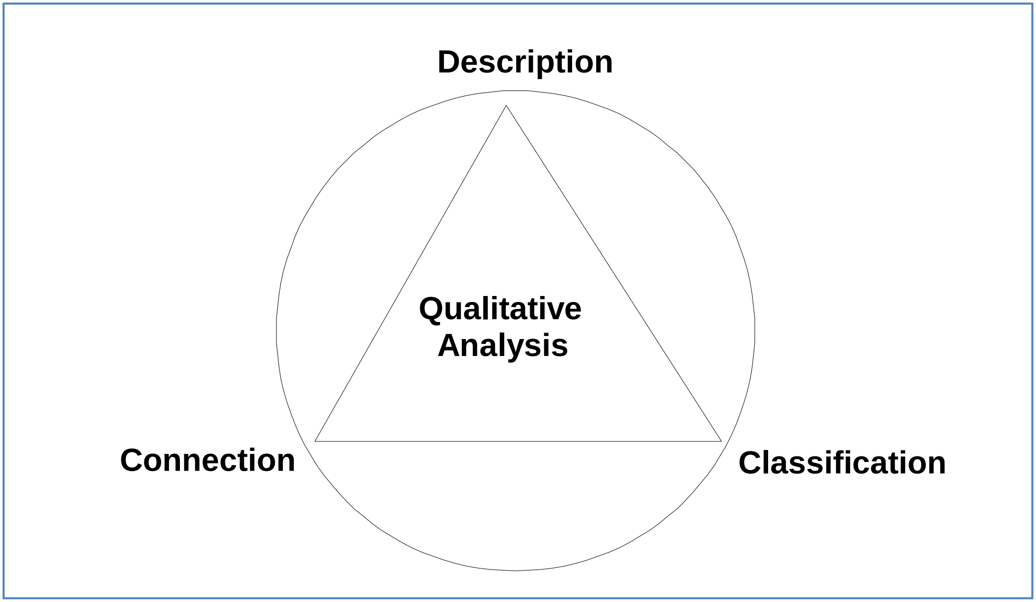


Figure 59: The description-classification-connection triangle

Let us list again at the three important elements of qualitative approaches:

1. ***Description:*** each qualitative analysis relies on «rich» data. Otherwise, you cannot interpret the full meaning of an observation!
2. ***Classification***: data structuring and reduction according to principled coding principles. The mass of qualitative data can be staggering as you may discover.
3. ***Connection***: Identification of relationships between concepts in order to make relations (and other structures) appear!

In *Figure 60: Circularity of the qualitative theory-finding approach,* we present the dynamic vision of the same principle, also from Dey (1993:53). It shows the *circularity* of a qualitative approach: After (or even during) classifying and connecting data you will have to look at data again or even go back to the field produce new data. At this stage, it is also possible that new research questions will pop up and that you could not anticipate in your research plan.

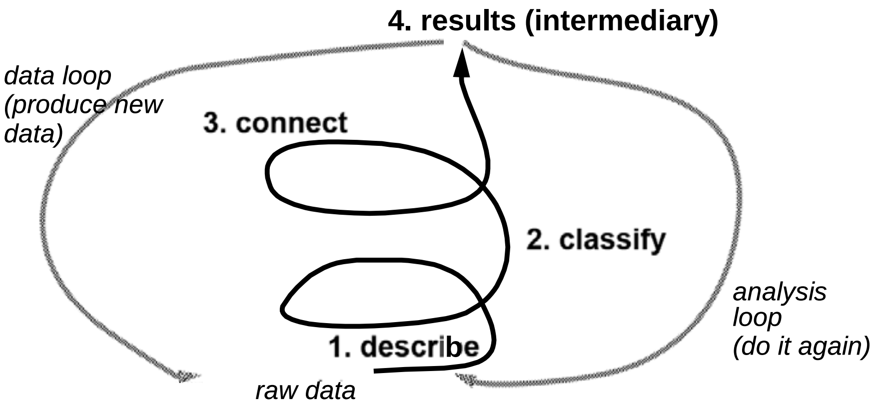


Figure 60: Circularity of the qualitative theory-finding approach

As we mentioned before, data reduction (classification) and analysis (connections) can be quite a challenge. As we shall see in the chapter on qualitative data analysis, modern qualitative researchers:

- produce a lot of drawings
- use matrices
- use (sometimes) quantitative data exploration techniques

Miles & Huberman (1994:10) illustrate the same principle with a time line and a transition diagram. Their view is slightly different. "Data reduction" is more or less the equivalent of "classify" and "visualization" the equivalent of "connect".

However, the fundamental principle is the same: ***Your principal difficulty is to find structure in the huge mass of data.*** In that respect, most qualitative analysis is no different from quantitative analysis.

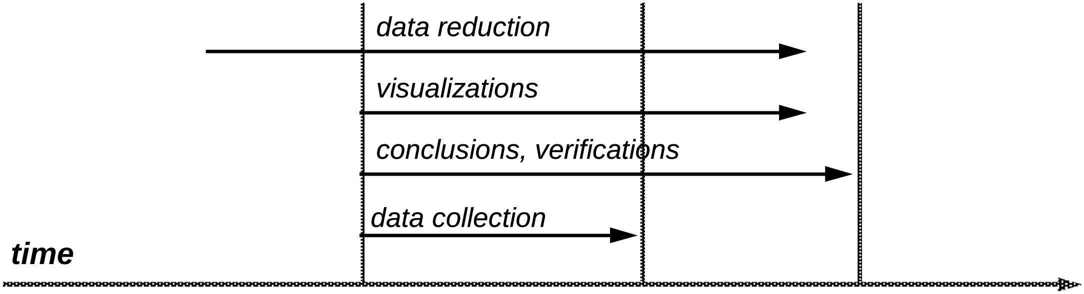


Figure 61: Timeline of qualitative research

A dynamic version of the same schema that shows revision loops that will happen is presented in “Figure 62: Transition diagram of qualitative research”. It also expresses the idea the qualitative theory-finding research is very circular in its nature.

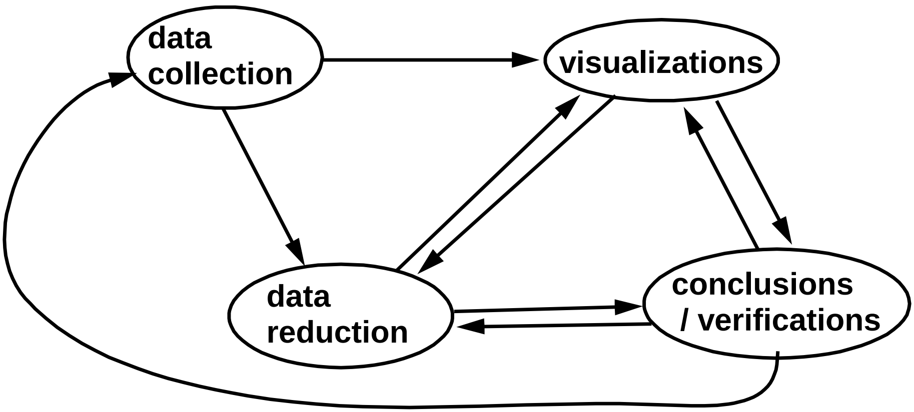


Figure 62: Transition diagram of qualitative research

Qualitative data are most frequently generated by the researcher (same as in quantitative designs). However, qualitative approaches prefer *natural* data and refer to the concepts of *meaning* and *process* (the last focus is shared with systems analysis and some design research).

Here are some elements that show the distinction between typical quantitative and qualitative research:

Types of approach	
Quantitative approaches search for:	**Qualitative approaches search for:**
Social or individual structures: *laws*	Social construction: *rules and languages* as they are *perceived* and *created* by subjects
Observable facts	*Units of meaning*, interpretations by people, e.g. subjective meaning and goals of an action.
Abstract behavior and attitudes or experimental situations	Actions and thoughts *in context*
Standardized macro-observations(applied to a population)	*Thick* micro-observations (i.e. few «settings», small groups, etc.)

Table 40: Qualitative vs. Quantitative research aims

10.3 Example of a qualitative MA thesis

Example 44. Master thesis of M-A Thibaut

Title: Le cartable électronique®. Un Environnement Numérique de Travail en construction. Pratiques éducatives et mutualisation, Master Thesis, TECFA, University of Geneva, 2004.

Research questions

1. Do teachers using the electronic learning environment stabilize pedagogical strategies?
   - Do they use these tools only when their old teaching and classroom management habits are not disturbed?
   - Can we observe the emergence of collaborative learning scenarios?
2. Given the importance of the perception usefulness in innovation studies: What benefits of using such an environment are identified by the teachers?
3. In what respects can teachers share within or outside the environments?
   - What are the teacher's positions about content development within the environment?
   - What are their strategies for reuse of materials found on the Internet and within the environment?

Method:

- Eleven teachers from different schools participated in the study
- Interviews used a "story telling" or "live story" method. This method asks little direct questions, but teachers will have to talk about difficult or enriching events. Focus was on facts, practice and applications, but also included discussion about representations and attitudes.
- Interviews lasted about 40 minutes.

- The interview was completed by a questionnaire regarding the ICT infrastructure at school and at home.
- Analysis was conducted after each interview and items to be discussed in consequent interviews were added or modified.

10.4 Summary

Theory-finding research designs most often use a ***qualitative approach*** whereas theory-testing designs are rather quantitative.

You should distinguish between qualitative theory-finding ***approaches.*** Qualitative ***techniques*** also may be used by quantitative theory-testing approaches.

Review questions

1. List the three important elements that relate to data collection and analysis in qualitative approaches
2. State two important differences between quantitative theory-testing and qualitative theory finding approaches.

Review case study

1. Download Dennis Dicks, Cindy Ives (2008), Instructional designers at work: A study of how designers design, *Canadian Journal of Learning and Technology*, 34(2). http://www.cjlt.ca/index.php/cjlt/article/view/495/226
2. Identify the research question(s)

3. Identify the name of the qualitative method used and identify its main characteristics.
4. Shortly explain the stages of this research.
5. What is the main result of this study?

11 Design-oriented research designs

In this chapter, we will introduce the design science perspective. Educational technology as design science uses mostly qualitative theory finding methodologies, but also may rely on quantitative approaches, such as experiments or surveys. The difference with respect to theory-testing and theory-finding approaches is the important role of the design, i.e. design rules and artifacts, as you shall see.

Learning goals

- Understand the aims of design research
- Understand the nature of the design process and the principle of traditional vs. agile participatory design
- Learn about design languages
- Understand the aims of so-called design-based research in educational technology
- Be able to conduct a simple evaluation study

Design sciences existed for a long time, e.g. in architecture and engineering, but only somewhat recently, instructional design and educational technology researchers started to make an explicit claim for the necessity of design-oriented research. A good example is the so-called design-based research movement.

Typical ingredients or steps of design research are summarized in *Figure 63: Ingredients of design research* (Pertti Järvinen, 2004)

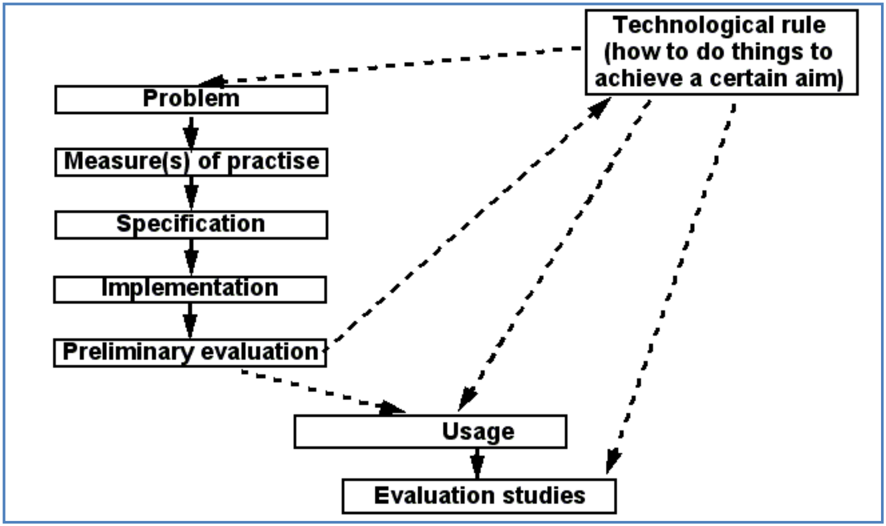


Figure 63: Ingredients of design research

Doing design-oriented research investigates at least one of the dotted lines.

11.1 Design rules

The **technological rule** (or what we call **design rules**) is a theory "on how to do things" and it can be the research's input, output, or both. Such design rules specify how to do things and are dependent on other theories (and beliefs)

Bunge (quoted by Järvinen:99) defines ***technological rule*** as *an instruction to perform a finite number of acts in a given order and with a given aim. A technological rule is defined as a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application*

Types of outcomes (artifacts, interventions) of design research

Design outcomes must use and create clear design languages. We may distinguish between the following types of ***output*** from a design research activity:

- Constructs (or concept) that form the language of a domain
- Models that are sets of propositions expressing relationships among constructs
- Methods that are a set of steps to perform a task (guidelines, algorithms)
- Instantiations that are realizations of an artifact in its environment

There exist two major types of design research

- ***Build something***: Demonstrate feasibility of an artifact or an intervention. A typical example in e-education would be a technological environment to support project-oriented teaching in advanced language education.
- ***Evaluate something:*** Development of criteria, and assessment of both artifact building and artifact usage. A typical example would the effectiveness of a better-designed learning management system.

If we combine types of output and types of design research, we will have 4*2 ways (outcomes * types) to lead interesting design research. Of course, these can be combined and usually are in a given research project.

Create new concepts	Apply new concepts
Build models	Evaluate models

Create guidelines	Evaluate guidelines
Apply guidelines to build something	Evaluate some creation

Table 41: Types of design research

Usually, it is the not the artifact (e.g. a software program) you build that is interesting, but something behind (constructs, models, methods) or around it (usage).

Design rule examples in educational technology

In educational technology, we find a variety of design levels. One example that tries to promote more systematic thinking about design is the Developing design documents (3D) model (Boot et al. 2007: 917). It includes three major dimensions:

1. stratification: Functionally different instructional and technical structures
2. degree of elaboration: conceptual, specification or implementation
3. formality: formal vs. informal

Below, we shall present a few examples of design rules (output of research) that are popular in educational technology. As you will see, design (or the essence of it in terms of design rules) can be expressed in various ways, e.g. as:

- concept map
- as list
- as UML diagram
- as formal or non-formal design language

Example 45. IMS Learning Design

IMS Learning Design (IMS LD) is a formal pedagogical standard. It is an educational modeling (or design) language to describe technology supported pedagogical scenarios that focus on learner activities. Currently, it represents the most popular formal language to describe learning designs. In IMS LD terminology, a pedagogical scenario is called a play. Major components of this design are:

- ***roles*** that are performed by learners, teachers, tutors, etc.
- ***activities***
- ***environments*** including ***services*** (e.g. a forum) and ***learning resources***
- The scenario is called ***method*** and contains in turn ***play***, ***act*** and ***role-parts***.

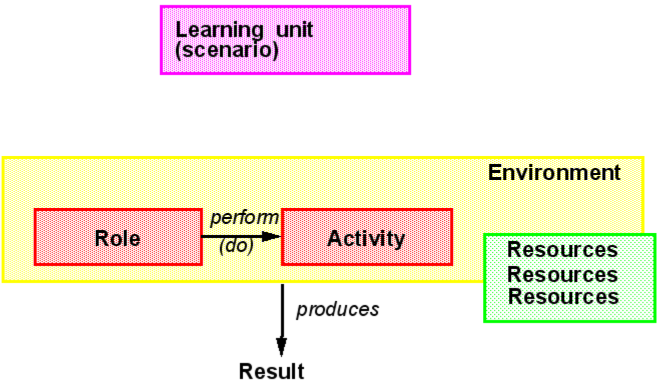


Figure 64: The nucleus of Learning Design

IMS LD is formally defined as XML markup language, but at a higher level it is specified as a [UML class diagram](#) and that we will not explain here. If you have computer science background you might be able to read it.

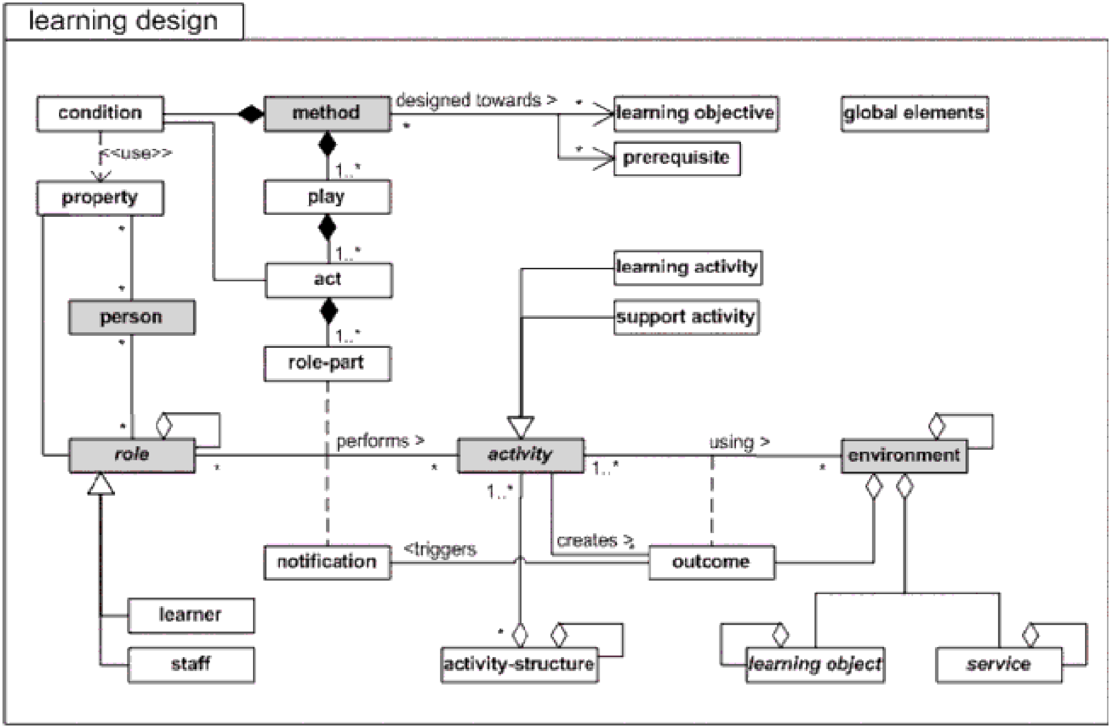


Figure 65: UML diagram of IMS Learning Design

Example 46. The MISA instructional design method

MISA is an instructional engineering method describing graphically the instructional design processes and their products, which define a learning system completely. MISA supports 35 main tasks or processes and around 150 subtasks. The method has been totally represented within the MOT knowledge editor.

A course designer works on "4 models"

1. *Knowledge* and *Skill* Representation
   DC: Design of Content (know-that *and* know-how)

2. Application of *Teaching Methods* and Approaches
   DP: Design of Pedagogical specifications
3. Specification of *Learning Materials*
   DM: Design of Materials
4. *Delivery* Planning
   DD: Design of Delivery

The 4 components split over the 6 phases lead to the 35 main tasks. Don't worry if you don't understand what these elements mean. Our point is to illustrate that many design theories split the design task into phases and modules.

Phase 1- Definition	100 Organization's Training System 102 Training Objectives 106 Present Situation 108 Reference Documents			104 Learners' properties
	Knowledge Axis	***Pedagogy Axis***	***Media Axis***	***Delivery Axis***
Phase 2 – Initial solution	210 Knowledge Model Orientation Principles ***212 Knowledge Model*** 214 Target Competencies	220 Instructional Principles ***222 Learning Event Network*** 224 Learning Unit Properties	230 Media Principles	240 Delivery Principles 242 Cost-Benefit Analysis
Phase 3 – LE architecture	***310 Learning Unit Content***	**320 Learning Scenarios** 322 Activity Properties	330 Development Infrastructure	340 Delivery Planning
Phase 4 – LE detailed Design	***410 Learning Resource Content***	420 Learning Resource Properties	430 Learning Resource List ***432 Learning Resource Models*** 434 Media Elements 436 Source Doc.	***440 Delivery Models*** 442 Actors and their resources 444 Tools and Telecommunication 446 Delivery Services
Phase 5 - Validation	540 Test Planning 542 Revision Decision Log			

Phase 6 – Delivery Plan	610 Knowledge/ Competency Management	620 Actors and Group Management	630 Learning System/Resource Management	640 Maintenance/ Quality Management

Table 42: MISA Documentation Elements – Phases and Axes

Regarding the learning scenarios (320), the graphical MOT design editor adopts the IMS Learning Design model. The IMS model we presented in UML above looks like this in MOT:

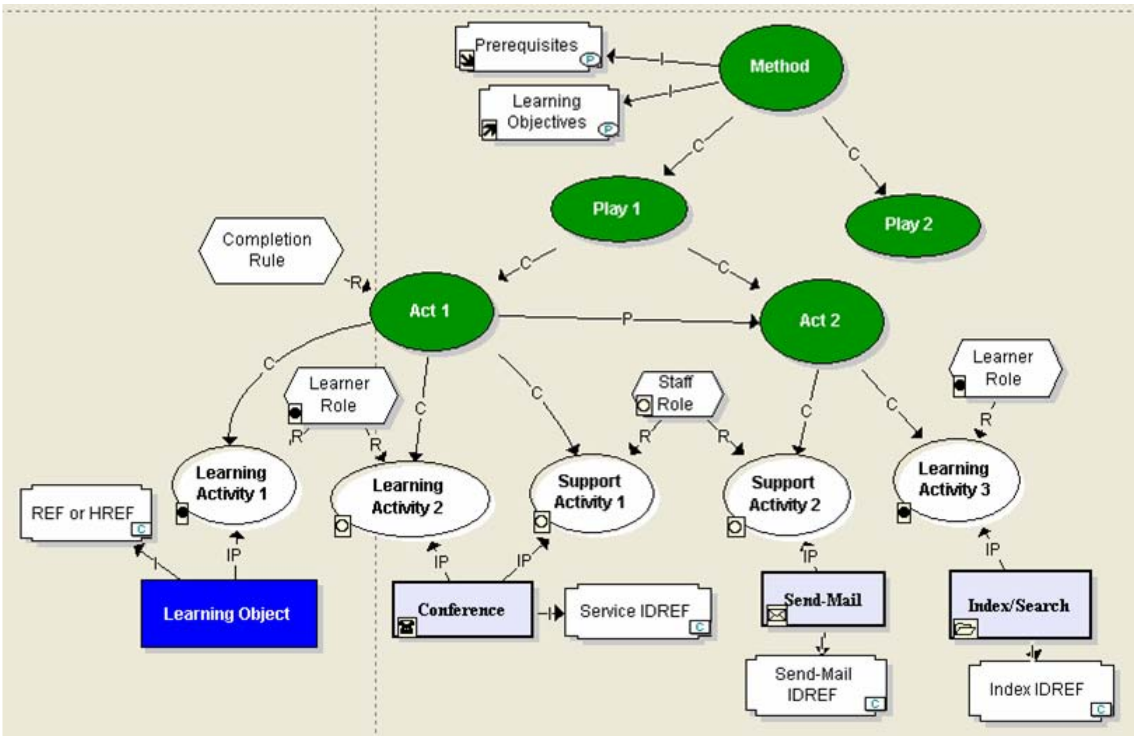


Figure 66: IMS Learning Design as MOTPlus concept map (G. Paquette and M.Léonard)

Remark: Using such methods and tools for instructional design is worth the effort if you plan to design whole courses with many students. Let us now look at instructional design models and that could be implemented with the help of such methods.

Example 47. Gagné’s 9 steps of instruction for learning

Gagné’s nine events of instruction represent a set of nine sequential rules specifying the contents of a “good” lesson (unit of learning). It is grounded in behaviorist-cognitivist theory of instruction.

1. *Gain attention,* e.g. present a good problem, a new situation, use a multimedia advertisement.
2. *Describe the goal*: e.g., state what students will be able to accomplish and how they will be able to use the knowledge; give a demonstration if appropriate.
3. Stimulate *recall of prior knowledge,* e.g. have the student engage with prior knowledge relevant to the current lesson (facts, rules, procedures or skills). Show how knowledge is connected, provide the student with a framework that helps learning and remembering. Tests can be included.
4. *Present the material* to be learned e.g. text, graphics, simulations, figures, pictures, sound, etc. Chunk information (avoid memory overload, recall information).
5. Provide *guidance for learning* e.g. presentation of content is different from instructions on how to learn. Use of different channel (e.g. side-boxes)
6. Elicit *performance "practice",* let the learner do something with the newly acquired behavior, practice skills or apply knowledge. At least use MCQ’s.
7. Provide *informative feedback* , show correctness of the trainee’s response, analyze learner’s behavior, maybe present a good (step-by-step) solution of the problem
8. *Assess* performance test, if the lesson has been learned. Also give sometimes general progress information

9. Enhance retention and *transfer*: inform the learner about similar problem situations, provide additional practice. Put the learners in a transfer situation. Maybe let the learners review the lesson.

Example 48. Learning scenario design rules expressed with UML diagrams

The Unified modeling language (UML) is the most popular design language in computer science. Many different types of design problems can be modeled. Some e-learning standards are for exampled modeled with UML diagrams. E.g., we already introduced the IMS learning design class-diagram model above.

UML also can be understood as a qualitative data analysis tool and as such, it is used in some educational technology research for describing learning scenarios. Figure 67 from the IMS LD Best Practice specification shows a diagram defining the structure of a competency-based learning activity. It defines two major alternatives: advising-then-anticipating and anticipating-then-advising.

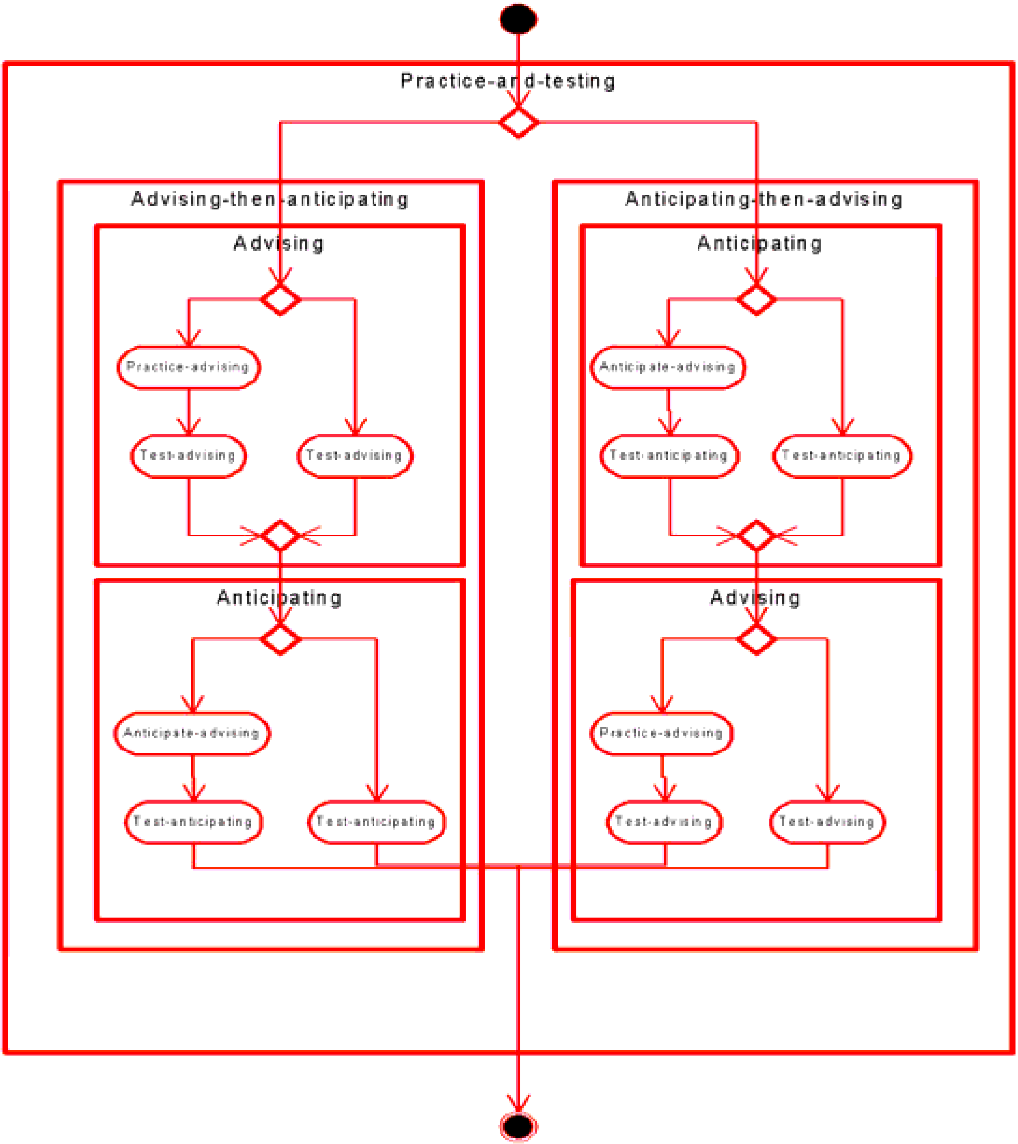


Figure 67: Activity Diagram for Competency-based learning. Source: IMS

While IMS learning design is rather a standard for describing learning designs (and therefore not research by itself), its conceptual tools are also used in research.

11.2 The design process

Modern design science is influenced by several fields, e.g. architecture or software engineering. Pertti Järvinen (2004: 103) formulated two main alternatives for the design process. You must choose between a more top-down approach (also called the waterfall model) and a more participatory and "agile" approach.

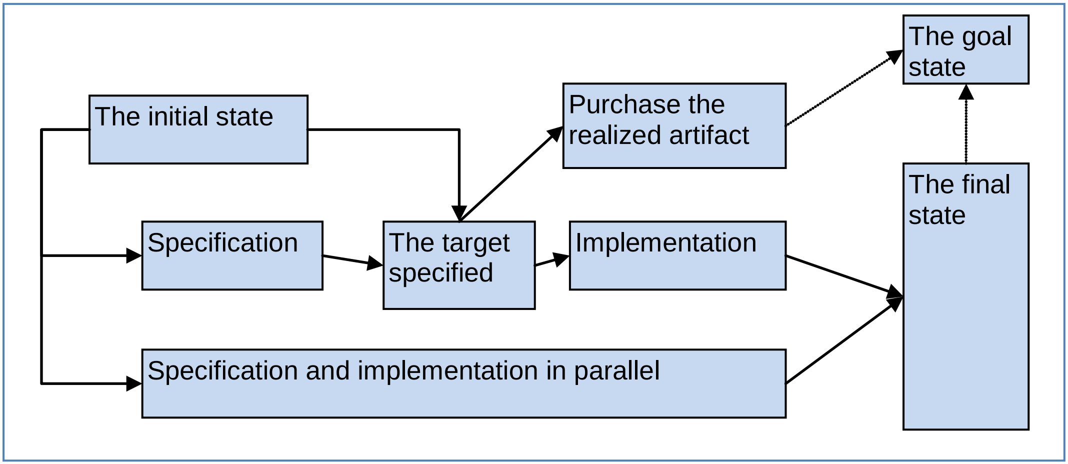


Figure 68: Alternatives concerning the building process and its outcomes

In educational technology research, one uses most often some kind of ***agile*** and ***iterative*** design method for developing new software and new designs. On the other hand, traditional instructional design theory rather uses the hierarchical "waterfall model". Let us now shortly present some "agile methods"

11.2.1 The user-entered participatory design model

User-centered design:

- involves users as much as possible so that they can influence it,
- integrates knowledge and expertise from other disciplines than just IT,
- is highly iterative so that testing can insure that design meets users' requirements.

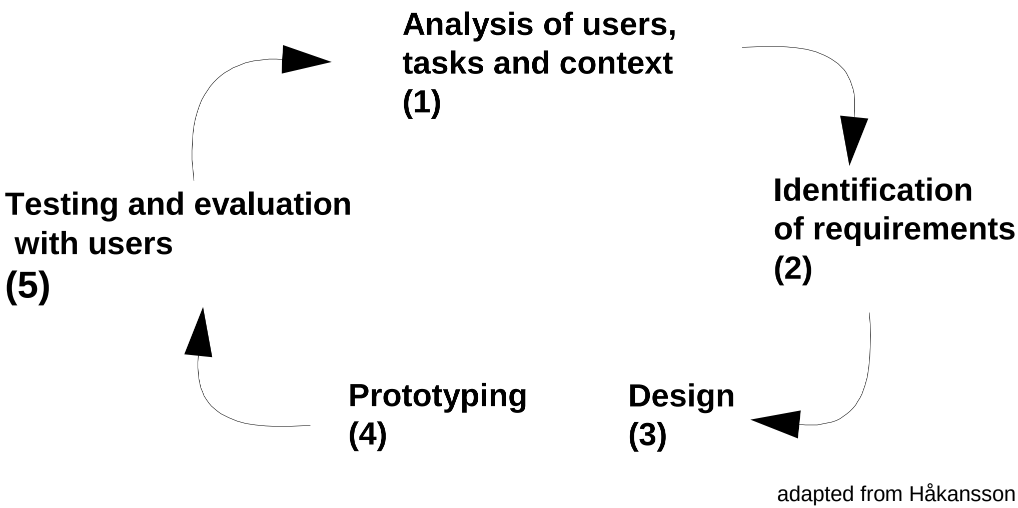


Figure 69: The participatory design model

Participatory design does **not** just mean analyzing users needs (ask them what they want and study task requirements), but it means that users ***actively*** will ***participate in all the design cycles***.

A similar model from Preece, Rogers and Sharp (2002), is shown in Figure 70 drawn by Håkansson. It shows that "design" implies building interactive artifacts.

Using and testing these artifacts will lead to reformulating the needs (requirements). Both will lead to redesign. At later stages, the instantiated artifact must be evaluated which again can lead to redesign.

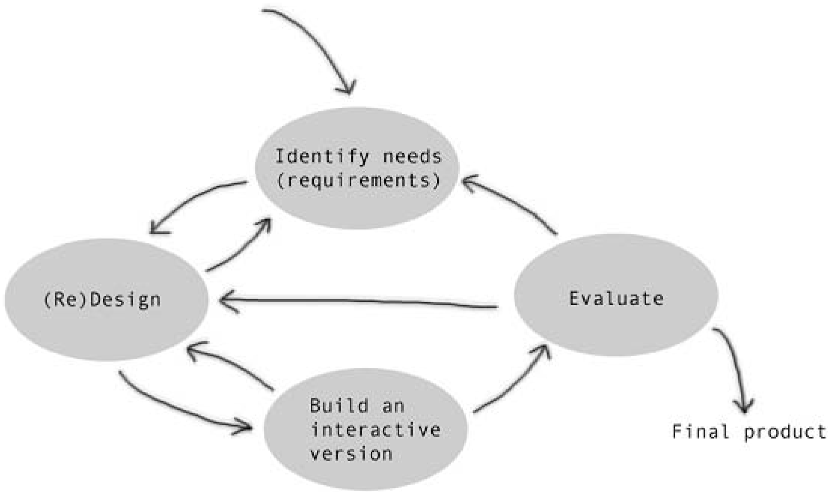


Figure 70: Dynamics of participatory design

11.2.2 Typical user analysis techniques

Most user analysis techniques rely on qualitative data analysis methods and that we shall introduce in other chapters. Just in anticipation, according to Håkansson, the most popular user analysis techniques are:

1. Questionnaires, if user number is high and if you know precisely what to ask (e.g. to identify user profiles, to test hypothesis gained from in-depth studies, etc.
2. Semi-structured Interviews, to explore new issues and to let participants develop argumentation (subjective causalities)
3. Focus groups, i.e. group interviews for collecting multiple viewpoints

4. Observations/Ethnography, to observe work as it happens in its natural setting (observe task related workflow, interactions) and to understanding the context (other interactions, conditions)
5. Scenarios (informal narrative descriptions), to understand activity flows. Users write *real* stories that describe in detail how someone will use your software (do not try to present specifications here!)
6. Cultural probes, an alternative approach to understanding users and their needs, developed by Gaver (1999)

11.2.3 Definition of requirements

Before constructing an artifact, you will have to define requirements. There exist different types that we shortly list:

- Functional requirements
- Environmental requirements
- Physical, social, organizational, technical
- User requirements
- Usability requirements

Remark: Most likely, the initial list of requirements may change during the design process. Typically, when users are exposed to the first real prototype, they may express a series of new needs.

11.2.4 Building prototypes

Prototypes can be anything. "*From paper-based storyboards to complex pieces of software: 3D paper models, cardboard mock-ups, hyperlinked screen shots, video simulations of a task, metal or plastic versions of the final product*" (Håkansson).

Prototypes are of different nature according to the stage and the evolution of the design process:

- Useful aid when discussing ideas (e.g. you only need a story-board here)
- Useful for clarifying vague requirements (e.g. you only need some UI interface mockup)
- Useful for testing with users (e.g. you only need partial functionality of the implementation)

11.3 Design-based research

Design-based research, also known as "design experiment" is an approach that has been specifically developed by educational technologists.

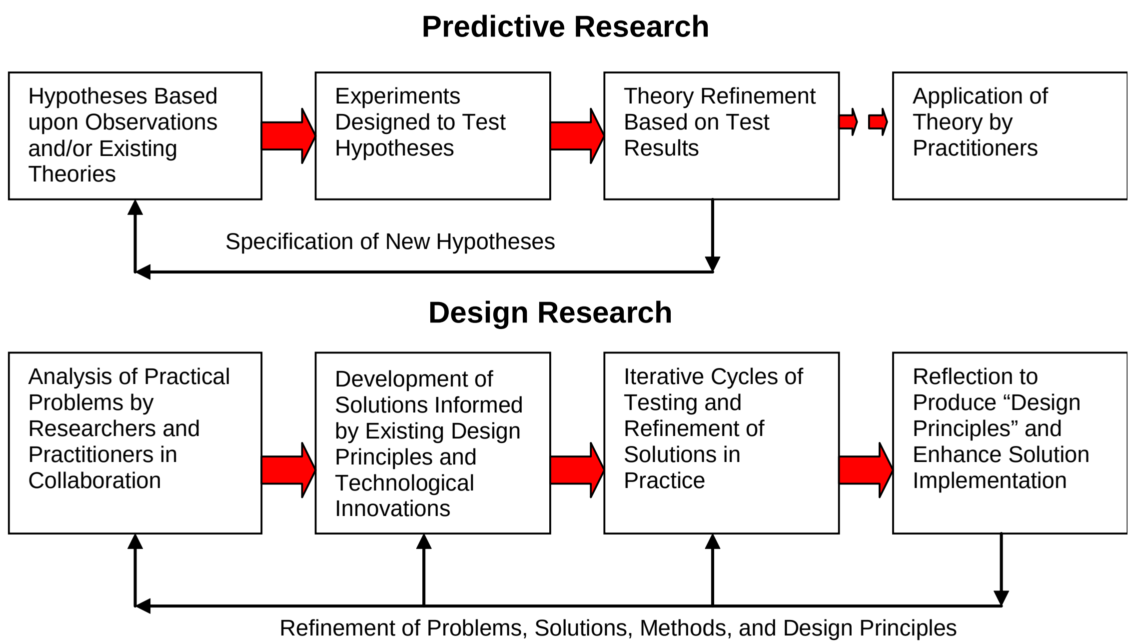
According to Collins et al (2004: 15), "*the term **design experiment** was introduced in 1992, in articles by Ann Brown (1992) and Allan Collins (1992). Design experiments were developed as a way to carry out formative research to test and refine educational designs based on principles derived from prior research.*" According to Reeves (2000:8), Brown's and Collins' design experiments have the following critical characteristics:

- addressing complex problems in real contexts in collaboration with practitioners,
- integrating known and hypothetical design principles with technological affordances to render plausible solutions to these complex problems, and
- conducting rigorous and reflective inquiry to test and refine innovative learning environments as well as to define new design principles.

According to Collins et al (2004: 16), design research was developed to address several issues central to the study of learning, including the following:

- The need to address theoretical questions about the nature of learning in context.
- The need for approaches to the study of learning phenomena in the real world rather than in the laboratory.
- The need to go beyond narrow measures of learning.
- The need to derive research findings from formative evaluation.

Reeves (2000:9; 2006), draws a clear line between research conducted with traditional empirical goals and research that is inspired by development goals



leading to "design principles" as illustrated in the next figure:

Figure 71: Empirical and development approaches to edutech research

Design-based research (DBR) also includes an action-research oriented perspective, i.e. researchers must try to change things.

> *The overall goal of research within the empirical tradition is to develop long-lasting theories and unambiguous principles that can be handed off to practitioners for implementation. Development research, on the other hand, requires a pragmatic epistemology that regards learning theory as being collaboratively shaped by researchers and practitioners. The overall goal of development research is to solve real problems while at the same time constructing design principles that can inform future decisions. In Kuhn's terms, these are different worlds. (Reeves, 2000: 12).*

Situatedness and complexity, i.e. situation-specific knowledge, is another important feature of most DBR research:

> *A core part of design-based research as applied work involves situating the work in "naturalistic contexts". (Barab & Squire, 2004: 11)*

> *Prototypically, design experiments entail both engineering particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them. This designed context is subject to test and revision, and the successive iterations that result play a role similar to that of systematic variation in experiment. (Cobb, diSessa, Lehrer, & Schauble (2003:9)*

Related to complexity and situatedness is the idea of iteration, i.e. DBR experiments are not one-time experiments, but they try to expand understanding of conjectures expressed with intervening variables. According to Sandoval (2004a:2), "*designed learning environments embody conjectures about learning and instruction, and the empirical study of learning environments allows such conjectures to be refined over time. The construct of embodied conjecture is introduced as a way to demonstrate the theoretical nature of learning environment design, and to frame methodological issues in studying such conjectures*". An **embodied** conjecture is a conjecture about how theoretical propositions might be reified within designed environments to support learning. Designed environments include **tools** (like software), **materials**, and **activity structures** (defined as the combination of task structure, how a task is organized, and social participation structures (Erickson, 1982).

Design-based research can be organized with so-called conjecture maps (Sandoval: 2004). They allow to drive and to organize the research project with a kind of concept map. Here is an example that identifies the important research components of a collaborative writing framework. It “tells” that research is base on a set of theories that we try to embody in a design and that will to (student cognitive) processes and finally to outcomes.

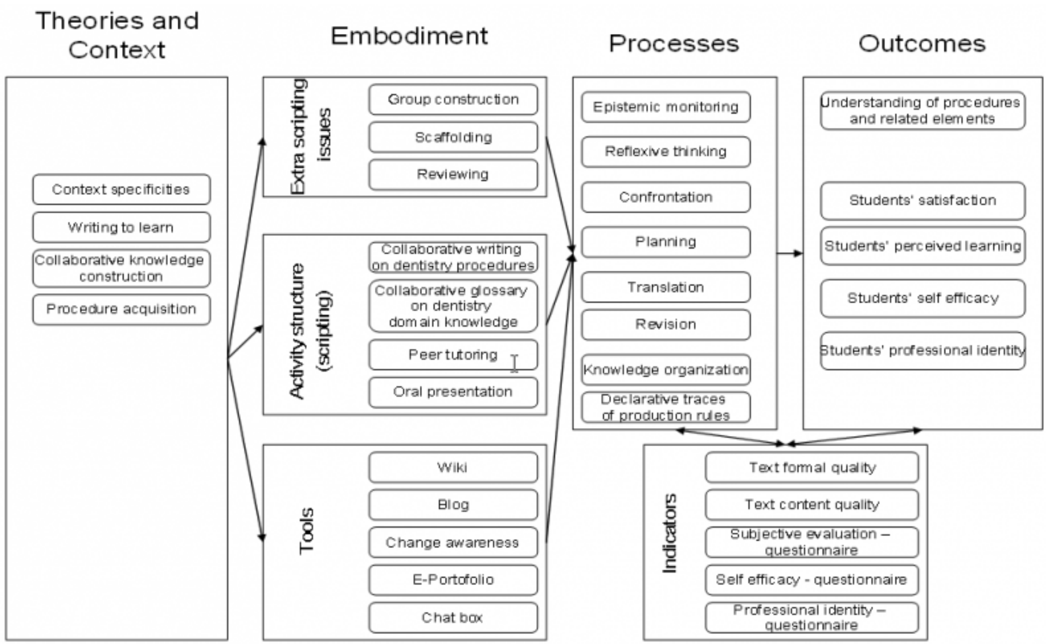


Figure 72: Conjecture map example - collaborative writing framework

Such a drawing can and should be refined over time, i.e. arrows should not just point from big box to big box but from little boxes to little boxes. The idea is that some of these relations then should be tested with some serious research methodology.

In Figure 73 we present another example that shows a conjecture map for just one research question *To what extent did the Tutoring Support Structure framework help in designing an effective socio-constructivist learning design* (Class, 2009)? This example shows that a certain number of theoretical conjectures at the theory level define how a tutoring support structure should be implemented. These theoretical elements then are instantiated as embodied conjectures, i.e. practical design rules. Techno-pedagogical design elements then should favor processes, i.e. what students do. These processes in turn then should lead to better learning.

As you may infer from these two examples, such conjecture maps are just a special kind of concept map to define research and design elements that depend on each other. As such, they are highly idiographic, i.e. researchers must come up with their own best representations and that depend on the overall research purpose. It also should be noted that conjecture maps should evolve over time. E.g. in the second example, you can see that arrows define relationships between specific boxes. These relationships then can be tested with data (if available).

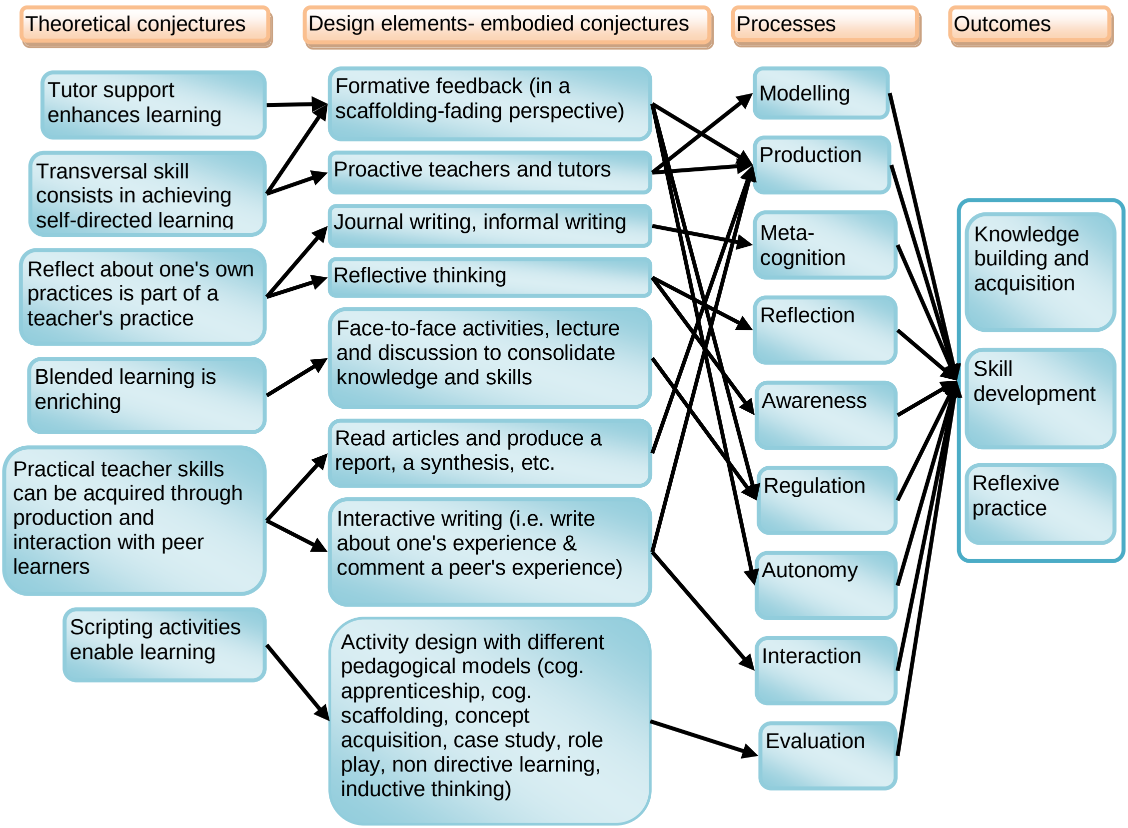


Figure 73: Conjecture map for a tutoring support structure question

11.4 Evaluation of designs

Evaluation is not just an issue in design research, but also in other approaches. So let's examine the general principle. According to Frechtling et al (2002), cited by Randolph (2008:22), there exist a lot of evaluation traditions to choose from, but a standard method for conducting an evaluation consists of the following steps:

- Develop a conceptual model of the program and identify key evaluation points,
- Develop evaluation questions and define measurable outcomes,
- Develop an evaluation design,
- Collect data,
- Analyze data, and
- Provide information to interested audiences.

Often, evaluation designs follow the same logic as theory testing designs. In educational technology, evaluation often uses as benchmark some "technological rule" and that can translate to a high-level evaluation grid. A good example is Merrill's first principles of instruction:

1. Does the courseware relate to real world problems?
2. Does the courseware activate prior knowledge or experience?
3. Does the courseware demonstrate what is to be learned?
4. Can learners practice and apply acquired knowledge or skill?
5. Are learners encouraged to integrate (transfer) the new knowledge or skill into their everyday life?

Another example is the Learning Object Review Instrument (LORI), available as an online form consisting of rubrics, rating scales and comment fields. The evaluation instrument is defined with nine dimensions:

1. Content Quality: Veracity, accuracy, balanced presentation of ideas, and appropriate level of detail
2. Learning Goal Alignment: Alignment among learning goals, activities, assessments, and learner characteristics
3. Feedback and Adaptation: Adaptive content or feedback driven by differential learner input or learner modeling

4. Motivation: Ability to motivate, and stimulate the interest or curiosity of, an identified population of learners
5. Presentation Design: Design of visual and auditory information for enhanced learning and efficient mental processing
6. Interaction Usability: Ease of navigation, predictability of the user interface, and the quality of UI help features
7. Accessibility: Support for learners with disabilities
8. Reusability: Ability to port between different courses or learning contexts without modification
9. Standards Compliance: Adherence to international standards and specification

Of course, the design rules themselves that are behind such evaluation grids, can be evaluated themselves.

Evaluation methodologies

Typical research questions that one could ask are:

- To what degree are users (e.g. students and teachers) satisfied with a new learning management system?
- In what ways do users think that a new intervention can be improved?

Design evaluation methodology draws on all major social science approaches for data gathering and data analysis. E.g., Håkansson cites the following data gathering methods: Heuristics, Experiments, Questionnaires, Interviews, Observations, and Think-aloud.

Evaluation methodologies are very different according to the kind of object that needs to be evaluated and according to the purpose of evaluation. We just shall shortly present two frameworks for usability analysis since usability studies are usually part of design research. Developed artifacts should be usable both in terms surface usability (users are able to use the interface) and cognitive ergonomics (users are able to use the interface to get some real task done).

Example 49. The Usability Net usability study model

Usability Net (http://www.usabilitynet.org/) provides a complete framework for usability evaluation studies. Usability procedures are incorporated in all stages of development:

- Planning and Feasibility: to ensure that usability activities are effectively incorporated into the design and development process, and influence the early feasibility stage of the design and development process.
- Requirements: users and developers identify usability requirements that can be tested later in the development process.
- Design: Create and develop a user interface design that is based on the requirements specification, and that supports the users with their task at hand
- Implementation: ensure that detailed design takes account of usability principles.
- Testing & Measure: assess the degree to which user and organizational requirements have been achieved, and to provide feedback in a form that can be used by designers and developers to improve the user interface design
- Post Release: monitor the usability of the system after release to ensure that it meets user needs in the field. This should be used as an input to requirements for a new version or release.

Methods that can be used at each design stage are listed in Figure 74: Usability net framework".

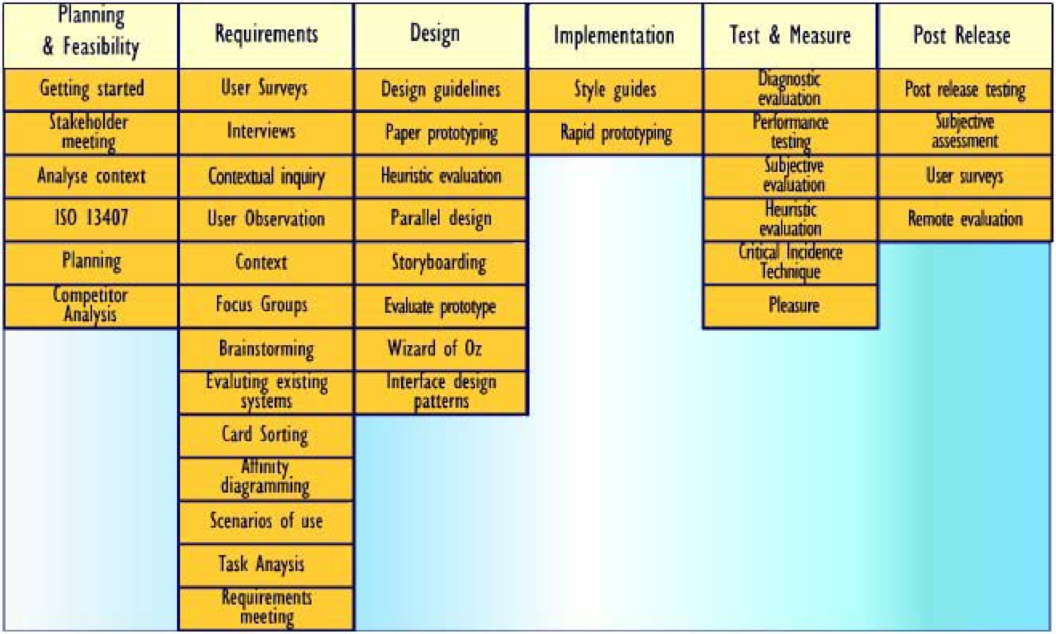


Figure 74: Usability net framework (http://www.usabilitynet.org/)

The point of this is model is that evaluation in design process is strongly tied to the global design procedure. At every design stage, one must think about evaluation. For example, if users do not participate in the requirement phase, it will be difficult to implement a test & measure program since it will not be clear what criteria should be used.

We shall come back to some data collection analysis techniques in the next part.

Example 50. Nielson's (1993) usability methods

In a more narrow, sense, usability studies refer to ***usability inspection***, a set of methods that are all based on having evaluators inspect the interface. Nielson (1995) lists and describes the typical evaluation methods:

- ***Heuristic evaluation*** is the most informal method and involves having usability specialists judge whether each dialogue element follows established usability principles
- ***Cognitive walkthroughs*** use a more explicitly detailed procedure to simulate a user's problem solving process at each step through the dialogue, checking if the simulated user's goals and memory content can be assumed to lead to the next correct action.
- ***Formal usability inspections*** use a six-step procedure with strictly defined roles to combine heuristic evaluation and a simplified form of cognitive walkthroughs.
- ***Pluralistic walkthroughs*** are meetings where users, developers, and human factors people step through a scenario, discussing each dialogue element.
- ***Feature inspection*** lists sequence of features used to accomplish typical tasks, checks for long sequences, cumbersome steps, steps that would not be natural for users to try, and steps that require extensive knowledge/experience in order to assess a proposed feature set.
- ***Consistency inspection*** has designers representing multiple projects inspect an interface to see whether it does things in the same way as their own designs.
- ***Standards inspection*** has an expert on some interface standard inspect the interface for compliance.

11.5 Examples of design-oriented master thesis

Example 51. Design and development of a scaffolding environment for students projects

Synteta, P. (2001). EVA_pm: Design and Development of a scaffolding Environment for Students projects. TECFA, University of Geneva.

http://tecfa.unige.ch/staf/staf-e/paraskev/memoire/important/writing/memoire.pdf

This study is centered on the design and development of a scaffolding environment for students' projects. A constructivist environment aims to scaffold Project-Based Learning (PBL) strategies to improve their effectiveness and serve as a reflection tool to help students develop meta-cognitive skills. It leverages XML (eXtended Markup Language) and suggests a vocabulary (DTD) that describes students' projects (assessments, theses, etc.) as a prompting tool. The vocabulary is well accompanied with the proposal of an appropriate XML editor to diminish the cognitive load of editing and with an online toolset ("commNcontrol" and "Virtual Book") to scaffold communication, visualization, peering, and progress tracking.

Research questions and objectives

- This study is also an intervention for improving PBL efficiency. It entails the development of a Scaffolding Learning Environment (SLE) that is trying to learn from the lessons of the past and leverage from stresses on new technologies like XML and the World Wide Web making a lightweight and easily portable environment.
- Most of the research for improving PBL efficiency tries to remediate specific weaknesses of PBL, but does not propose a complete system that supports a substantial student project through all it is phases and for all contexts.
- Our key goal was to develop a constructivist environment and a method for scaffolding student projects (assignments) from their management up to the writing of their final report.

Therefore, the objectives of this SLE are:

- to help students develop scientific inquiry and knowledge integration skills, to focus on important and investigate key issues;

- to support them directing investigations;
- to make students better manage the time and respect the time constraints;
- to overcome possible writer's block, or even better to avoid it;
- to help students acquire knowledge on project design and research skills;
- to improve team management and collaboration (especially collaborative editing of student groups);
- to make students reflect on their work;
- to support the tutor's role in a PBL approach;
- to facilitate monitoring and evaluation for the tutor;
- to help the tutor verify whether knowledge is being acquired;
- to motivate the peers, and eventually to distribute the results to bigger audiences.

Research questions: see above

Method

A very important part of this research was to conceive a grammar that would model the work of an academic project. There are different sources of information that have been used to achieve this goal. (....)

Survey of needs was gathered with a questionnaire: In order to gather precious information from the key persons involved in projects, like professors and their assistants, a questionnaire was articulated in such a way that would provoke a productive discussion, leading to comments and suggestions that would improve this research. The idea was to give the questionnaire to a small sample of the unit and stop the survey when the same answers came up again.

The development method that has been adopted corresponds to participatory design and specifically to *cooperative prototyping*: Both "prototyping" and "user involvement" (or "user centered design") are concepts that have frequently been suggested to address central problems within system development in recent years. The problems faced in many projects reduce to the fact that the systems being developed do not meet the needs of users and their organizations. [...]

Example 52. XML-based argumentation authoring tool

> Benetos, Kalliopi (2006). Computer-Supported Argumentative Writer. An authoring tool with built-in scaffolding and self-regulation for novice writers of argumentative texts. M Sc MALTT (Master of Science in Learning and Teaching Technologies), TECFA, University of Geneva.

http://tecfa.unige.ch/staf/staf-k/benetos/thesis/doc/kalli_benetos_memoire.pdf

This master thesis relates to work on computer-supported argumentation, i.e. the design of a cognitive tool. K. Benetos produced an online authoring tool using PHP, DOM, XML, XSLT and JavaScript, to help novices of argumentative text composition to better develop and structure their written texts. The tool is based on an underlying XML-based schema (developed with instructors) that is representative of argumentative texts and will offer a visualization and scaffolding of the composition process.

Working hypothesis

(H1) A computer-supported authoring tool based on a schema inherent to written argumentative texts can help improve the texts written by novices of written argumentation:

1. in the quantity of arguments produced;
2. in the quality of arguments produced
    a) scope (variety of arguments):

- epistemological point of view (Baker, Quignard, Lund, Séjourné, 2003)
- function of the argument (support and/or negotiate) (Dolz, 1996);

b) depth:

- inclusion of counter-arguments and conclusions (Brassart, 1996)

3. structural quality of arguments and text as a whole
   a) i. use of connectives (Akiguet and Piolat, 1996)
   b) ii. organization of arguments
   c) iii. conclusions

(H2): Through the use of a computer-supported authoring tool that offers structural and cognitive aid, novices will learn to recognize the components of the schema inherent to argumentative writing.

(H3): Feedback resulting from self-evaluation and procedural progress in the form of an actualized visual representation can enhance motivation, self-regulation and improve text structure and linearization.

Methodology (excepts)

- Needs analysis based on literature on user-centered design
- Theoretical framework: To allow investigation into a computer-supported tool based on a schema inherent to written argumentative texts, it was necessary to first design a framework for argumentative writing
- Adaptation of prototype - refinement approach
- Testing and interviews with users and stakeholders were conducted in each phase

- Reporting at the end of each phase permitted the recording of testing results for use in the identification of successes and problems within the design and testing processes.

The project was conducted in three phases: Design Analysis - System Design, Functionality and Usability - Testing with Students.

Testing with students consisted of 4 activities over a 1 and a half hour session:

1. Writing of an argumentative essay
2. Post-test
3. Interview on writing and post-test activities
4. Interview on the visualization (of the tool)

11.6 Summary of design-oriented approaches

Design-oriented approaches cover a large spectrum of research. In educational technology, we probably can distinguish between three major kinds:

1. So-called ***design experiments*** that attempt to create new pedagogical designs. Some of these are large scale, i.e. would extend through a whole course design
2. ***Design of technological artifacts***, such as multi-media learning environments, learning design engines, or virtual learning environments.
3. Formal and semi-formal ***learning design models and languages*** (design rules).

Review question

- Why did "design-based research" emerge in educational technology in the early 1990s?
- What is the purpose of a conjecture map?
- What is the purpose of participatory design?

Review assignment

1. Conduct a little usability study of a teacher tool to define a learning design. download and install Compendium LD:
    - http://compendiumld.open.ac.uk/
2. Roughly apply the following procedure:
    - Write down a requirements list
    - Design a training sequence (help is included with the system)

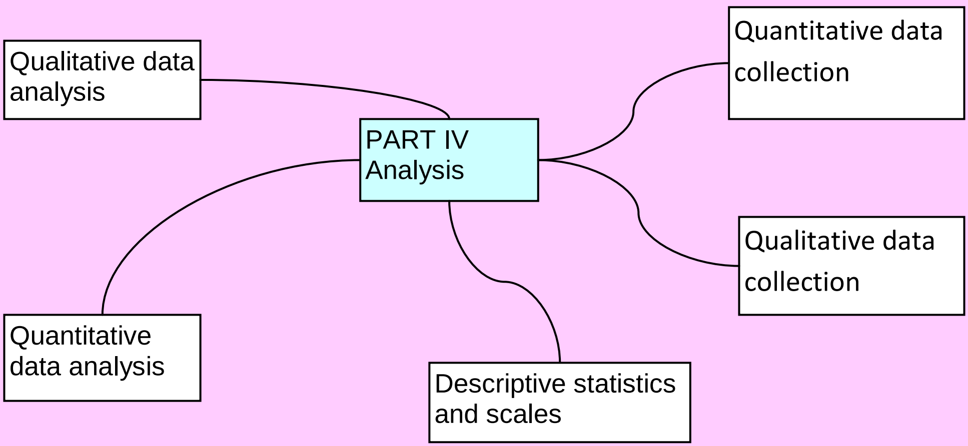
- Design a testing sequence
- Carry it out with 2 users
- Make suggestions about missing features and usability problems

Review case study

1. Download Chris Brook and Ron Oliver (2003), Online learning communities: Investigating a design framework, *Australian Journal of Educational Technology* 19(2), 139-160. http://www.ascilite.org.au/ajet/ajet19/brook.html
2. State the main purpose of this paper
3. Identify the central framework developed (Tip: It is a figure) and identify the seven important factors that can influence community development
4. According to your intuitive understanding of virtual environments, is this model still valid and why?

PART IV – DATA COLLECTION AND ANALYSIS

This part will introduce first various quantitative and qualitative data collection methods. We then will introduce data analysis, both for qualitative and quantitative data.



12 Quantitative data collection methods

This chapter will introduce quantitative data collection methods and focus on survey research and questionnaire construction.

Learning goals:

- Learn to discriminate between different data sources
- Learn the basic steps of questionnaire design
- Understand that measure of behavior (or perception of behavior) is better than opinions in most cases.
- Learn some principles about question response-item design.
- Understand that you should find similar research and reuse questionnaires whenever you can.
- Learn how to present a questionnaire.
- Recall some sampling principles.

In educational technology as well in most other social sciences, we work with a variety of quantitative **data sources**. In particular, we may distinguish between:

1. Researcher generated data, for example:
    - Tests, e.g. a measure of task performance
    - Questionnaires

- Quantified qualitative observations of various kinds, e.g. texts written by students, transcribed interviews.

2. Real data, for example:
    - Grades
    - Official and semi-official “Statistics", e.g. population data
3. Log files, for example:
    - Traces of user interactions with a system, for instance use of tools in a learning management system.
    - These data are sometimes generated from tools specifically made for research or they just "exist" (e.g. it is easy to retrieve database entries for forum participations)

In this chapter, we will ***focus on survey design*** and therefore questionnaire design since real data are available “as is” and log file analysis is a more difficult avenue of investigation.

12.1 Survey research and questionnaires

The methodology of survey research is now over sixty years old and is well documented in many methodology textbooks. It involves acquiring information from people about their attitudes, behaviors, experiences, socio-economic conditions, and other items through questionnaires. These questionnaires can be delivered on paper, through a face-to-face interview, over the phone or over the Internet. Usually survey research attempts to test a theory about a fairly large population, e.g. “university students in human sciences” or teenagers at the end of their mandatory school education in all OECD countries. The survey is then only administered to a representative sample, typically a few hundred people.

Questionnaire design is not easy. Firstly, you must be aware that survey data rely on ***subjective data***, i.e. what people believe that they do or think and moreover even what they think that they should tell. Second, questions are only indicators of thought. This is why one usually asks several questions in order to measure a single theoretical concept. Design of good questions and good response items is tricky. Beginners usually make a lot of mistakes. For all these reasons, it is important to rely as much as possible on ***published questionnaires*** that have been developed and tested by serious researchers.

Questionnaire design – step by step

Below we formulate a short recipe for designing a questionnaire.

1. Make a list of concepts (theoretical variables) in your research questions for which you need data.
2. For each of these concepts make sure that you identify its dimensions (or make sure that they are not multi-dimensional). If you do not know, what "dimensions" are, go back and read about the operationalization of general concepts in chapter 0.
   - Consult the research literature, i.e. find similar research that used questionnaires.
   - Discuss with domain experts
   - Make a list of conceptual variables (either simple concepts or dimensions of complex concepts)
3. For each conceptual variable think about how you plan to measure it
   - First of all (!) go through the literature and find out if and how other people went about it
   - It is much better to use a suitable published instrument than building your own. You can then compare your results and you will have much less explanations and justifications to produce! Finally, as we said

before, you are less likely to design bad questionnaires that way.

4. Plan some measurement redundancy
    - Do not measure a conceptual variable with just one question or observation. Use at least four questions
5. Rather ask people how they behave instead of how they think they behave
    - E.g. don't ask: "*Do you use socio-constructivist pedagogies?*", but ask several questions about typical tasks assigned to students.
6. Do not ask people to confirm your research questions
    - E.g. in a survey or test, do not ask: "*Did you manage to make your teaching more efficient with this new technology?*" Again, ask/observe what the teacher really does and what his students had to do and then did.
7. Test your questionnaire with a least two people. The chance is very high, that some of your questions are really badly designed ...

Table 43: Steps for designing a questionnaire

Finally, you also could triangulate surveys with data of different nature, e.g. combine survey data with objective data and quantified observational data (like log file analysis) or even qualitative data like interviews with a few selected individuals.

12.2 Question and response item design

Below, we formulate a few rules that you should respect and that you also can use a checklist.

Wording and contents of the questions

- Only ask questions that your target population understands
- Questions should avoid addressing two issues in one question!

  Bad example: Did you like this system and didn't you have any technical problems with it?
- Make the questions as short as possible. Else, people will not read/remember the whole question.
- Ask several questions that measure the same concept. Try be all means to find sets of published items (questions) in the literature that you can reuse

Response items

- Avoid open-ended answers (these will give a lot of coding work)
- Use scales that have at least a range of five response options, otherwise people will have a tendency to drift to the "middle" and you will have no variance. E.g. avoid:
- agree () neither/or () disagree ()
- Response options should ideally be consistent across items measuring a same concept
- If you feel that most people will check a "middle" value, use a large "paired" scale without a middle point

  e.g. 1=totally disagree, 10=totally agree

  1 2 3 4 5 6 7 8 9 10

Again: Use **published scales** as much as you can. This strategy will help you in various ways. You get better reliability (user's understanding of questions) since published items have been tested. Scales construction will be easier and faster (you can skip doing statistics like Cronbach’s alpha). It will make your results more comparable

Testing

- You must test your questionnaire with at least two people!
- From our experience in methodology course teaching we can say that we ***never*** have seen an even moderately acceptable questionnaire made in one go by a beginner student. Do not overestimate your skills!

Example 53. Social presence questionnaire

Social presence is an important variable in (informed) distance education. We shall have a look at a study that tries to link social presence to learner satisfaction.

The GlobalEd questionnaire by Gunawerda & Zittle (1997), and which can be found in the Compendium of Presence Measures (http://www.presence-research.org/Questionnaires.html#GlobalEd), was developed to evaluate a virtual conference. Participants (n=50) of the conference filled out the questionnaire. Internal consistency of the social presence scale was a=0.88. Social presence was found to be a strong predictor of user satisfaction.

The questionnaire used the following 14 questions to measure *social presence* (the total questionnaire included 61 items):

- Messages in GlobalEd were impersonal
- CMC is an excellent medium for social interaction
- I felt comfortable conversing through this text-based medium
- I felt comfortable introducing myself on GlobalEd
- The introduction enabled me to form a sense of online community
- I felt comfortable participating in GlobalEd discussions
- The moderators created a feeling of online community
- The moderators facilitated discussions in the GlobalEd conference

- Discussions using the medium of CMC tend to be more impersonal than face-to-face discussion
- CMC discussions are more impersonal than audio conference discussions
- CMC discussions are more impersonal than video teleconference discussions
- I felt comfortable interacting with other participants in the conference
- I felt that my point of view was acknowledged by other participants in GlobalEd
- I was able to form distinct individual impressions of some GlobalEd participants even though we communicated only via a text-based medium.

A 5-point rating scale was used for each question

Example 54. socio-constructivist teachers questionnaire

In a questionnaire designed by B. Class and that was based on Dolmans (2004), the problem was how to identify socio-constructivist elements in a distance teaching course for interpreter trainers.

Decomposition of *socio-constructivist desig*n in (1) active or constructive learning, (2) self-directed learning, (3) contextual learning and (4) collaborative learning, (5) teacher's interpersonal behavior (according to Dolmans et al., 1993)

Remark: headers regarding these dimensions (e.g. "Constructive/active learning") are not shown to the subjects. We do not want them to reflect about theory, but just to answer the questions. So they are just shown below to help your understanding

	Statements: Teachers stimulated us ...	Totally disagree	Disagree	Some-what agree	Agree	Totally agree
		1	2	3	4	5
(Constructive/active learning)						

4	... to search for explanations during discussion	O	O	O	O	O
5	... to summarize what we had learnt in our own words	O	O	O	O	O
6	... to search for links between issues discussed in the tutorial group	O	O	O	O	O
7	... to understand underlying mechanisms/theories	O	O	O	O	O
8	... to pay attention to contradictory explanations	O	O	O	O	O
(Self-directed learning)						
9	... to generate clear learning issues by ourselves unclear	O	O	O	O	O
10	... to evaluate our understanding of the subject matter by ourselves	O	O	O	O	O
(Contextual learning)						
11	... to apply knowledge to the problem discussed	O	O	O	O	O
12	... to apply knowledge to other situations/problems	O	O	O	O	O
13	... to ask sophisticated questions	O	O	O	O	O
14	... to reconsider earlier explanations	O	O	O	O	O
(Collaborative learning)						
15	... to think about our strengths and weaknesses concerning our functioning in the tutorial group	O	O	O	O	O
16	... to give constructive feedback about our group work	O	O	O	O	O
17	... to evaluate our group cooperation regularly	O	O	O	O	O
18	... to arrange meetings with him/her to discuss how to improve our functioning as a group	O	O	O	O	O

12.3 General questionnaire design issues

The Introduction

A questionnaire (whether on paper or on-line) should include a short introduction that states the purpose of this questionnaire

Example 55. Introduction for a questionnaire

The purpose of this questionnaire is to help us understand how well you liked the on-line delivery of the first blended edition of the Certificate for Interpreter Trainers. Each one of the 117 statements below asks about your experience in the on-line part of the Certificate.

Data will be processed and published only statistically. The following questions will be dealt with: personal information, teachers' behavior, learning environment, tutoring support structure, tools and skills. Filling in this questionnaire will take you about 20 minutes. Please be assured that your responses will be treated confidentially, and that they will not affect your assessment. Thank you very much for your cooperation.

Such an introduction guarantees that you only will publish statistical data (no names and it will specify how long it will take to answer the questions. It is important to give an accurate estimation; else participants may get angry and abort the procedure.

Ergonomics

As we said before, the most important advice we can provide is the following: Test the questionnaire with 2-3 persons, observe difficulties and other problems and fix them.

At the presentation level:

- Do not include anything else than questions and response items (besides the introduction)
- Make sure that people understand where to "tick".

Coding information for the researcher

It is useful to include coding information for the researcher. However, if you do so, use very small fonts. Else, participants will be distracted.

- Assign a code (e.g. number) to each question item (variable) and assign a number (code) to each response item
- This will help you when you transcribe data or analyze data
- Use "small fonts" (this information is for you)

Below is a question from a paper-based survey with several sub-questions about teachers' behavior. You can see that each question is numbered and the response items have codes. These are irrelevant for the user (and you really should use small fonts for these), but they are useful for data transcription and also to help you map variables in your statistics program to the questions and response items.

Example 56. A question set

Below you will find general statements about teachers' behavior. Please indicate to what extent you agree or disagree with them?

Please tick the appropriate circle on the scale (totally disagree - totally agree) for each statement.

Statements: Teachers stimulated us ...		Totally disagree 1	Disagree 2	Somewhat agree 3	Agree 4	Totally agree 5
Q4	... to search for explanations during discussion	O	O	O	O	O
Q5	... to summarize what we had learnt in our own words	O	O	O	O	O
Q7	... to reconsider earlier explanations	O	O	O	O	O

12.4 Experiments

Designing a true experiment needs advice from some expert. Typically, a beginner makes the mistake to differentiate 2 experimental conditions by more than one variable, i.e. you will really be able to understand what exact treatment led to observed effects.

There are many kinds of experimental measures

- observations (e.g. Video, or recordings of computer input)
- tests similar to surveys
- tests similar to examination questions)
- performance tests (in seconds)
- tests similar to IQ tests

Consider all the variables in your hypothesis

- Most often, the dependant variables (to explain) are measured with tests
- Usually the independent (explanatory) variables are defined by the experimental conditions (so you don't need to measure anything, just remember to which experimental group the subject belonged)

See the literature, experimental research publications usually explain fairly well the "method"!

- First, read articles about similar research!
- Consult test psychologists if you need to measure intellectual performance, personality traits, etc.
- Use typical school tests if you want to measure typical learning achievement

12.5 Sampling methods

12.5.1 The ground rules

The number of cases you have to take into account is rather an absolute number

- Sample size is hence not dependent on the size of the total "population" you study, unless you plan to study sub-populations.

The best sampling strategy is random selection of individuals, because:

- There is a likely chance to find representatives of each “kind” in your sample. Do you remember the randomization principle of experimentation?
- You avoid auto-selection (i.e. that only "interested" persons will answer your survey or participate in experiments).

When you work with small samples, you may use a quota system:

- E.g. make sure that you have both "experts" and "novices" in a usability study of some software
- E.g., make sure that you (a) both interview teachers who are enthusiastic users and the contrary, (b) schools that are well equipped and the contrary in a study on classroom use of new technologies.

12.5.2 A first look at statistical significance

Statistical significance of results depend both on strength of correlations and size of samples. Therefore, the more cases you have got, the more likely your results will be interpretable! Let us illustrate this principle with an example:

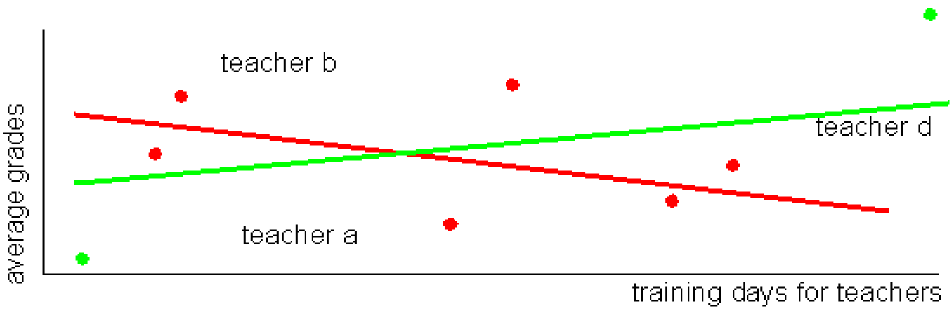


Figure 75: Correlation between teacher training and average of student grades

Let us assume that initially you have data from only 6 teachers (the red dots): Your data suggest a negative correlation: more training days lead to worse averages. Now let us see what happens if we only add 2 new teachers (the 2 green dots). The observed relation will switch from negative to positive, i.e. the data suggests a (weak) positive correlation.

This reversal effect shows that doing a statistical analysis on very small data sets is like gambling. If your data set had included 20 teachers or more, adding these 2 additional "green" individuals would not have changed the relationship. This is why (expensive) experimental research usually attempts to have at least 20 subjects in a group.

12.5.3 Typical sampling for experiments

Sampling for experiments is a simpler art. You should have

- *preferably* 20 subjects / experimental condition
- *at least* 10 / experimental condition (but expect some relations to be non-significant)

Example 57. The effect of multimedia on retention

The model includes three variables

- Explanatory (independent) variable X: Static diagrams vs. animation vs. interactive animation
- Dependant (to be explained) variable Y_1: Short term recall
- Dependant (to be explained) variable Y_2: Long-term recall

Both dependant variables (Y_1 and Y_2) can be measured by recall tests

For variable X we have three conditions. Therefore, we need 3 * 20 = 60 subjects. If you expect very strong relations, you can get away with 3 * 12

Remark: we cannot administer the three different conditions to each individual (because by moving from one experiment to another they will learn). You may consider building 3 * 3 = 9 different kinds of experimental materials however and have each individual do each experiment in a different condition. However, they may get tired or show other experimentation effects ... and producing good material is more expensive than finding subjects are.

12.5.4 Typical samples for survey research

Try to get as many participants as you can if you use written or on-line surveys. Dealing with on-line data does not cost very much, but you certainly will get a sampling bias.

40 participants is a minimum, 100 are good and 200 are excellent for a master thesis. Otherwise, you cannot do any sort of interesting data analysis, because your significance levels will be too high (i.e. bad) when you analyze even moderately complex relationships.

12.5.5 Typical samples for aggregate data

You may find official aggregated statistics about schools, districts, countries etc. Since these data reflect real "realities" you can do with less, (however talk to an expert, a lot depends on the kinds of analysis you plan to do).

12.6 Summary

The major quantitative data collection methods are very well documented in most social science methodology textbooks. We shall repeat again our most important advice here:

Reuse ***published*** instruments as much as you can!

Review questions

1. Why do questionnaires measure a single theoretical concept with an index?
2. In the context of survey research, what are indices?

Review case study

1. Download Elgort, I., Smith, A. G. & Toland, J. (2008). Is wiki an effective platform for group course work? *Australasian Journal of Educational Technology*, 24(2), 195-210. http://www.ascilite.org.au/ajet/ajet24/elgort.html
2. Identify the central research questions. Tip: Look at the end of the "background" section.
3. How was *attitude to group work* measured? (Tip: download the questionnaire presented in the annex).

13 Qualitative data acquisition methods

In this chapter, we shall introduce qualitative data collection methods and techniques. We first will discuss sampling strategies since qualitative research often starts with open-ended questions. We then provide an overview of various data collection techniques and provide some details about interviewing.

Learning goals

- Be able to design a sampling strategy for a simple qualitative research problem
- Be able to discriminate between major data collection strategies
- Know the key features of semi-structured interviews

13.1 Sampling strategies in qualitative research

In educational technology (as well in most other social sciences) one works with a variety of qualitative data. Since qualitative research most often focuses on "rich" data, sampling is more difficult than for quantitative research and we shall start with this issue.

Often you only work with 1-2 big cases (i.e. classes, organizations). The reason is that qualitative analysis is highly labor intensive. However, within each big case you also have to think about sampling! For example, an innovation researcher when looking at organizations may interact with various people and study/observe various processes:

- informants within the organization
- external experts (domain/subject experts/practitioners)
- clients and other interacting organizations
- observed processes (e.g. workflow analysis)
- texts (e.g. written decisions, files, ...)

Another example would be study that examines the impact of an initiative on a public space (e.g. publicly accessible computer rooms)

- external decision makers and interest groups
- organized local groups (e.g. parent's associations)
- population of the area
- events and behaviors associated with this initiative

Sampling is often multi-stage (by waves): Research in progress can show new phenomena that need investigation and therefore sampling

Miles & Huberman (1994:28) present the following general sampling strategies

Type of case	**Usage**	**Broad categories**
maximal variation	will give better scope to your results (but needs more complex models!)	major strategies

homogeneous	provides better focus and conclusions will be "safer" since it will be easier to identify explaining variables and to test relations	
critical	exemplify a theory with a "natural" example	
according to theory, i.e. your research questions	will give you better guarantees that you will be able to answer your questions....	
confirming / infirming	test the limits of an explanation	validation
extremes and deviant cases	test the boundaries of your explanations, seek new adventures	
typical	show what is normal, average or typical	
intense	complete a quantitative study with an in-depth study	specialization
according to dimension	Study of particular phenomena	
snow ball	According to information received during study	inductive approach

opportune	follow new leads	
all	(rarely possible)	representativeness
quota	selection of subgroups	
according to reputation	recommendations of experts	
comparative method	according to operative variables	
according to criteria	according to criteria you want to study	
convenient	those who are willing ...	bad
political	Exclusion/inclusion for political reasons	

Table 44: general sampling strategies for qualitative research

There are no general rules about sampling, but we can formulate a few heuristics and recommended practices! Use this table to think the kind of sampling you need for *your own* research. Choosing well your cases means avoiding trouble later ...

- Avoid adopting a sampling-by-induction strategy (more difficult)
- ***Look at your research questions***! Can you answer all of them (measure concepts, find causalities, etc.)?

- Understand the scope of the sampling task: Sample roles (functions organization), groups, organizations, institutions, “programs”, processes ...
- Reduce your ambitions (research questions) when your sampling lists get to large.
- You always can add cases (snowball strategy).

For ***intra-case*** sampling:

- Identify types of information you need.
- Sample all categories (activities, processes, events, dates, locations, agents ...).
- Again, think about the research questions you want to answer and their scope.

For ***inter-case*** sampling, it is a good strategy to adopt a kind of similar systems design:

- Select similar cases that have a nice variance within your operative variables (dependant and independent).
- To test variants of e-learning designs, select relatively similar domains, or relatively similar target populations.
- You then can add contrasted (extreme) cases to test the external validity (generalization potential) of your analysis

Remember: qualitative research is very expensive

- 2-3 big cases (e.g. courses, schools, designs) are enough for a master thesis.
- 12-30 cases within all cases (e.g. people, processes) are enough for a master thesis.
- Also, consider completing qualitative strategies with quantitative approaches.

13.2 Data gathering techniques (empirical measures)

Here is a conceptual overview of various types of data gathering techniques:

activity	**medium**	**principal objective**
Observe	observation of behaviors	Global observation of an organization, culture, activity, etc.
Record activities	Video recordings and transcriptions of natural activities	In-depth study of activities and interactions in context
Provoke activities	Recordings and transcriptions	In-depth study of various researcher provoked formal activities.
Gather texts	Written traces	Written traces of activities (e.g. decision protocols, guidelines, log files)
Ask people	interviews	Extraction of information in people's head
Participate	Activity sharing	Participatory observation shares research and work

Table 45: Types of data collection techniques

As you can see, the researcher intervention and the media are of different nature. Such a taxonomy is useful to help you thinking about your role and things you can look at. We shall now present a list of qualitative data collection methods and that is much more operational.

Popular data collection methods in educational technology

There exist many data collection methods, and some can't be described on the same level. However, for information purposes, we present you with a simple flat list. We shall introduce some of these further down.

Some additional names of methods also have been introduced in the chapter on design-oriented research.

Name	**Purpose**
Semi-structured interviews	To find collect subjective representations of behaviour and attitudes with respect to a list of research questions
Phenomenological in-depth interviews	To study complete worlds views of individuals (such interviews are repeated)
Structured interviews	To answer theory-driven research questions and to compare
Video taping	To analyse learner behaviour or classroom interactions in depth.
Field observations	To absorb all sources of information, including the physical settings, language used, interaction patterns.

Participant observation	To transform practice, e.g. introduce a new pedagogical model
Ethnographic field observations	To study “cultures”, e.g. in a company or a research community
Focus group interviews	To elicit controversial and common opinions about a subject.
Dialog analysis	To study mechanisms of collaboration, e.g. in collaborative learning
Thinking aloud	To study cognitive processes, e.g. problem-solving activities
Task observations	Similar as above
Repertory grid technique	To elicit personal constructs
Scenario writing	To elicit informal narrative descriptions to understand activity flows.
Delphi method	structuring a group communication process with experts to deal with a complex problem.
Collection of documents	(various purposes)

Table 46: popular qualitative data collection methods

Different roles for qualitative technology

Do not confuse the "technique" and "approach" levels when you talk about qualitative methods. Qualitative methods can just refer to specific data-gathering techniques but also to designs that are more global. In the following table, we show the different status of qualitative data acquisition technology in quantitative vs. qualitative research.

<table>
<tr><th>Examples</th><th colspan="2">Some different objectives and techniques for quantitative vs. qualitative approaches</th></tr>
<tr><td>method</td><td>quantitative approaches</td><td>qualitative approaches</td></tr>
<tr><td>Field observation</td><td>preliminary work for questionnaire design</td><td>"Deep understanding of an institution’s or culture’s working</td></tr>
<tr><td>examine activities</td><td rowspan="2">quick studies of work activities and interactions to prepare initial design specifications
systematic usability studies</td><td>dialogue analysis</td></tr>
<tr><td>provoked activities</td><td>understanding of reasoning processes</td></tr>
<tr><td>Text analysis</td><td>formal content analysis
most often work counting or more sophisticated like Latent semantic analysis (LSA)</td><td>categorization and understanding of concepts</td></tr>
</table>

Interviews	• fixed questions to systematically gather relatively complex attitudes, opinions and descriptions of behaviors	• open interviews or semi-structured interviews to engage subjects in

This table is not very complete, but it shows that qualitative designs are more geared towards studying a phenomenon in depth whereas mostly quantitative designs put more emphasis on scale or preparation of quantitative studies.

13.3 Observation and examination of activities

13.3.1 Long-term observation of behaviors in natural contexts

Observation in natural contexts is an essential instrument for *in-depth studies* of cultures and/or organizations. This method takes *time* and requires some field note technique skills, i.e. conventions on how to write down observations

In addition, the researcher's role in the organization, group, and culture needs to be clarified.

Below we present a typical field note technique that will allow an ethnographer to take notes that will allow him later to distinguish between various kinds of information.

Marks	**Usage**
?...?	verbatim quotations
? ... ?	paraphrases

(…)	contextual data (or researchers interpretations)
< … >	Analytical categories) derived from the subject's conceptual frameworks
/ …	Analytical categories) derived from the researcher's conceptual frameworks
____	time elapsed

Table 47: Field note technique example

To observe shorter key episodes, e.g. specific educational sequences in a classroom, one also can make video recordings.

13.3.2 Computer mediated transcriptions

We defined computer-mediated transcriptions as data that is collected through tools that participants will use. This technique is very popular in educational technology. There exist various kinds of tools, e.g. specially made experimental artifacts, various kinds of portals (e.g. a learning management system), computer-supported collaborative learning or work environments, etc. Many tools used in e-education already include a module to register detailed user acts for research purposes.

Two types of activities are usually observed:

- user-machine interactions
- mediated user-user interactions

In addition, screen activities can be filmed or electronically registered. It is also possible to use special eye-tracking devices in order to find out precisely at which interface elements users are looking at. Such recordings provide extra information, e.g. non computer-mediated user-user communication

Analysis of transcriptions takes an enormous amount of time!

- either you have to spend days/weeks for manual coding (preferably using specialized software adapted to the media type)
- or you need high technical skills to write scripts to reduce and "massage" data

Likely, you also have to invent your own data analysis and visualization techniques. Be sure to search the literature for coding and analysis techniques! Finally, we provide the following advice:

- Think very hard about the concepts you need to measure!
- Be as superficial as possible, e.g. use quantitative data reduction techniques if you can find out how to do so.

13.3.3 Elicitation of cognitive processes

The ***thinking aloud*** method combined with protocol analysis (Ericsson & Simon, 1983) is a popular method in cognitive science and expert system design. It is used to collect relatively "objective" data about thinking processes, problem solving in particular.

There can be important experimentation effects:

- ex-post rationalization of behavior,
- analytical thinking instead of case-based/pattern matching
- influence of experimenter

- subject may become silent and confused ...

Basic principle: Users are given tasks and are asked to think aloud what they do.

The Ericsson & Simon procedure for elicitation cognitive processes can be summarized as follows

- The experimenter is completely silent...
- ...except when subject is ± 15s silent
- Let the user keep talking!

When this procedure is used in usability testing, the procedure is different:

- The experimenter can push subjects in certain directions, e.g. ask them to do tasks
- Subjects can ask for help,
- Testers ask questions (e.g. clarifications, opinions, ...)

13.3.4 Transcriptions of user activities in semi-formal situations

Usually audio or video recordings are used to capture user activities. Videos take a lot of time to analyze and specialized annotation software that can help with this process.

You also should ask prior permission to use a tape-recorder or a camera if you do this in a work context and you should be aware that taping could strongly modify user behaviors in such contexts.

13.3.5 Texts

Text analysis (other than "texts" mentioned above) concerns artifacts like official documents, student/teacher paper productions, etc.

Do not ask for everything when you start your field research. People do not always like to give away written traces of their activities, and therefore you need to establish a confidence relation first. There exists a large amount of analysis techniques.

13.4 Interviews

There exist several kinds of interview types and each has its purpose in research.

Type	**composition**	**function / advantages**
Information interviews	check-list	Initial studies
Semi-structured interviews	list of questions and “probes”	Main interview type in qualitative research • subjects are allowed to “talk” and therefore to think • difficult to analyze
Structured (directive)interviews	list of fixed questions	Semi-quantitative studies: • easier analysis • better comparison • faster than semi-structured

Interviews with a fixed list of questions and closed questions	list of questions with response items	Quantitative studies • fast interview • reliable • easy to analyze • needs good understanding of the studied phenomenon

Table 48: Overview of interview types

Interviewing is a well-documented technique in most methodology textbooks. We shall first present a short list of general advice and then examine several interview types.

13.4.1 General advice for interviews

Interviewees (in natural settings) do not have time to lose. Here are a few ground rules you might consider:

- focus on the *essential,*
- check if some information is available in other forms (e.g. written memos, rules, etc.),
- learn the *jargon*
- consult all other available information before the interview

Regarding the question whether you should use a recorder or just take notes, there are several considerations.

If you do a qualitative single-round study that focuses on what users think, you probably should tape the conversation. However, you should be aware that transcription of a 90 minute interview may take a whole day and coding another day. In addition, some people do not like to be taped. So alternatively, you can consider taking a friend with you. Two people can take enough notes, but make sure to look at the transcripts right after the interview.

If you are engaged in design-oriented research (e.g. putting in place a new model of teaching with a new environment), note taking may be a good enough options, since the data are meant to be used to redesign the system and to open up new avenues. You always can administer quantitative questionnaires for final evaluation. In addition, it is often better to see a person at least two times (or more) and "dig" some more instead of spending weeks or month to do transcriptions. In short: You have very limited resources (most of the time) and you have to choose between reliability (transcriptions) or between doing more intensive and repetitive fieldwork.

13.4.2 The information interview

The information interview is usually conducted before you start research. Its typical objectives are:

- Help determining your research goals, e.g. you need to find out if your potential research subject is of any interest, etc. ;
- Prepare your research questions, i.e. identify interesting issues and critical explaining and to be explained variables
- Prepare more inductive field research, e.g. you need information about the workings of an organization, process, procedure, about people and their roles, etc.

It is important to find *the* right person for such exploratory interviews.

- Often you may first interview *a domain specialist;* e.g. if you plan to do master about using virtual environments for foreign language teaching, you should find an expert in foreign language teacher or better: an expert in technology-supported foreign language teaching

- Sometimes *any person* that has knowledge on your subject area *and time* will also do.
- Avoid over-taxing key actors: You must make sure that key actors will agree to participate in semi-structured interviews in later stages in your research. Being interviewed twice may not please some of them.

13.4.3 The structured interview

The structured interview uses a fixed list of questions with open responses (usually a few sentences). This technique is very close to survey research and its closed questionnaires. It can be used to systematically gather comparable information about relatively complex variables (beliefs, behaviors, etc.).

A structured interview questionnaire needs a *lot of preparation! M*ake sure that each concept you are interested in can reliably be measured by your open questions. Also, make sure that you have the time to administer and analyze these.

To prepare the questionnaire you ought to do 2-3 semi-structured interviews (or at least some information interviews). In addition, make *pre-tests* with 2-3 subjects in order to be sure that your questions are understandable

You have to think about analysis methods beforehand. Usually text is manually coded with a precise codebook. However, there exist some quantitative content analysis methods. Also, consider using surveys with closed response items as a much cheaper alternative!

13.4.4 The semi-structured interview

Semi-structured interviews are the preferred interview type in typical qualitative research. They allow getting answers for precise questions and, concurrently, allowing the interviewee to *reason*. The goal of such interviews is to extract "meaning", i.e. so called "deep" or "thick" structures.

As any interview, semi-structured interviews must be well *prepared. Read your research questions* and identify the ones that need interviewing. The interview is usually prepared in **two** layers:

1. Firstly a list of general question
2. For each of these questions you then write down a "secret" list of points ("probes") that need to be covered. During the interview you must "probe" the interviewee for all those points

It is important to adopt an appropriate interviewing behavior:

1. *Let the person talk!!!*... and use your detailed probes later if the person doesn't address these him/herself!
2. It is important that the interviewee be allowed to develop chains of reasoning (e.g. perceptions of causality, associations between concepts, etc.).
3. Carefully word your questions. E.g., watch out for sensitive questions. Put them at the end and if you are lucky, the subject will mention some of these topics anyhow.
4. Use indirect questions that project the interviewee into a situation instead of asking direct opinions: Examples:

   Don't ask: "do you work well with person A?"

   But: "do you have frequent contacts with A", "how do you coordinate", etc.

   Don't ask: "do you know how to use this software"?

   But: "How frequently do you use this software", "What do you do with it?", etc.

5. When appropriate, ask about concrete cases:
   - E.g., to decision makers, present a hypothetical case, and ask how they solve it. E.g. in usability testing, give them precise tasks to solve.

- Alternatively, let them present a scenario, a case or critical incident.

En résumé:

- Rather ask what people *do* than what they feel
- In many situations, it is useful to present the interviewee with a scenario and then also use it also to let people reflect on more general issues

13.5 Summary

Qualitative methodology requires as much or even more planning than quantitative methodology. In the research plan, you should select:

- A general methodology (or sometimes more than one)
- Appropriate sampling
- Appropriate data collection techniques
- Analysis strategies (to be discuss later)

Review questions

- What is the favourite interview tool in educational technology research?
- How would proceed if to need to know how students solve a problem?
- Why is the phenomenological interview costly?
- Why do quantitative researchers sometimes use qualitative tools?
- What is the safest sampling strategy for a beginner?

Review case study

1. Download Jennifer H. Kelland, Heather Kanuka (2007). "We just disagree:" Using deliberative inquiry to seek consensus about the effects of e-learning on higher education, *Canadian Journal of Learning and Technology,* 33 (3). http://www.cjlt.ca/index.php/cjlt/article/view/161/157
2. State the main research question
3. Define what the authors mean by "deliberative inquire"
4. Summarize the conclusions for each of the identified major issues.

14 Descriptive statistics and scales

This chapter introduces simple descriptive statistics. The purpose of descriptive statistics is to summarize data distributions. In addition, descriptive statics (in particular the mean and standard deviation) are the basis of most statistical analysis techniques.

Learning goals

- Understand the concept of a statistical variable as compared to a theoretical variable
- Be able to distinguish between the three major data types
- Identify, interpret and use simple measures of centrality and dispersion
- Be able to produce and interpret simple distribution charts
- Understand some principles of data preparation
- Be able to create simple additive scales

14.1 Variables and data types

Quantitative data analysis concerns numbers, i.e. variable quantities that we collect through various measures. Examples are survey questionnaires, tests, experimental conditions or more qualitative observations that have been transformed to numbers. Statistical variables are ***what we measure*** with various methods (e.g. survey questions, test items, observations, elements of log files), and ***what we manipulate***, e.g. two experimental conditions.

One of the main goals of statistical analysis is to summarize the structure that can be found in the data. A first step in statistical data analysis is to summarize the distribution of the variables and a second one to compute indices from several variables that measure a single theoretical concept.

Let us first recall the distinction between independent and dependant variables:

- **Independent variables** are measures or conditions that we will use to **explain** (i.e. predict) other variables
- **Dependant variables** are the ones that are explained by independent variables

Table 49: dependent vs. Independent variables

Descriptive statistics do not make a difference between these variables. It is up to you to decide which variables should explain something and what they should explain.

Types of quantitative variables

Quantitative data come in different **types** or forms. Depending on the data type you can or cannot do certain kinds of analysis. There exist three basic data types and the literature uses various names for these:

Types of measures	**Description**	**Examples**
nominal or category	enumeration of categories	male, female district A, district B, software widget A, widget B

ordinal	ordered scales	1st, 2nd, 3rd
interval or quantitative (or "scale" in SPSS)	measure with an interval	1, 10, 5, 6 (on a scale from 1-10) 180cm, 160cm, 170cm

Table 50:Taxonomy of quantitative data types

In quantitative research designs, it is not very interesting to present descriptive statistics. However, they play an important role in early stages of data analysis, e.g. you can check data distributions and make better-informed decisions about inferential data analysis techniques.

On the other hand, descriptive statistics are often used to compare different cases in comparative systems designs or they are used to summarize qualitative data in more qualitative studies. In any case, avoid filling up pages of your thesis with tons of Excel diagrams. !!

Let us recapitulate: descriptive statistics have two main roles in data analysis:

- to summarize a set of variables for comparing them across systems, e.g. compare performance in science literacy of a country with an OECD average.
- to summarize a set of data in order to help selecting appropriate techniques for analyzing relations between variables (inferential statistics)

In addition, coefficients (numbers that summarize information) of descriptive statistics are the basis for more advanced statistics, e.g. models of causal relationships or multivariate data reduction techniques.

14.2 Overview of descriptive statistics

As stated before, descriptive statistics summarize data distributions, i.e. they provide you with a summary of how values of a given variable or a set of variables occur. We could distinguish three kinds of descriptive statistical summaries, as we shall see now.

14.2.1 Coefficients that measure the centrality of variable

These coefficients measure some idea of the "most typical" or "most representative" data point. E.g. on a grading scale of 0-100, the average student might have 80 points.

- ***Mean*** also called ***average*** is the most popular measure. Computing a mean only makes sense for interval variables.
- ***Median*** is the data point that in the middle of "low" and "high" values, i.e. near 50% of the sample has higher values and another near 50% has lower values. It can be used with both interval and ordinal variables
- ***Mode*** is the most frequent value encountered, i.e. the highest point in a histogram or the biggest slice in a pie. To be used with ordinal or nominal variables.

Means are only meaningful for interval data, the median can be used for both interval and ordinal data. The mode can be used for any scale, but typically is used with ordinal and nominal data.

14.2.2 Charts

- Histograms can be used with all data types
- Pie Charts can be used as alternative to histograms, but they include less information.

We shall present some histograms below.

14.2.3 Coefficients that measure the dispersion of a variable

- The ***Standard deviation*** (SD) is the mean deviation from the mean, i.e. the average of all differences from the mean. SD is the square root of **variance.**
- The **variance** is the average of squared distances. It is used to compute complex statistics but rarely for direct interpretation. The SD is preferred since it has the same units as the original variable.
- ***High*** and ***low*** values are the extremes at both ends of an interval or ordinal scale
- ***Quartiles*** are based on the same principles as the median. They define points for 1/4 intervals (25%, 50% and 75% of the population)

14.2.4 Measures of normality

- Many statistical procedures require a so-called **normal** distribution of data. As we shall explain below, normal distributions are symmetric and have a bell-shaped curve. About 70% of the data should lie within one standard deviation (SD) of the mean and 95% should lie within two SDs.
- **Skew** or **skewness** is a tilt to the left or to the right. The skewed part is also called **tail**. According to Garson, skew should be within the +2 to -2 range when the data are normally distributed. Some authors use +1 to -1 as a more stringent criterion when normality is critical. Below is an example of a skewed distribution with a left tail of the *Self-confidence in ICT Internet tasks index* from the PISA 2006 study. The skewness coefficient is **-1.2.**

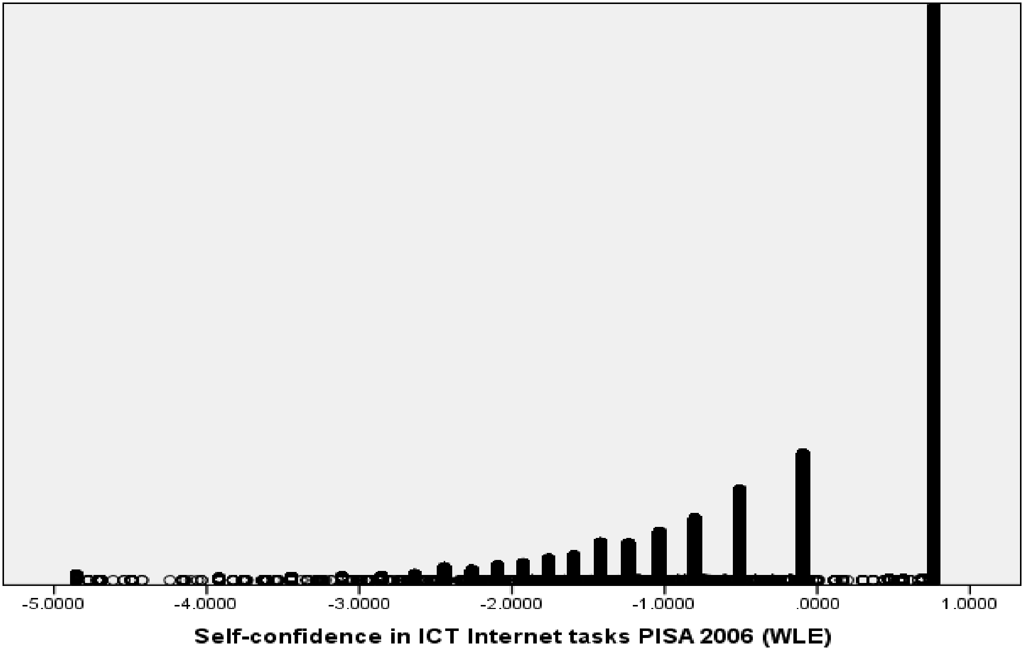


Figure 76: Skewed self-confidence in ICT Internet tasks (all countries)

This figure shows that a lot of pupils feel confident about simple Internet tasks.

- **Kurtosis** measures how "peaked" a distribution is. The popular **Fisher kurtosis** coefficient sets normality at zero. According to Garson, "*common rule-of-thumb test for normality is to run descriptive statistics to get skewness and kurtosis, then use the criterion that kurtosis should be within the +2 to -2 range when the data are normally distributed (a few authors use the more lenient +3 to -3, while other authors use +1 to -1 as a more stringent criterion when normality is critical). Negative kurtosis indicates too many cases in the tails of the distribution. Positive kurtosis indicates too few cases in the tails.*" In our example, kurtosis is **1.3**.

In the PISA 2006 examples that follow below, you will see other distributions with various kinds of skews and kurtosis.

- **Outliers** are often defined as cases that are further away from the mean than three standard deviations, but there exist other definitions. If you have small datasets (e.g. members that participate in a training course), such outliers can alter dramatically the outcomes and you should watch out for them. In huge samples that have **designed test scores** like the PISA studies, only 1.3% of students are at proficiency level 6 (708 points) in the literacy tests, i.e. about 2 standard definitions apart, and only very few are above 800 points. In other words, you do not have to worry about outliers in such studies because (a) test have been designed to have a "normal" distribution *and* the sample size is huge, eliminating the relative importance of extremes.

Below you will find the frequencies of one the science scales for all students. The black curve represents the potential "normal distribution".

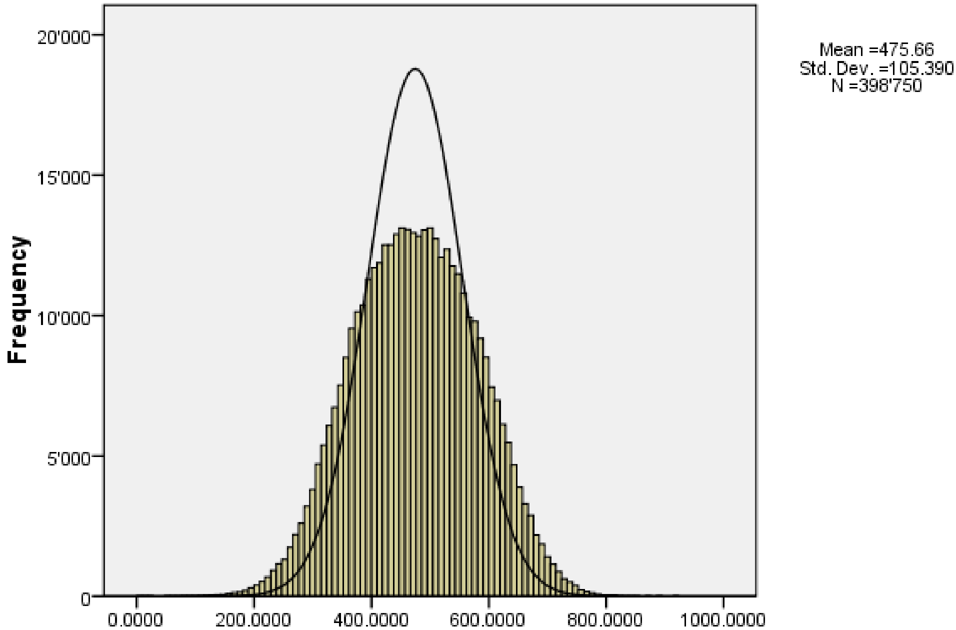


Figure 77: Plausible value in science - PISA 2006

14.2.5 Combined data and charts

A popular chart is the **boxplot**. It displays various information, like the quartiles. In addition, it will display outliers, i.e. extreme values. We shall introduce this technique in the chapter on exploratory data analysis.

14.3 Distribution example from the PISA 2006 study

We shall illustrate descriptive statistical summaries with variables from the PISA 2006 study. We extracted the Swiss students. This sub-sample included about 12'000 individuals, which is a huge sample, compared to typical studies in educational technology.

We had at look at the following survey question from the **ICT Familiarity Component** of the Student Questionnaire.

Q4 How often do you use computers for the following reasons?

(e) Use spreadsheets (e.g. <Lotus 1 2 3 ® or Microsoft Excel ®>)

Possible response items were:

Almost every day

A few times each week

Between once a week and once a month

Less than once a month

Never

In the SPSS dataset this variable is called *IC04Q05 Use spreadsheets IC4e* and the data distribution looks like this:

IC04Q05 Use spreadsheets IC4e

	Frequency	Percent	Valid Percent	Cumulative Percent
1 Almost every day	571	4.7	4.8	4.8
2 Once or twice a week	1806	14.8	15.1	19.9
3 Few times a month	3024	24.8	25.3	45.2
4 Once a month or less	3181	26.1	26.6	71.8
5 Never	3377	27.7	28.2	100.0
Total	11959	98.1	100.0	
Missing	7 N/A	10	.1	
8 Invalid	24	.2		
9 Missing	199	1.6		
Total Missing	233	1.9		
Total		12192	100.0	

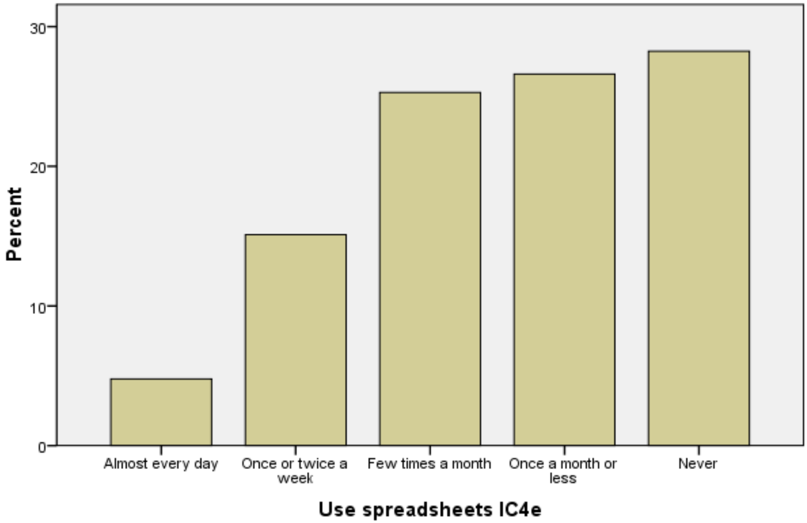
Out of 12192 pupils, 11959 answers are valid. The largest category is pupils who never used a spreadsheet (28.2%). Only very few use it often, i.e. almost every day (4.7%).

Some of the statistics are:

Statistics - IC04Q05 Use spreadsheets IC4e		
Valid N		11959
Missing		233
Mean		3.58
Median		4.00
Mode		5
Std. Deviation		1.182
Skewness		-.397
Kurtosis		-.818
Range		4
Minimum		1
Maximum		5
Sum		42864
Percentiles	25	3.00
	50	4.00
	75	5.00

The most typical pupil (media) has a score of 4, i.e. he/she uses a spreadsheet once per month or less.

Below are two kinds of histograms. A bar chart that shows response items and a frequency chart that shows some statistical information plus the expected normal distribution curve.



Histogram

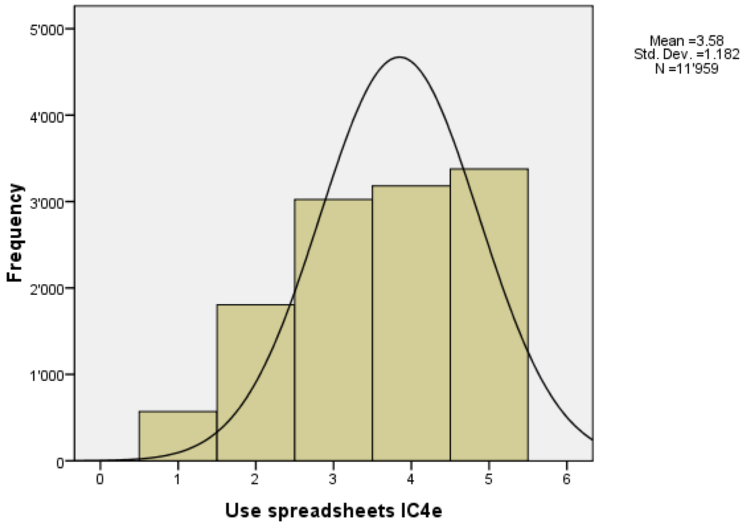


Figure 78: Use spreadsheets IC4e - PISA 2006 Swiss sample

It can be argued that some statistics like the mean, standard definition, kurtosis and skewness should not be used for ordinal variables in analysis. However, in descriptive statistics, these coefficients provide information that is useful to have. You only have to be careful when you interpret. E.g. a mean or **3.58** in using spreadsheets, means that the average user is between "few times a month" and "once per month or less", i.e. regularly but really not often. The median (**4**) is safer to interpret: The typical student uses a spreadsheet once a month or less.

It is always safer to interpret true interval data, e.g. sophisticated predictive indices that have been built from several questionnaire items and that we shall introduce below.

14.4 Data preparation

Before you start any interesting analysis work, you will have to do some preparation work, in particular

- Find and learn a statistics program
- Import the data and clean them
- Do the documentation (inside the program), .e.g. .create variable names and labels, response item names and labels, missing values and selection of data type. If you don't get this right, you will be very sorry later on ...

14.4.1 Statistics programs and data preparation

Firstly, you should select a good statistics program.

- If available, plan to use a commercial statistics program like SPSS or Statistica. This way you get both local support and access to a huge range of analysis methods.

There also exists good freeware (but these programs are slightly more difficult to use):

- IDAMS Statistical Software, which is sponsored by UNESCO

Some freeware can even do things that you cannot do with commercial software, e.g. advanced data visualization. However, these systems are rather meant for experts. E.g.:

- R is a freely available language and environment for statistical computing and graphics, which provides a wide variety of statistical and graphical techniques: linear and nonlinear modeling, statistical tests, time series analysis, classification, clustering, etc.

Do ***not use programs*** like Excel. You only lose your time since cannot even do the most simple statistics that are required for any serious work. Only use spreadsheet programs for simple data summaries like pie charts if you think that you can get away with these or if the main thrust of your thesis does not involve any kind of serious data analysis.

14.4.2 Data documentation

All statistical programs require that you document the data. The minimal documentation steps are the following:

1. Enter the data
   - Assign a number to each response item (planned when you design the questionnaire)
   - We also suggest to enter a clear code for missing values (no response), e.g. -1, but a blank can also do.
2. Make sure that your data set is complete and free of errors
   - Some simple descriptive statistics (minima, maxima, missing values, etc.) can help to detect really bad coding errors (e.g. *55* instead of '5').
3. Learn how to document the data in your statistics program
   - Enter labels for variables, labels for responses items, display instructions (e.g. decimal points to show)
   - Define data-types (interval, ordinal or nominal)

Table 51: Essential data documentation steps

14.5 Creation of composite scales (indices)

Composite scales measure one theoretical concept, e.g. *the feeling of being there* (social presence) or *confidence in ICT skills* or *use of computers in the classroom*. Such a concept cannot be measured directly and this is why they are also called ***latent variables***. To measure such “soft” implicit variables with questionnaires, several questions are asked. They then can be combined into a single composite variable, also called **index** (pl. **indices**) or **scale**.

We can distinguish between two kinds of composite scales

1. Indices that summarize not necessarily strongly correlated measures, e.g. global computer skills.
2. Indices that are unidimensional, i.e. they measure the same theoretical concept.

There exist many forms of scales and we will just discuss the simplest forms here.

14.5.1 Simple scales based on averages

Most scales are made by simply by computing the means of the different questions and that use same range of response items, e.g. a five-point scale. These are sometimes called "Likert scales".

Use the following procedure:

- Eliminate questions that have a high number of non responses
- Make sure not to take into account so-called missing values (non-responses) when you add up the responses from the different items. A real statistics program (SPSS) does that for you.

Make sure when you create your questionnaire or when you use survey data from someone else, that all questions use the same range of response items, else you will need to standardize (see below). It does not make sense to compute the means from five-point scales with items from ten-point scales!

You cannot just add up any kind of questions and declare the result to be an index of a theoretical variable. Questions that are used to compute an index should measure the same theoretical dimension or variable. Either you can theoretically justify your choice of items and/or (better) you can demonstrate that questions strongly correlate. We shall come back to this quality issue shortly.

14.5.2 Standardized z-score scales

Sometimes you will have to use standardized scales. One popular standardization formula is the "Z-transformation" and that will produce the so-called **standard score**, also called z-values, z-scores, normal scores, and standardized variables. The formula to compute a standard score for an individual is the following:

standard score = deviation score of individual / standard deviation standard score = (X_i - mean) / standard deviation

Standard scores can be easily compared, because the standard score indicates how far from an average a particular score is in terms of standard deviation.

The mean (average) is always 0

The standard deviation is always 1

In other words, standard scores show how much an individual is different in terms of the global distribution. This deviation or difference is expressed in terms of N standard deviations. E.g. a score of 2 means that a given individual is 2 standard deviations above the average individual in the sample.

Figure 79 (from Wikipedia) compares the various measures of the normal distribution: standard deviations, cumulative percentages, Z-scores, and T-scores. This figure tells that 70% of the population is found within the range of the standard deviation. Above +1 SD an individual is in the top 15% and that below -1 SD she/he is in the lowest 15%. Z-scores should typically range from -3 to 3.

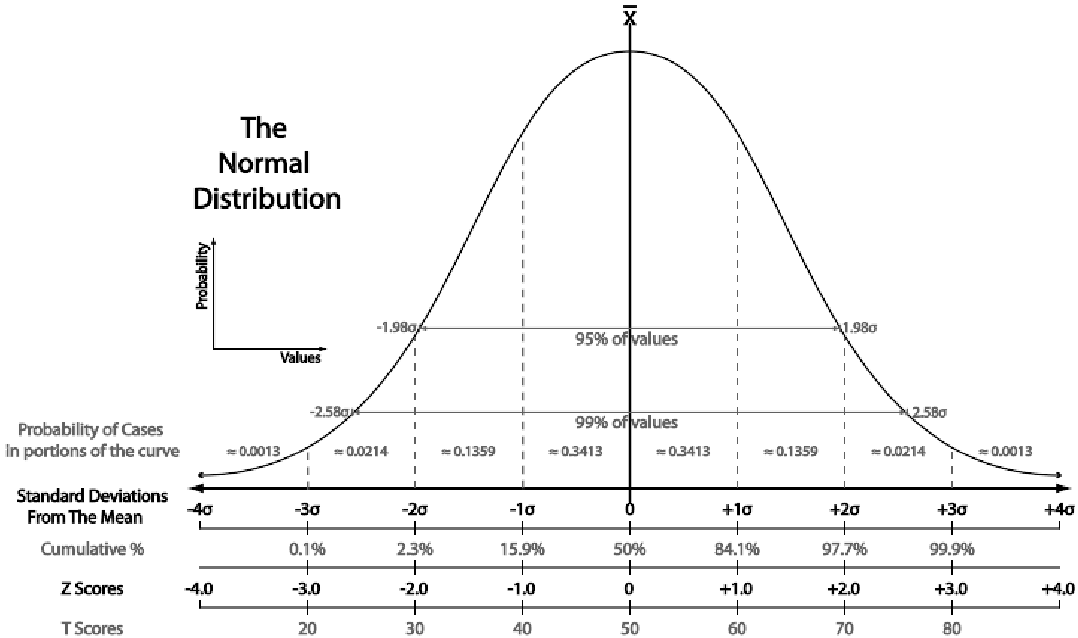


Figure 79: The normal distribution (Wikipedia)

People may find it difficult to think in terms of mean=0 and standard deviation=1 and there exist esthetic variations like the **T scores**. T scores are computed with the following formula and are used with the hope that people will understand it better with reference to the familiar "percent" schema.

T=z*10+50

The mean is 50 and the standard deviation is 10. The PISA 2006 study used a similar test score schema with a mean=500 and a standard deviation=100.

Remarks:

- It is important to understand that many statistical methods assume that data is normally distributed. These are called **parametric**. Non-parametric statistics do not require assumptions about the data distribution.
- Standard scores keep kurtosis and skewness, i.e. parametric statistical analysis will lead to the same results whether you standardize or not. Standardization of variables with different scales however is mandatory to compute composite scales or cluster analysis.
- In the US, standard scores are used to compare students from different schools because in some schools there is so-called grade inflation (typical scores only vary between B and A) and in others it is not the case.
- When distributions are very different from normal, (e.g. a J-shaped curve), other standardization methods might be used, since the z-transformation assumes that the mean and standard deviation correctly describes centrality (the typical individual) and dispersion (the typical deviation of individuals).

14.5.3 The quality of a scale

Again, we would like to repeat that you should use a ***published set of items to measure a variabl***e (if available). If you do, you can avoid making long justifications!

A first criterion is **sensitivity**: questionnaire scores should discriminate. For example, if exploratory research has shown higher degree of presence in one kind of learning environment than in another one, results of a presence questionnaire should demonstrate this.

A second criterion is **unidimensionality** (a kind of scale reliability): Internal consistency between items used to build a scale that measures the **same latent variable** (theoretical concept) must be high. There exist several methods to test this. The most popular is **Cronbach's alpha**. It measures the extent to which item responses correlate with each other. According to Garson, *"If alpha is greater than or equal to .6, then the items are considered unidimensional and may be combined in an index or scale. Some researchers use the more stringent cutoff of .7"*.

A third criterion relates to **construct validity**: results obtained with the questionnaire can be tied to other measures, i.e. similar to results obtained by other tools (e.g. in depth interviews). In addition, results should correlate with similar quantitative variables.

Example 58. The COLLES Instrument

The Constructivist On-Line Learning Environment Surveys (COLLES) we already introduced, measures the user experience in a teaching unit. It includes 24 statements measuring 6 dimensions.

- We only show the first two (i.e. four questions concerning relevance and four questions concerning reflection).
- Remark: In the real questionnaire, you do not show labels like "Items concerning relevance" or "response codes".

Statements	**Almost Never**	**Seldom**	**Some-times**	**Often**	**Almost Always**
response codes	**1**	**2**	**3**	**4**	**5**
Items concerning relevance					
a. my learning focuses on issues that interest me.	O	O	O	O	O
b. what I learn is important for my prof. practice as a trainer.	O	O	O	O	O
c. I learn how to improve my professional practice as a trainer.	O	O	O	O	O
d. what I learn connects well with my prof. practice as a trainer.	O	O	O	O	O

Items concerning Reflection					
... I think critically about how I learn.	O	O	O	O	O
... I think critically about my own ideas.	O	O	O	O	O
... I think critically about other students' ideas.	O	O	O	O	O
... I think critically about ideas in the readings.	O	O	O	O	O

The algorithm to compute each scale is simple: For each individual, add the response codes and divide by number of items you have. Make **sure** that you do not add "missing values" Therefore, a better method is to use a ***mean function*** in your software package since it automatically will take into account the fact that you may have missing values:

Relevance = mean (a, b, c, d)

Example - Individual A, who answered a=sometimes, b=often, c=almost always, d= often gives:

(3 + 4 + 5 + 4) / 4 = 4

Example - Individual B, who answered a=sometimes, b=often, c=almost always, d=missing gives:

(3 + 4 + 5) / 3 = 4

and certainly ***not***:

(3 + 4 + 5 + 0) / 4 or (3 + 4 + 5 -1) / 4

Scales construction is easy if you know how to use your statistics program. E.g. in SPSS you find the variable computing tool in menu: *Transform -> Compute Variable.*

14.5.4 Weighted maximum likelihood scales

There exist more complex models to construct scales, and in particular the ones used in ***item response theory***. A typical research example is the so-called Programme for International Student Assessment (PISA). PISA studies take place every three years and collect information about 15-year-old students in participating countries. Its main purpose is to find out how well students are prepared to meet the challenges of the future, rather than how well they master particular curricula. (OECD 2009, foreword).

PISA assessment produces two kinds of data:

1. Assessment of **literacy** in various domains (cognitive items), e.g. PISA 2006 covered reading, mathematics and science. The main study also included attitudinal questions.
2. ***Contextual data*** (student background questionnaire, school questionnaire and optional parents questionnaire)

   "The PISA 2006 context questionnaires included numerous items on student characteristics, student family background, student perceptions, school characteristics and perceptions of school principals. In 16 countries (optional) parent questionnaires were administered to the parents of the tested students. Some of the items were designed to be used in analyses as single items (for example, gender). However, most questionnaire items were designed to be combined in some way so as to measure latent constructs that cannot be observed directly. For these items, transformations or scaling procedures are needed to construct meaningful indices" (OECD 2009: 304).

To compute indices, PISA employs scaling models based on item response theory (IRT) methodologies. This **item response modeling** is based on so-called **weighted likelihood estimates**, which are difficult to understand. We shall just report the general principle here.

> *"The relative ability of students taking a particular test can be estimated by considering the proportion of test items they get correct. The relative difficulty of items in a test can be estimated by considering the proportion of test takers getting each item correct. The mathematical model employed to analyse PISA data, generated from a rotated test design in which students take different but overlapping tasks, is implemented through test analysis software that uses iterative procedures to simultaneously estimate the likelihood that a particular person will respond correctly to a given test item, and the likelihood that a particular test item will be answered correctly by a given student. The result of these*

procedures is a set of estimates that enables a continuum to be defined, which is a realisation of the variable of interest. On that continuum it is possible to estimate the location of individual students, thereby seeing how much of the literacy variable they demonstrate, and it is possible to estimate the location of individual test items, thereby seeing how much of the literacy variable each item embodies. This continuum is referred to as the overall PISA literacy scale in the relevant test domain of reading, mathematics or science. [...]

For each of these literacy variables, one or more scales are defined, which stretch from very low levels of literacy through to very high levels. When thinking about what such a scale means in terms of student proficiency, it can be observed that a student whose ability estimate places them at a certain point on the PISA literacy scale would most likely be able to successfully complete tasks at or below that location, and increasingly more likely to complete tasks located at progressively lower points on the scale, but would be less likely to be able to complete tasks above that point, and increasingly less likely to complete tasks located at progressively higher points on the scale." (OECD 2009:284)

PISA 2006 then used two kinds of scales.

(1) PISA test scales are normalized with a mean of 500 and a standard deviation of 100, e.g. some kind of variant of the T score scale. These are also called **PISA scales.** For example, the *scientific literacy performance* measures some kind of overall science performance, but not just that. It also encapsulates a model of a multi-factor model of domain-related cognitive competences. The scale takes into account:

- the degree to which the transfer and application of knowledge is required
- the degree of cognitive demand required to analyze the presented situation and synthesize an appropriate answer:
- the degree of analysis needed to answer the question
- the degree of complexity needed to solve the problem presented:
- the degree of complexity needed to solve the problem presented
- the degree of synthesis needed to answer the question

For each of these factors exist test items that measure various levels of difficulty. E.g. the difficult 717 points *S485Q05(2) Acid Rain* test requires that "*the reason for a control in an investigation is understood and explicitly recognised. An ability to understand the modelling in the investigation is a pre-requisite.*" (OECD 2009: 291). At the other end, the low level 399 points *S213Q02 Clothes* test requires that "*Can select the correct apparatus to measure an electric current.*". These PISA scales then are divided into 6 bands (levels) to help with standardized interpretation of national scores for example.

Scientific literacy performance band definitions on the PISA scale:

Level	Score points on the PISA scale
6	Above 707.9
5	633.3 to 707.9
4	558.7 to 633.3
3	484.1 to 558.7
2	409.5 to 484.1
1	334.9 to 409.5

The distribution of subjects follows a bell-shaped normal curve, e.g. only 1.3% reach level 6 (above 707.9) points.

(2) Some contextual indices were built through simple arithmetical transformations (e.g. averages).

(3) Most contextual indices were computed again through IRT scaling technology using weighted likelihood estimates (logits). Questionnaire items were either dichotomous or Likert-type (typically with four or five response items). These indices were normalized around the mean of 0 of all OECD countries with a standard deviation of 1. Again, we shall not explain how these scales were computed, but we just will present an example below that concern familiarity with ICT.

Example 59. PISA 2006 ICT familiarity

“The ICT familiarity questionnaire was an optional instrument administered which was administered in 40 of the participating countries in PISA 2006, for which four scaled indices were computed.” (PISA 2006 Technical Report, OECD 2009). We shall discuss this example in detail, also with the purpose to show again what questionnaire items could be use to construct index variables (scales that measure theoretical variables)

These scales were made with logit (weighted maxium likelihood estimations, WLE). They were standardized as standard scale with the OECD mean = 0 and OECD SD = 1.

Values from the questionnaire have been inverted, so that higher values are "better". Inverting means, that the lowest value of a scale becomes the highest and the other way round as shown in the following example, a questionnaire item about "browsing Internet". Usually one would design a questionnaire so that responses are in the "right" order, i.e. "high scores" are associated with "high values".

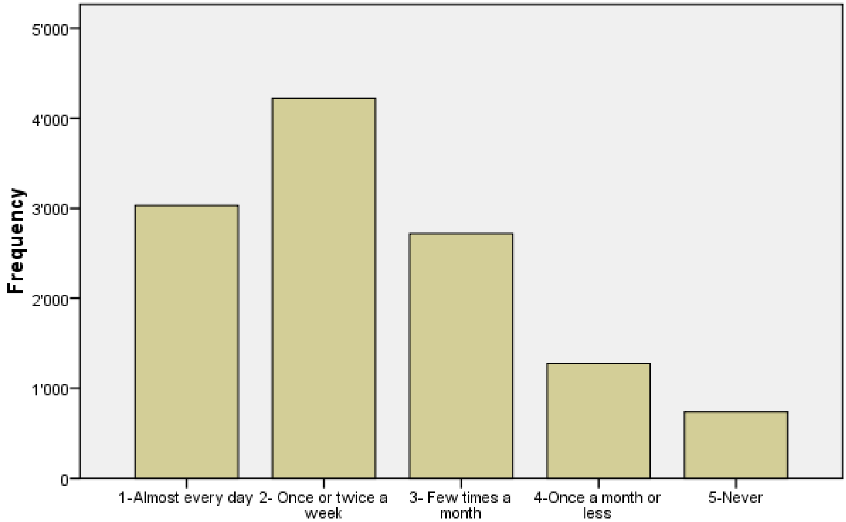


Figure 80: Browse Internet (before inverting)

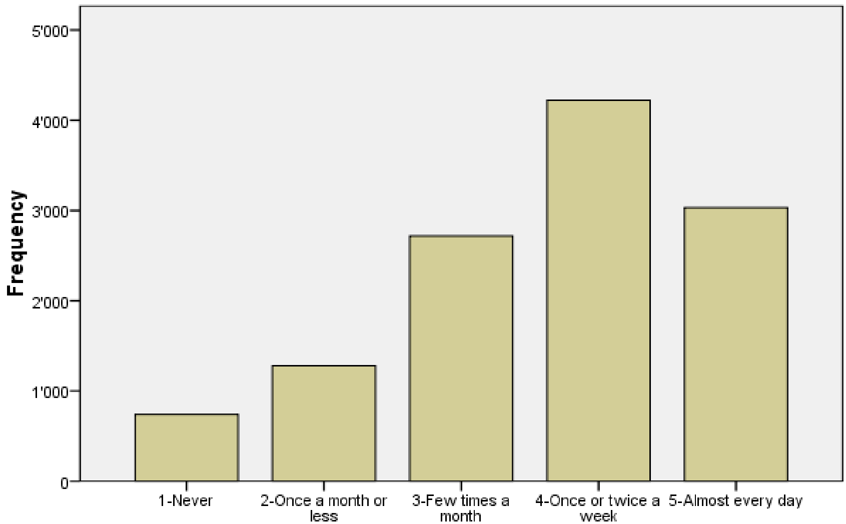


Figure 81: Browse Internet (after inverting)

For these inverted response items, four indices have been computed:

- ICT Internet/entertainment use (INTUSE).
- ICT program/software use (PRGUSE)
- Self-confidence in ICT Internet tasks (INTCONF)
- self-confidence in high-level ICT tasks (HIGHCONF)

These indices can be used to compare countries or other subpopulations. We shall shortly present the four indices below and point out some interesting differences in the distribution.

ICT Internet/entertainment use

One of the indexes (composite scale) computed was the **ICT Internet/entertainment use** (INTUSE). It includes six question items with the following wording:

IC04Q01 a) Browse the Internet for information about people, things, or ideas

IC04Q02 b) Play games

IC04Q04 d) Use the Internet to collaborate with a group or team

IC04Q06 f) Download software from the Internet to (including games) 0.43

IC04Q09 i) Download music from the Internet

IC04Q11 k) For communication (e.g. e-mail or chat rooms)

Each item was measured with a five-point scale:

(1) Almost every day

(2) Once or twice a week

(3) A few times a month

(4) Once a month or less

(5) Never

Figure 82 shows the frequency distribution. As you can see, the distribution is fairly "bell shaped", but there are some extremes to the left (almost never) and the right (very often). From this type of index, it is not possible to know how exactly how the various questions items contributed. Also the data points from -4/+4 cannot be translated to individual question scores. They represent OECD **standard deviations**. E.g. a value of 3.5 means that a student has a score 3.5 times ***OECD standard deviations*** higher than the mean. In other words, a very brilliant student.

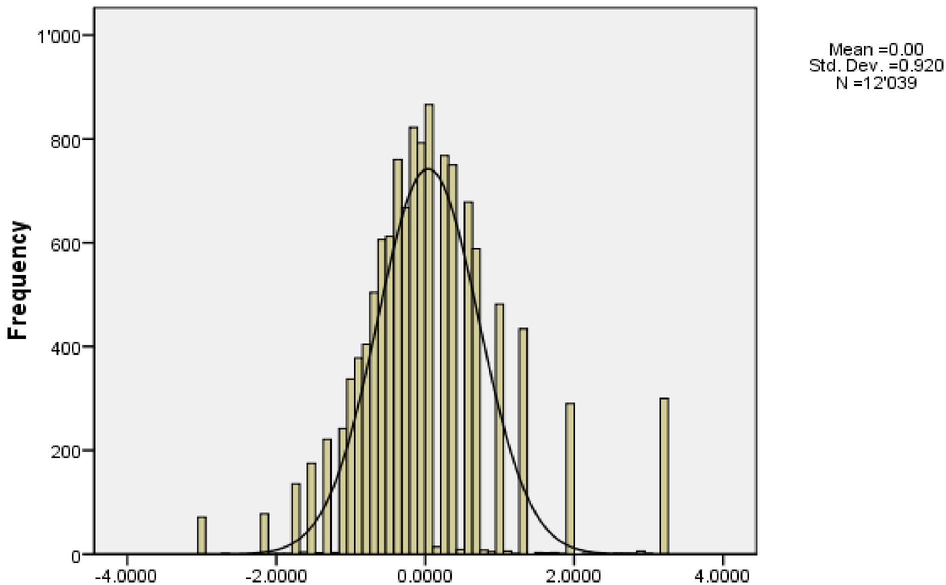


Figure 82: Internet/entertainment use PISA 2006 (WLE)

Statistics		
INTUSE ICT Internet/entertainment use PISA 2006 (WLE)		
N	Valid	12039
N	Missing	153
Mean		-.001633

Median		-.143800
Mode		.0889
Std. Deviation		.9198212
Skewness		.841
Kurtosis		2.712
Range		6.2201
Minimum		-3.0404
Maximum		3.1797
Sum		-19.6627
Percentiles	25	-.555500
	50	-.143800
	75	.363400

In many studies, the simpler method of computing the mean between of the questionnaire items is used. Statistically speaking this is a less good solution, since the response items (*Almost every day*, *Once or twice a week*, *A few times a month*, *Once a month or less*, *never*) form a typical ordinal scale. It therefore is argued that the mean is not an optional descriptor of the centrality of an individual's responses. On the other hand, computing a simple mean is much easier. In this case, the difference between the two indices is not too important and they are highly correlated (r=.933). However, taking the simple mean creates a "flatter" curve.

Correlations

		INTUSE ICT Internet/entertainment use PISA 2006 (WLE)	INTUSE_MEANS ICT Internet/entertainment use PISA 2006 (Means)
INTUSE ICT Internet/entertainment use PISA 2006 (WLE)	Pearson Correlation	1	**.933**
	Sig. (2-tailed)		.000
	N	12039	12039
INTUSE_MEANS ICT Internet/entertainment use PISA 2006 (Means)	Pearson Correlation	**.933**	1
	Sig. (2-tailed)	.000	
	N	12039	12039

Below you can find the summary statistics and the histogram for the *INTUSE_MEANS ICT Internet/entertainment use PISA 2006 (Means)* index variable.

Statistics		
INTUSE_MEANS ICT Internet/entertainment use PISA 2006 (Means)		
N	Valid	12039
N	Missing	153
Mean		3.3448
Median		3.4000
Mode		3.67
Std. Deviation		.92046
Variance		.847
Skewness		-.309
Kurtosis		-.549
Range		4.00
Minimum		1.00
Maximum		5.00
Percentiles	25	2.6667
	50	3.4000
	75	4.0000

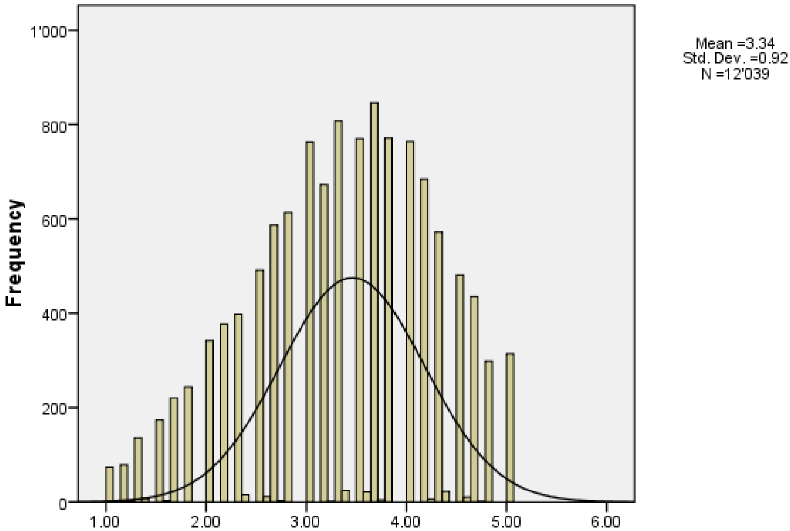


Figure 83: Internet/entertainment use PISA 2006 (Means)

The typical student has a score of 3.4 (median) and the average student of 3.3 (mean. This translates roughly by "several times per week" a student uses Internet for entertainment use. There were 6 questions from "Browse the Internet about people etc" to "For communication". If a respondent answers for each something like *Once or twice a week* or *A few times a month* he/she will get that kind of average, but we do not know for sure. The same student could do some activities *almost every day* and other activities much less.

In order to make sure that a battery of question items measures the same theoretical construct (i.e. Internet use for entertainment purposes), one can compute a coefficient that is called Cronbach's alpha. In our case, the alpha is **0.725**, which is sufficient but not great.

6.2 ICT program/software use

Items for the **ICT program/software use** (PRGUSE) index, used the same response items as INTUSE and include five questions:

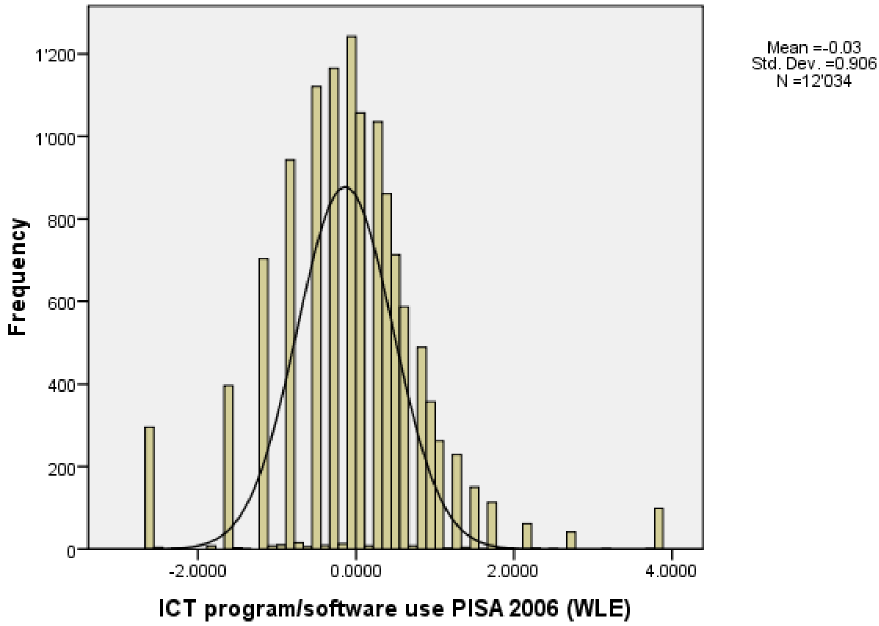
IC04Q03 c) Write documents (e.g. with <Word or WordPerfect>

IC04Q05 e) Use spreadsheets (e.g. <Lotus 1 2 3 or Microsoft Excel®>)

IC04Q07 g) Drawing, painting or using graphics programs

IC04Q08 h) Use educational software such as Mathematics programs

IC04Q10 j) Writing computer programs



Statistics		
PRGUSE ICT program/software use PISA 2006 (WLE)		
N	Valid	12034
N	Missing	158

Mean		-.025253
Median		.077700
Mode		-.0969
Std. Deviation		.9063436
Skewness		.220
Kurtosis		2.788
Range		6.4050
Minimum		-2.5771
Maximum		3.8279
Sum		-303.8948
Percentiles	25	-.526100
	50	.077700
	75	.521700

6.3 Self-confidence in ICT Internet tasks

A third index was computed for **self-confidence in ICT Internet tasks** (INTCONF). The items were measured with a four point scale again

1. I can do this very well by myself
2. I can do this with help from someone
3. I know what this means but I cannot do it
4. I don't know what this means

The questions entering the index were:

IC05Q01 a) Chat online

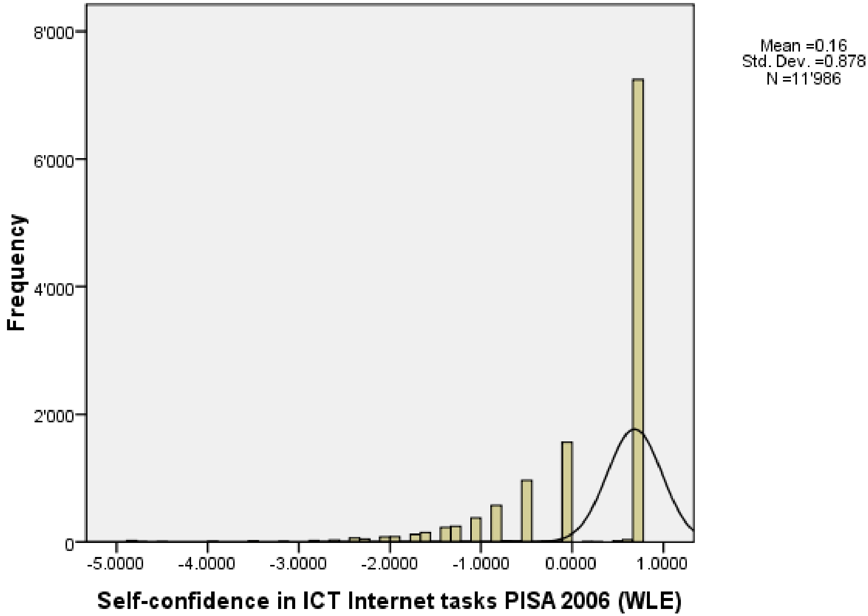
IC05Q07 g) Search the Internet for information

IC05Q08 h) Download files or programs from the Internet

IC05Q09 i) Attach a file to an e-mail message

IC05Q13 m) Download music from the Internet

IC05Q15 o) Write and send e-mails



Statistics		
INTCONF Self-confidence in ICT Internet tasks PISA 2006 (WLE)		
N	Valid	11986
N	Missing	206
Mean		.164309
Median		.763800
Mode		.7638
Std. Deviation		.8781368
Skewness		-1.569
Kurtosis		2.809
Range		5.6179
Minimum		-4.8541
Maximum		.7638
Sum		1969.4109

These data suggest that most of the population has a **similar** level. The median (.76) is much higher than the mean (.16). This also suggests that some part of the population has real trouble compared to the "typical" population. This INTCONF index, however does not tell much about how to interpret absolute values. A simple additive scale like the one we computed above would be more useful. Since the INTCONF is scaled with respect to the OECD mean, we can however compare countries both in terms of centrality and distribution patterns.

6.4 self-confidence in high-level ICT tasks

Finally, **self-confidence in high-level ICT tasks** (HIGHCONF) was measured with the following questions using the same response items as INTCONF.

IC05Q02 b) Use software to find and get rid of computer viruses

IC05Q03 c) Edit digital photographs or other graphic images 1.01

IC05Q04 d) Create a database (e.g. using <Microsoft Access>)

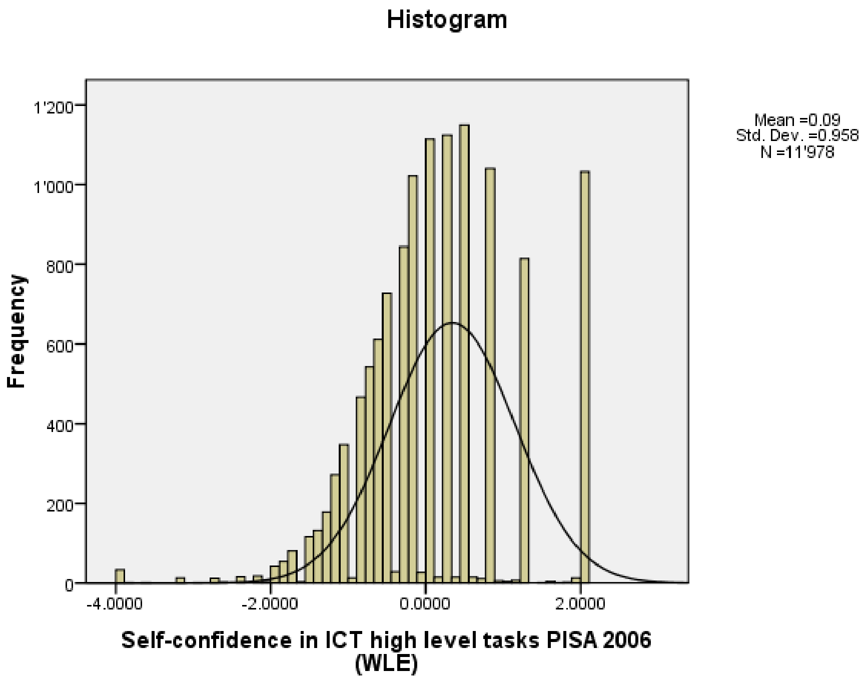
IC05Q10 j) Use a word processor (e.g. to write an essay for school)

IC05Q11 k) Use a spreadsheet to plot a graph

IC05Q12 l) Create a presentation (e.g. using <Microsoft PowerPoint>)

IC05Q14 n) Create a multi-media presentation (with sound, pictures, video)

IC05Q16 p) Construct a web page



Statistics		
HIGHCONF Self-confidence in ICT high level tasks PISA 2006 (WLE)		
N	Valid	11978
N	Missing	214
Mean		.094825
Median		.039400
Mode		.4864
Std. Deviation		.9579116
Skewness		.156
Kurtosis		.793
Range		6.0901
Minimum		-3.9905
Maximum		2.0996
Sum		1135.8184

These scales are fairly well correlated, as we shall discuss in the article on exploratory data analysis.

14.6 Summary

Descriptive data analysis techniques are mostly used to prepare further analysis.

However, they may be used as evidence in more qualitative field studies or comparative systems designs.

Review questions

1. What is the difference between a mean and a median? Which is more representative of the typical case?
2. Which coefficients can be used to detect non-normal distributions?
3. When is it mandatory to use z-scores in analysis?
4. List the three major data types.

Review case study

1. Download the PISA 2006 results from http://www.pisa.oecd.org/
2. Compare student performance in science between Jordan, Quatar and Tunisia. Explain what kind of information you used and justify.
3. Remark: This exercise also requires from you that you are able to identify

the appropriate document on a web site.

15 Quantitative data analysis

This chapter introduces simple bivariate statistics. The purpose of so-called inferential statistics is to test relationships between two or more variables. We shall present the three most popular methods for analyzing relationships between two variables.

Learning goals

- Understand the importance of data assumptions and the bad influence of outliers.
- Understand the "finding structure" principle of statistical data analysis
- Be able to identify the major stages of (simple) statistical analysis
- Know the difference between the four kinds of statistical coefficients
- Be able to select a procedure for bivariate analysis according to data types
- Be able to interpret and create crosstabulations
- Be able to understand and create analysis of variance
- Be able to create and understand simple regression analysis

15.1 Scales and data assumptions

Quantitative data come in different ***types*** as we have seen in the previous chapter. Let us recall the three data types:

- nominal, i.e. categorized observations (e.g. country names)
- ordinal, i.e. rankings
- interval, i.e. quantitative scaled observations (e.g. a test score)

For each combinations of types of measures, you will have to use particular analysis techniques. In other words, most statistical procedures only work with certain kinds of data types. There is a bigger choice of statistical techniques for quantitative (interval) variables. Therefore scales like (1) strongly agree, (2) agree, (3) somewhat agree, etc. usually are treated as interval variables, although it is not very correct to do so.

Data types are not the only technical constraints for the selection of a statistical procedure, sample size and data assumptions are others. Let us now introduce the so-called ***data assumptions***. In addition to their data types, many statistical analysis types only work for given sets of data distributions and relations between variables. In practical terms this means that not only you have to adapt your analysis techniques to types of measures but you also (roughly) should respect other data assumptions.

Linearity

A most frequent assumption about relations between variables is that the relationships are linear.

In Figure 84, the relationship is non-linear: students that show little daily computer use have bad grades, but so do the ones that show very strong use.

Popular measures like the Pearson's r correlation will not work, i.e. it will show a very weak correlation and therefore you will miss this non-linear relationship.

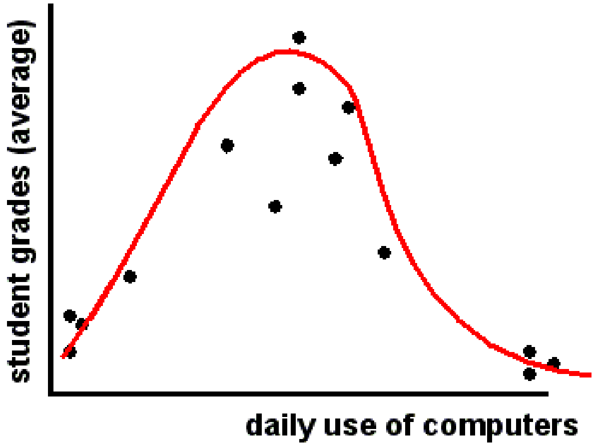


Figure 84: Non-linear relationship

Normal distribution

Most methods for interval data also require a so-called *normal distribution* (see the previous chapter). If your data include "extreme cases" and/or is skewed (asymmetrical), some individuals will have much more weight than the others will.

Hypothetical example:

- Because of the extreme student in the graph to the left (red) who uses the computer for very long hours we will obtain a positive correlation and a positive regression rate, whereas all the other data points suggest an inexistent correlation. Mean use of computers does not represent "typical" usage in this case, since the "red student" pulls the mean "upwards".

- The extreme student in the picture to the right (green dot) will not have a major impact on the result, since the other data are well distributed along the two axes. In this second case, the mean represents a typical student.

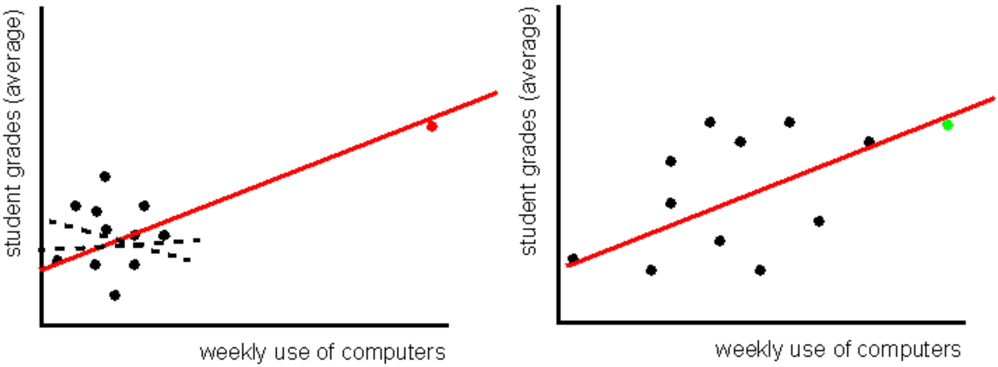


Figure 85: Effect of extreme values in non-normal vs. normal distributions

In addition, you also should understand that extreme values already have more weight with variance-based analysis methods (i.e. Regression analysis, Anova, Factor analysis, etc.) since distances are computed as squares.

15.2 Basic principles of statistical analysis

15.2.1 Finding structure

The goal of statistical analysis is quite simple: ***find/prove structure in the data***. We can express this principle with two synonymous formulas:

DATA = STRUCTURE + NON-STRUCTURE

DATA = EXPLAINED VARIANCE + NOT EXPLAINED VARIANCE

DATA = RELATION + NOT EXPLAINED VARIANCE

Example: Simple regression analysis

DATA = *predicted* regression line + *residuals* (unexplained noise)

Regression analysis tries to find a line that will maximize prediction and minimize residuals.

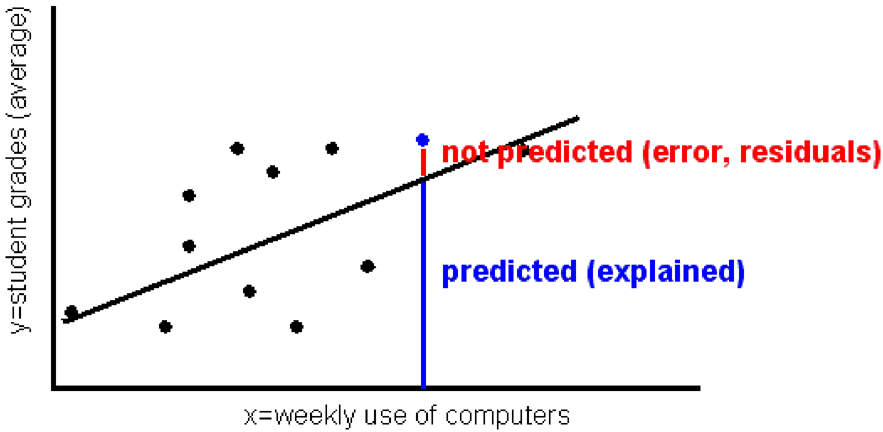


Figure 86: Structure in regression analysis

15.2.2 Stages of statistical analysis

Let us have look of what we mean be statistical analysis and what you typically have to do. We already discussed the first few steps in the previous chapter and we shall come back to most other stages throughout this chapter:

1. Clean your data
   - Make very sure that your data are correct (e.g. check data transcription)
   - Make very sure that missing values (e.g. not answered questions in a survey) are clearly identified as missing data
2. Gain knowledge about your data
   - Make lists of data (for small data sets only!)
   - Produce descriptive statistics, e.g. means, standard-deviations, minima, maxima for each variable
   - Produce graphics, e.g. histograms or box plot that show the distribution
3. Produce composed scales
   - E.g. create a single index variable by computing the mean from set of questions
4. Make graphics or tables that show relationships
   - E.g. Scatter plots for interval data (as in our previous examples) or cross-tabulations
5. Calculate coefficients that measure the strength and the structure of a relation
   - Strength examples: Cramer's V for cross-tabulations, or Pearson's R for interval data
   - Structure examples: regression coefficient, tables of means in analysis of variance
6. Calculate coefficients that describe the percentage of variance explained
   - E.g. R^2 in a regression analysis or Eta^2 in analysis of variance
7. Compute the significance level, i.e. find out if you have to right to interpret the relation
   - E.g. Chi^2 for crosstabs, Fisher's F in regression analysis

Table 52: Main stages of statistical analysis

Remark: With a good statistical data analysis programs, you easily can do several steps in one operation.

15.2.3 Types of statistical coefficients

Each statistical analysis produces various kinds of coefficients, i.e. numbers that will summarize certain kinds of information. Always make sure to use only coefficients that are appropriate for your data. There are four big kinds of coefficients and you will find these in most analysis methods:

Type of coefficient	
1. Strength of a relation	Coefficients usually range from -1 (total negative relationship) to +1 (total positive relationship). 0 means no relationship.
2. Structure (tendency) of a relation	Summarizes a trend
3. Percentage of variance explained	Tells how much structure is in your model
4. Significance level of your model	Computes the chance that your relationship is a random distribution, i.e. that there is no relationship between variables. Typically, in the social sciences a sig. level lower than 5% (0.05) is acceptable. Do not interpret data that is above!

Table 53: Types of statistical coefficients

These four types are mathematically connected: E.g., the significance level is not just dependent on the size of your sample, but also on the strength of a relation.

15.2.4 Overview of statistical methods

Statistical data analysis methods can be categorized according to data types. The following table shows popular bivariate analysis methods for a given independent (explaining) variable X and a dependent (to be explained) variable Y.

		Dependant variable Y	
		Quantitative (interval)	**Qualitative (nominal or ordinal)**
Independent (explaining) variable X	**Quantitative**	Correlation and Regression	Logistic regression , or transform X into a qualitative variable and see below
	Qualitative	Analysis of variance	Crosstabulations

Table 54: Popular bivariate statistical methods

A similar table can be made for multivariate analysis and that we shall not introduce here.

		Dependant variable Y	
		Quantitative (interval)	**Qualitative (nominal or ordinal)**
Independent (explaining) variable X	**Quantitative**	Factor Analysis, multiple regression, SEM, Cluster Analysis,	Logit, or transform X into qualitative variables and see below or split a variable into several dichotomic (yes/no) variables and see to the left.
	Qualitative	Anova	Multidimensional scaling etc.

Table 55: Popular multivariate analysis

15.3 Crosstabulation

Crosstabulation is a popular technique to study relationships between normal (categorical) or ordinal variables Crosstabulation is simple, but beginners get it often wrong. You do have to remember the basic objective of simple data analysis:

Explain variable Y with variable X.

= explain variance of variable Y with variance of variable X

= show co-variance

For crosstabulations, this will translate like this:

Given that $X=x_1$ what is the chance that $Y=y_1$, $Y=y_2$, etc.

Given that $X=x_2$ what is the chance that $Y=y_1$, $Y=y_2$, etc.

Since you want to know the probability that a value of X leads to a value of Y, you will have to compute percentages, as we shall explain below.

In a tabulation, the X variable is usually put on top (i.e. its values show in columns) but you can do it the other way round. Just make sure that you get the percentages right!

Steps to compute percentages

1. Compute percentages across each item of X (i.e. "what is the probability that a value of X leads to a value of Y")
2. Then compare (interpret) percentages across each item of the dependant (to be explained) variable

Let us recall the simple experimentation paradigm in which most statistical analysis is grounded since research is about comparison. Note: X is put to the left (not on top):

Treatment	effect (O)	non-effect (O)	Total effect for a group
treatment: (group X)	bigger	smaller	100 %
non-treatment: (group non-X)	smaller	bigger	100 %

You have to interpret this table in the following way: The chance that a treatment (X) leads to a given effect (Y) is higher than the chance that a non-treatment (non-X) will have this effect. We shall present a real statistical cross-tabulation example below.

Statistical coefficients for cross-tabulation

Let us first discuss a few coefficients that can summarize the strength of a relation:

- ***Phi*** is a chi-square based measure of association and is usually used for 2x2 tables
- The ***Contingency Coefficient*** (Pearson's C) is an adjustment to Phi, intended to adapt it to tables larger than 2-by-2.
- ***Somers' D*** is a popular coefficient for ordinal measures (both X and Y). There exist two variants: "Symmetric" and "Y dependant on X".

There exist several statistical significance tests:

- ***Pearson's chi-square*** based test is by far the most common. This statistic is used to test the null hypothesis, i.e.no association of columns and rows in tabular data. It can be used with nominal data.

In SPSS:

- You find crosstabs under menu: *Analyze->Descriptive statistics->Crosstabs*
- You then can select percentages in "Cells" and coefficients in "statistics". This will make it "inferential", not just "descriptive".

Example 60. Crosstabulation – ICT training X presentation software

We want to know if ICT training will explain use of presentation software in the classroom. These variables are measured with two survey questions:

1. Did you receive some formal ICT training?
2. Do you use a computer to prepare slides for classroom presentations?

Now let us examine the results shown in the table below.

			X= Did you receive some formal ICT training?		Total
			No	Yes	
Y= Do you use a computer to prepare slides for classroom presentations?	Regularly	Count	4	45	49
		% within X	**44.4%**	**58.4%**	57.0%
	Occasionally	Count	4	21	25
		% within X	**44.4%**	**27.3%**	29.1%
	2 Never	Count	1	11	12
		% within X	**11.1%**	**14.3%**	14.0%
	Total	Count	9	77	86
		% within X	**100.0%**	**100.0%**	100.0%

The probability that computer training ("Yes") leads to superior usage of the computer to prepare documents is very weak (you can see this by comparing the percentages line by line.

The statistics tell the same story:

- Pearson Chi-Square is 1.15 with a significance level of .562. This means that the likelihood of results being random is > 50% and you have to reject the relationship
- Contingency coefficient = 0.115, significance = .562. (same result)

Therefore, we can conclude: Not only is the relationship very weak, but it cannot be interpreted. In other words, there is absolutely no way to assert that ICT training leads to more frequent use of presentation software.

Example 61. Crosstabulation – Teachers beliefs X classroom activities

We want to know if teachers' agreement with the belief *that students will gain autonomy when using Internet resources* will have an influence on classroom practice. For instance, will a teacher organize more activities where learners have to search information on the Internet, if s/he believes that Internet use can favor autonomy? We have two variables.

- X = Teachers' agreement with: *Learners will gain autonomy through using Internet resources*
- Y = Teachers' classroom activity: Search information on the Internet

			X= Learners will gain autonomy through using Internet resources (teacher agreement)				
			0 Fully disagree	1 Rather disagree	2 Rather agree	3 Fully agree	Total
Y= Search information on the Internet (teacher practice)	0 Regularly	Count	0	2	9	11	22
		% within X	**.0%**	**18.2%**	**19.6%**	**42.3%**	**25.6%**
	1 Occasionally	Count	1	7	23	11	42
		% within X	**33.3%**	**63.6%**	**50.0%**	**42.3%**	**48.8%**
	2 Never	Count	2	2	14	4	22
		% within X	**66.7%**	**18.2%**	**30.4%**	**15.4%**	**25.6%**
	Total	Count	3	11	46	26	86
		% within X	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Results show a weak and significant relationship: the more teachers agree that students will increase learning autonomy from using Internet resources, the more is it likely that they will let students use Internet in the classroom.

The statistical coefficient we use is "Directional Ordinal by Ordinal Measures" with Somer's D":

Values	**Somer's D**	**Significance**
Symmetric	-.210	.025
Y = Search information on the Internet - Dependent	-.215	.025

Therefore, teacher's beliefs explain somewhat why they let students use the Internet, but the relationship is very weak (Somer’s D=0.21)

15.4 Simple analysis of variance

Analysis of variance (and it is multivariate variant Anova) are the favorite tools of the experimentalists. It is also popular in quasi-experimental research and survey research as the following example shows.

Example: Does presence or absence of ICT usage influence grades?

- X has an influence on Y, if the means achieved by different groups (e.g. ICT vs. non-ICT users) are significantly different.

X is an experimental condition (therefore a nominal variable) and Y usually is an interval variable. Significance improves when:

- Means of the X groups are different (the further apart the better)
- Variance inside X groups is low (certainly lower than the overall variance), in other words: groups should be homogenous

There are three important statistical coefficients:

- **Standard deviations** for **each group** and for **the global sample**: As explained above, the standard deviation tells how far from the mean point is the typical average individual.
- **Eta** is a correlation coefficient
- **Eta²** measures the explained variance

In SPSS, analysis of variance can be found in two different locations:

- Analyze->Compare Means
- General linear models (avoid this is you are a beginner)

Example 62. Differences between teachers and teacher students

In this example, we want to know if teacher trainees are different from real teachers regarding classroom activities. We look at three kinds of variables:

- The frequency of different kinds of learner activities (COP1)
- The frequency of exploratory activities outside the classroom (COP2)
- The frequency of individual student work (COP3)

Each of these variables was measured with an index. The COP1, COP2, COP3 indices can range from 0 (little) to 2 (a lot) We compare the average (mean) of the two groups for each variable.

Population		COP1 Frequency of different kinds of learner activities	COP2 Frequency of exploratory activities outside the classroom	COP3 Frequency of individual student work
1 Teacher trainee	Mean	1.528	1.042	.885
	N	48	48	48
	Std. Deviation	.6258	.6260	.5765
2 Regular teacher	Mean	1.816	1.224	1.224
	N	38	38	38
	Std. Deviation	.3440	.4302	.5893
Total	Mean	1.655	1.122	1.035
	N	86	86	86
	Std. Deviation	.5374	.5527	.6029

Table 56: Differences between teachers and teacher students – SD and mean

Standard deviations within groups are rather high (in particular for students), which is a bad thing: it means that among students, individuals are highly different.

Let us now examine the Anova table and its measures of associations. We first look at the *sig.* level, which should be below 0.5.

Variables (Y) explained by population (X)		Sum of Squares	df	Mean Square	F	Sig.
COP1 Frequency of different kinds of learner activities * Population	Between Groups	1.759	1	1.759	6.486	.013
	Within Groups	22.785	84	.271		
	Total	24.544	85			
COP2 Frequency of exploratory activities outside the classroom * Population	Between Groups	.703	1	.703	2.336	.130
	Within Groups	25.265	84	.301		
	Total	25.968	85			
COP3 Frequency of individual student work * Population	Between Groups	2.427	1	2.427	7.161	.009
	Within Groups	28.468	84	339		
	Total	30.895	85			

Table 57: Differences between teachers and teacher students – Anova table

As you can see, the variable COP2 cannot be explained by the “teacher trainees vs. teachers” variable, since sig. =0.130. The other two relations are statistically significant and therefore interpretable.

The measures of association (Eta) are also fairly week as the table below shows:

	Eta	Eta Squared
Var_COP1 Frequency of different kinds of learner activities * Population	.268	.072
Var_COP2 Frequency of exploratory activities outside the classroom * Population	.164	.027
Var_COP3 Frequency of individual student work * Population	.280	.079

Result: Associations are week and explained variance is weak. The "COP2" relation is not significant. We can state that teachers use more different learner activities than teachers-in-training and that they organize more frequently individual student work

15.5 Regression Analysis and Pearson Correlations

We already introduced the principle of linear regression above. It is use to compute a trend between an explaining variable X and explained variable Y. Both must be quantitative variables.

Regression analysis tries to find a line that will maximize prediction and minimize residuals.

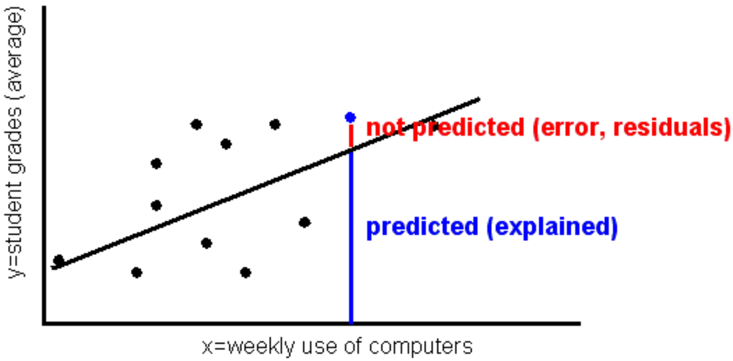


Table 58: Linear regression principle

DATA = *predicted* regression line + *residuals* (unexplained noise)

Regression and correlation coefficients

- The two ***regression coefficients*** summarize the model, i.e. mathematically describe the line.

Y = A + X * B

B represents the slope of the line

A is a constant and represents the offset from 0

- The ***Pearson correlation (r)*** summarizes the strength of the relation
- ***R square (R^2)*** represents the variance explained.

Example 63. Teacher age and out of classroom activities

We would like to answer the question: *Does teacher age explain exploratory activities outside the classroom*? I.e., is it more likely that older teachers organize out of class exploratory activities?

- Independent variable X: Age of the teacher
- Dependent variable Y: Frequency of exploratory activities organized outside the classroom

The Regression Model Summary produced by SPSS is shown in Table 59. We can see that there is a weak correlation (R=0.316) and that the relationships is significant (.027)

R	R Square	Adjusted R Square	Std. Error of the Estimate	Pearson Correlation	Sig. (1-tailed)	N
.316	.100	.075	.4138	.316	.027	38

Table 59: Teacher age and out of classroom activities – regression model summary

The regression Model Coefficients are shown in Table 60.

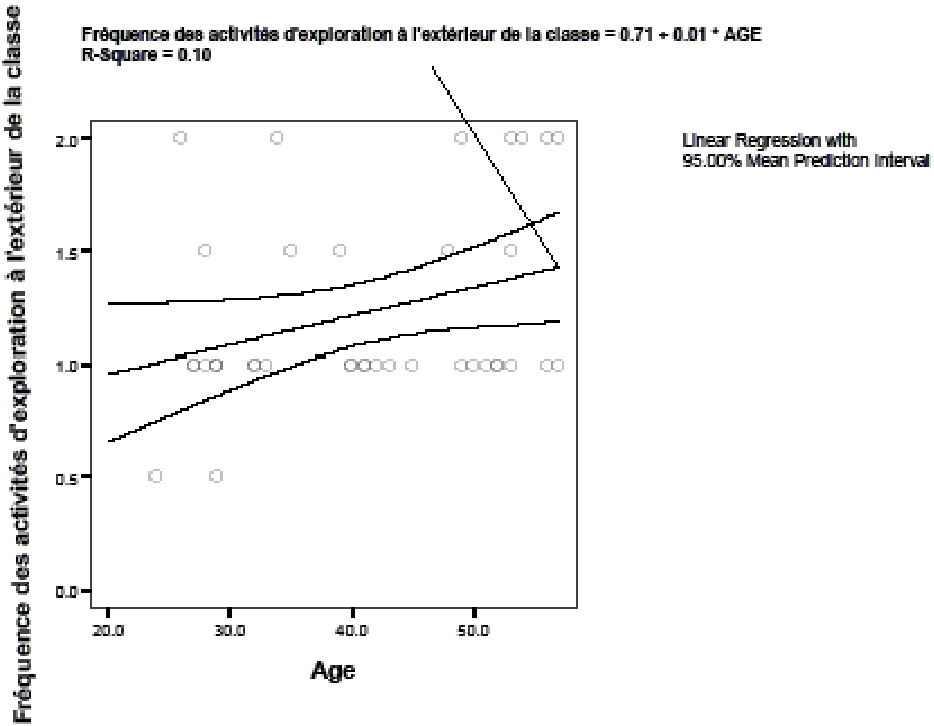
	Coefficients		Stand. coeff.	t	Sig.	Correlations
	B	Std. Error	Beta			Zero-order
(Constant)	.706	.268		2.639	.012	
Age	.013	.006	.316	1.999	.053	.316
Dependent Variable: COP2 Frequency of exploratory activities organized outside the classroom						

Table 60: Teacher age and out of classroom activities – regression model

Formally speaking, the relation is:

Exploratory outside classroom activities = .705 + 0.013 * AGE

It also can be interpreted as: "*only people over 99 are predicted to get a top score of 2*". Below is a scatter plot of this relation:



Looking at this graphic, there is no need for statistical coefficients to see that the relation is rather week and why the prediction states that it takes 100 years to get there ☺.

15.6 Summary

The main purpose of statistical analysis is to test relationships between two or more variables.

The analysis method you choose is conditioned by the data types.

Review questions

1. Use crosstabulation to test a relationship between two _______________ variables.
2. Use regression to test a relationship between two _______________ variables
3. Use analysis of variance to test a relationship between a _______________ variable and a ________________ variable.
4. List the four different types of statistical coefficients.
5. Can you interpret a relation that has a significance level of 0.5?

Review case study

1. Download Sandrine Turcotte and Christine Hamel (2008). Necessary conditions to implement innovation in remote networked schools: The stakeholders' perceptions, *Canadian Journal of Learning and Technology,* 34(1). http://www.cjlt.ca/index.php/cjlt/article/view/176/172
2. Identify the big central question of this study
3. Which innovation condition was considered to be the most important by

teachers

4. In what respect are teacher's perceptions different than the one by pedagogical consultants?
5. This study uses a Manova, which is a multivariate version of analysis of variance. Try to find a conceptual introduction about this technique on the Internet. Tip: Use the resources we added in the resources chapter.

16 Exploratory data analysis and data reduction

This chapter will shortly introduce **exploratory data analysis** (EDA), **multivariate data reduction** and related subjects. We will focus on looking at distributions with boxplots and uncovering structure with data reduction techniques. We also introduce repertory grid technique, a qualitative method that uses quantitative data analysis techniques.

Learning goals

- Be able to use boxplots to explore data distributions and to answer research questions in design and innovation studies.
- Understand the use of principal component and cluster analysis for exploratory purposes.
- Understand the purpose of repertory grid technique.

In this chapter, we only will provide very high-level introductions. Details about multivariate techniques such as factor analysis and cluster analysis are outside the scope of this introduction. We also should mention that many additional multivariate statistical techniques exist, both for exploratory and confirmatory inferential statics.

16.1 Exploratory data analysis with boxplots

Exploratory data analysis can be defined as a set of techniques but also as a spirit. According to NIST handbook, exploratory Data Analysis (EDA) is an approach/philosophy for data analysis that employs a variety of techniques (mostly graphical) to maximize insight into a data set, uncover underlying structure, extract important variables, detect outliers and anomalies; test underlying assumptions, develop parsimonious models; and determine optimal factor settings. According to Wikipedia and referring to Tukey, the objectives of EDA are to:

- Suggest hypotheses about the causes of observed phenomena
- Assess assumptions on which statistical inference will be based
- Support the selection of appropriate statistical tools and techniques
- Provide a basis for further data collection through surveys or experiments

A boxplot is an efficient method of graphically displaying numerical data. It depicts the following information: the smallest observation (sample minimum), the lower quartile (25%), the median (50%), the upper quartile (75%), and the largest observation (sample maximum). If there are outliers, the boxplot indicates them as well. The box is constructed from the bottom, lower quartile to the top, upper quartile. The whiskers connect the box to the smallest and largest values that are not outliers.

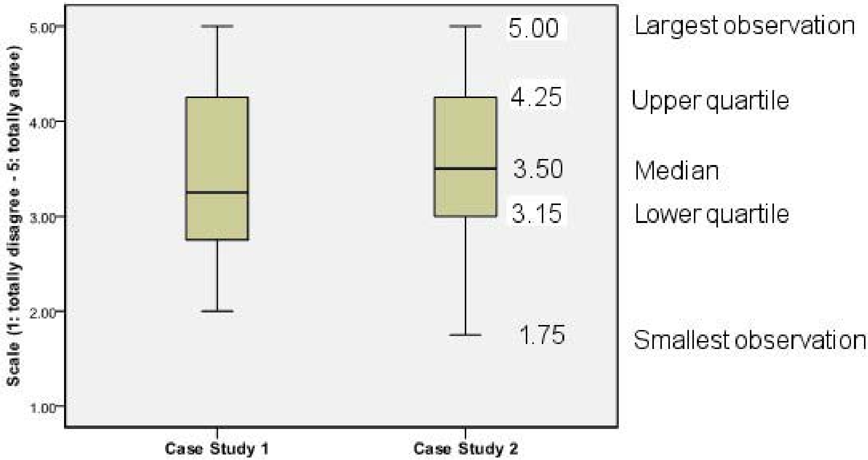


Figure 87: Example of a boxplot

Thus, in a normal distribution, the entire sample is represented in the whiskers. Outliers (see Figure 88: Representation of outliers) - either extreme or mild – are observations that are distant from the rest of the sample. They are not represented in the whiskers. Extreme outliers are observations that lie outside the box at a distance of more than three times the inter-quartile range (IQR: the difference between the third and first quartiles); they are indicated in the figure by a star. Mild outliers are observations that lay more than 1.5 times the IQR from the first or third quartile but not as far as extreme outliers; these are indicated in the figure by a dot.

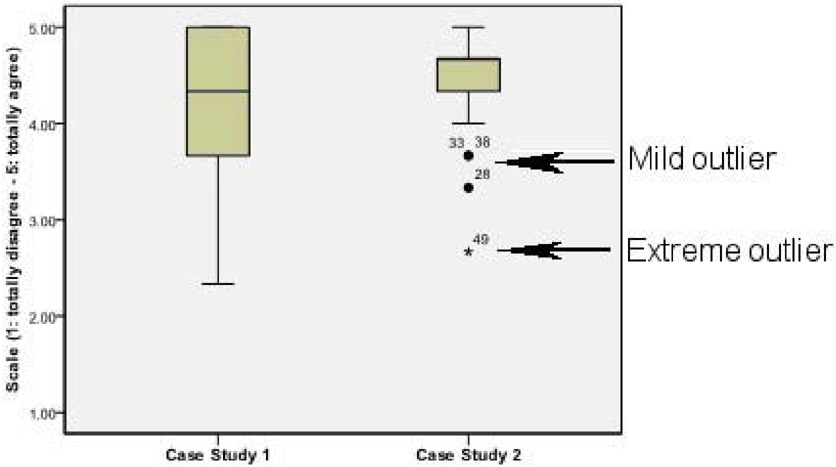


Figure 88: Representation of outliers

To interpret a boxplot, the researcher looks at the numerical values of the three quartiles, representing respectively 25 percent, 50 percent and 75 percent of the sample. S/he also looks at the general shape of the box and whiskers for indications of symmetry or asymmetry and outliers.

According to Benjamini (1998, p. 257), a boxplot represents five summaries of the data and allows to identify five crucial informations at simple glance: location, spread, skewness, and longtailedness. ***Location*** is displayed by the cut line at the median (as well as by the middle of the box). ***Spread*** is defined by the length of the box (as well as by the distance between the ends of the whiskers and the range). ***Skewness*** is defined by the deviation of the median line from the center of the box relative to the length of the box (as well as by the length of the upper whisker relative to the length of the lower one, and by the number of individual observations displayed on each side). ***Longtailedness*** is the distance between the ends of the whiskers relative to the length of the box (as well as by the number of observations specifically marked).

We recommend using boxplots in design and innovation studies, e.g. to present user opinions about a new course design using a technological environment) or to present objective data extracted from log files or the portalware's database.

Example 64. User's opinion about tutor support

Source: Barbara Class, Study of a blended socio-constructivist conference interpreters trainers training course empowered by an activity based, collaborative learning environment, PhD Thesis (draft). TECFA, University of Geneva, 2008.

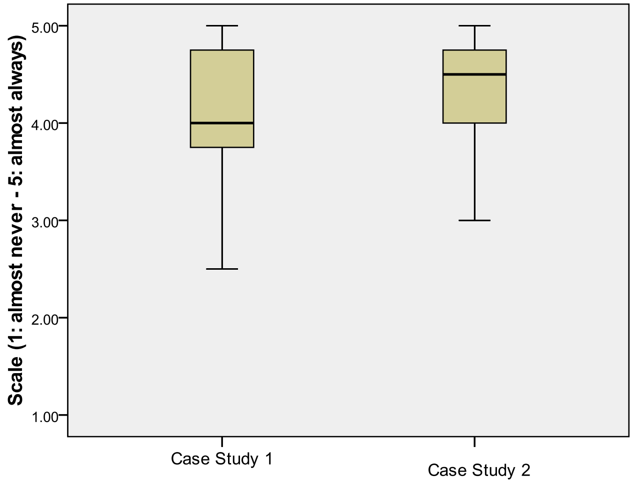


Figure 89: Learner's option about tutor support

This boxplot shows that in case study 1, the distribution is high regarding a tutor support index we shall not explain here. It varies between 2.50 (halfway between disagree and somewhat agree) and 5 (totally agree). The typical learner agrees (median=4) that teaching staff stimulated and encouraged him/her in his/her learning enterprise. In Case Study 2, the general shape of the boxplot is the same but distribution is less important. For both case studies, whiskers are asymmetrical, the lower whisker being much longer than the upper one, observations are negatively skewed. E.g. In case study one, results show that 25% of learners rather disagree, 25% totally agree and 50% agree that teaching staff stimulated and encouraged them in their learning enterprise.

16.2 Cluster Analysis

Cluster analysis or classification refers to a set of multivariate methods for grouping elements (subjects or variables) from some dataset set into clusters (types) of similar elements (subjects or variables). A typical use case would be the classification of teachers into 4 to 6 different groups regarding their use of ICT in the classroom.

There exist different kinds of cluster analysis. The most popular ones are hierarchical cluster analysis and K-means cluster. Hierarchical cluster analysis tries to identify similar cases in progressive steps. It allows producing a dendogram (tree diagram of the population). A dendogram shows proximity (distance) of cases.

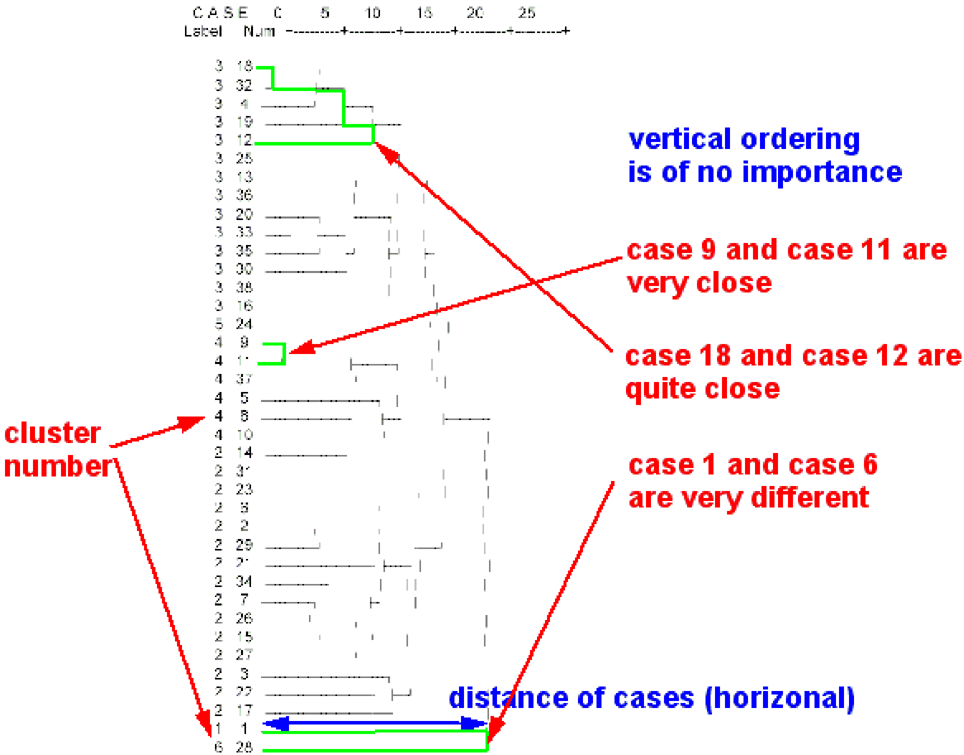


Figure 90: Dendogram in hierarchical cluster analysis

Example 65. Classification of teachers with respect to ICT use

A hierarchical analysis of 36 survey variables allowed identifying six major types of teachers with respect to ICT use:

- Type 1 : The "convinced teacher"
- Type 2 : The "active teacher"
- Type 3 : The "motivated teacher working within a bad environment"
- Type 4 : The "willing but not ICT competent teacher"

- Type 5 : The "ICT-competent teacher unwilling to use ICT in the class"
- Type 6 : The "Willing and relatively weak in ICT teacher"

Most teachers belong to type two and type three. Types 1,5 and 6 only include one teacher. In order to come up with labels such as the "convinced teacher" you will have to list the means of all cluster variables for each type and then use your imagination. The descriptive statistics for ***some*** of the 36 variables used for analysis is presented below. Numbers represent ***means*** for each type.

	Types [number of teachers]					
	1 [1]	2 [15]	3 [14]	4 [6]	5 [1]	6 [1]
Importance attributed to student collaboration and help tools	4.7	2.1	1.5	2.9	.0	5.0
Importance attributed to student communication tools	4.0	2.4	1.7	2.7	1.0	4.3
Effects of computer use to prepare and manage teaching	3.0	2.9	2.2	2.8	2.3	2.3
Importance of ICT use in the classroom	.0	2.7	1.9	2.3	1.0	3.0
Advanced computer hardware that teachers own at home.	.5	.8	.4	.3	1.0	.0
Level of ICT competence in documentation and communication tools	2.3	2.6	2.3	1.7	3.0	1.8
Variety of learner activities	1.3	1.8	1.9	1.7	2.0	1.0
Satisfaction with the ICT environment in the school	2.0	.8	.6	.0	.5	.0
Consultation et production de documents	.4	.9	.6	1.0	.6	1.2
Use of learning software in the classroom	2.0	1.7	.9	1.5	1.0	2.0

Table 61: Descriptive statistics for clusters (means)

Example 66. Use of tools in a distance teaching portal

Barbara Class in her PhD thesis already introduced above used cluster analysis to determine learner profiles with respect to tools use. From the portal database she could extract data related to the effective use of the forum, the shoutbox, the personal messages and the journal. Different use of these four tools reveals three different profiles. A first group (14 learners) uses all tools but rather little. A second group (14 learners) uses all tools in an average way and the journal most of all, even more than the “lot group”. A third group (17 learners) uses all tools a lot but uses most the Shoutbox:

Frequency of use	Cluster		
	Few	Average	A lot
Forum	1.14	2.21	2.59
Shoutbox	1.43	1.43	2.71
Personal messages	1.50	2.36	2.41
Journal	1.21	2.50	1.82

Table 62: Real use of tools split in 3 categories (1: few, 2: average, 3: a lot)

According to data gathered from a questionnaire – use according to perception- there exist three profiles: a first group (19 learners) who think they use all tools few; a second group (13 learners) who think they use all tools in an average way but think they use the journal a lot; a third group (18 learners) who think they use all tools a lot except the journal.

Frequency of use	Cluster		
	Few	Average	A lot
Forum	3.95	4.00	3.89
Shoutbox	1.74	2.15	3.17
Personal messages	2.74	2.69	3.39
Journal	1.84	3.15	2.11

Table 63: Frequency of use of tools – perception of use (1: never, 4: very often)

As you can see in the examples, cluster analysis is a powerful tool to identify groups of people that have similar characteristics. Cluster analysis also can be conducted on variables to find variables that are close to each other. We shall present an example when we discuss repertory grid analysis.

16.3 Factor analysis and principal component analysis

Factor analysis and principal component analysis (PCA) transform a correlation matrix of possibly correlated variables into a smaller number of factors, called principal components. Like cluster analysis, factor analysis reduces dimensions. Components identify underlying (latent) variables. Factor analysis also can identify which variables "go together".

The first component explains as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible.

Let us present an example made with the ***PISA 2006*** data for ***Swiss*** youngsters we already used in the chapter on descriptive statistics. The ICT Familiarity Component of the questionnaire included more than 30 questions. 16 questions were asked about how well they could do certain ICT tasks. Here is the wording of question five and some of its sub-questions:

Q5 How well can you do each of these tasks on a computer?

a) Chat online

b) Use software to find and get rid of computer viruses

c) Edit digital photographs or other graphic images

d) Create a database (e.g. using Microsoft Access)

e) Copy data to a CD (e.g. make a music CD)

f) Move files from one place to another on a computer

g) Search the internet for information

h) Download files or programs from the Internet.

i) Attach a file to an E-mail message

j) Use a word processor (e.g. to write an essay for school)

k) Use a spreadsheet to plot a graph

l) Create a presentation (e.g. using Microsoft PowerPoint)

m) Download music from the Internet

n) Create a multi-media presentation (with sound, pictures, video)

o) Write and send E-mails

p) Construct a web page

The possible response items were the following

1- I can do this very well by myself

2- I can do this with help from someone

3- I know what this means but I cannot do it

4- I don’t know what this means

The correlation matrix (not shown here) of these 16 times 15 relations show that most of these variables are somewhat correlated. With a principal component analysis, we extracted four factors and that explain about 62% of the total variance as the following table shows:

Total Variance Explained			
Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	2.777	17.357	17.357
2	2.634	16.462	33.820
3	2.311	14.444	48.263
4	2.223	13.896	62.159
Extraction Method: Principal Component Analysis.			

Table 64: Total Variance Explained (ICT abilities PISA 2006)

The following table shows how each variable correlates with the four extracted factors.

Rotated Component Matrix				
	Component			
	1	2	3	4
IC05Q01 How well - Chat IC5a	.269	.075	.727	.231
IC05Q02 How well - Virus IC5b	.653	.331	.173	.063
IC05Q03 How well - Edit photos IC5c	.566	.357	.159	.287

IC05Q04 How well - Database IC5d	.441	.599	-.095	.027
IC05Q05 How well - Copy data to CD IC5e	.714	.134	.194	.297
IC05Q06 How well - Move files IC5f	.463	.113	.163	.644
IC05Q07 How well - Search Internet IC5g	.162	.015	.390	.664
IC05Q08 How well - Download files IC5h	.584	.130	.359	.304
IC05Q09 How well - Attach e-mail IC5i	.326	.249	.523	.381
IC05Q10 How well - Word processor IC5j	.118	.252	.187	.734
IC05Q11 How well - Spreadsheet IC5k	.056	.712	.029	.350
IC05Q12 How well - Presentation IC5l	.067	.730	.117	.279
IC05Q13 How well - Download music IC5m	.579	.129	.535	.036
IC05Q14 How well - Multi-media IC5n	.352	.652	.258	-.009
IC05Q15 How well - E-mails IC5o	.098	.161	.753	.379
IC05Q16 How well - Web Page IC5p	.274	.592	.360	-.131
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

Table 65: Component matrix of subjective ICT competence (PISA 2006)

Looking at this component matrix and component plots in Figure 91 and Figure 92 we now can put names on these underlying newly found variables.

1. Component one could be labeled: Subjective competence in downloading
2. Component two could be labeled: Subjective competence in use of production tools
3. Component three could be labeled: Subjective competence in Internet use

Review question

- Looking at Table 65 and the component plots in Figure 91 and Figure 92, can you explain why we chose those labels
- Do you agree with them and why?
- Can you come up with a label for component four?

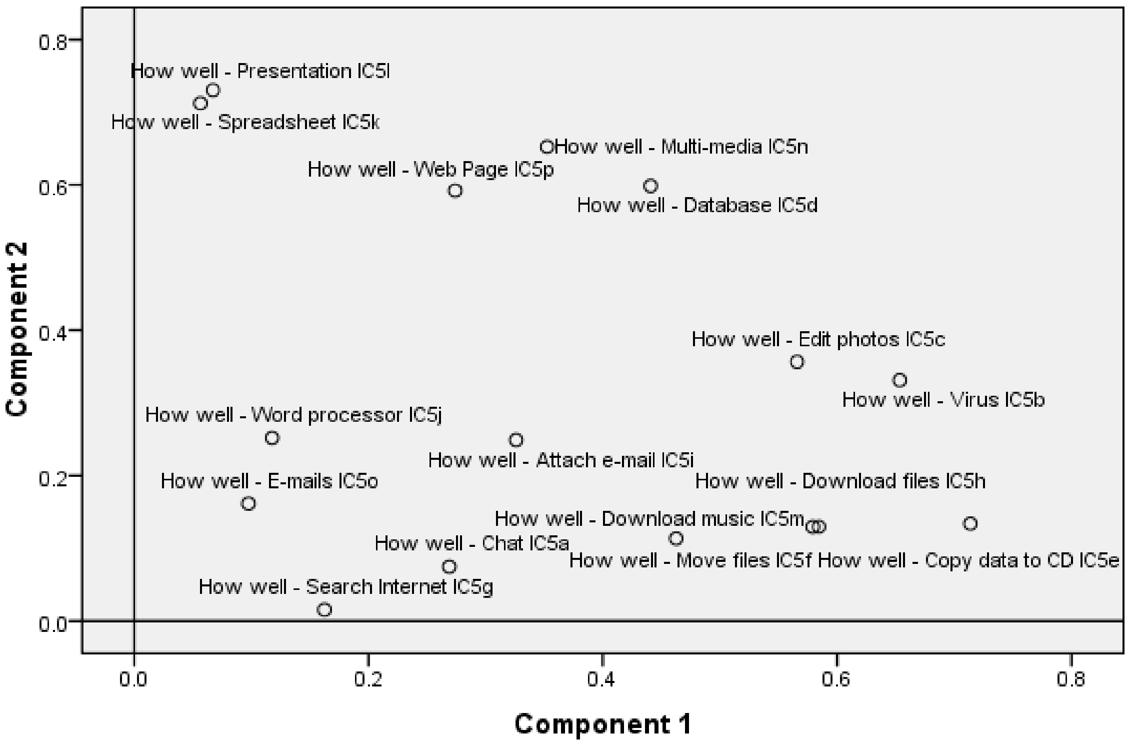


Figure 91: Component plots for factor1 and factor2

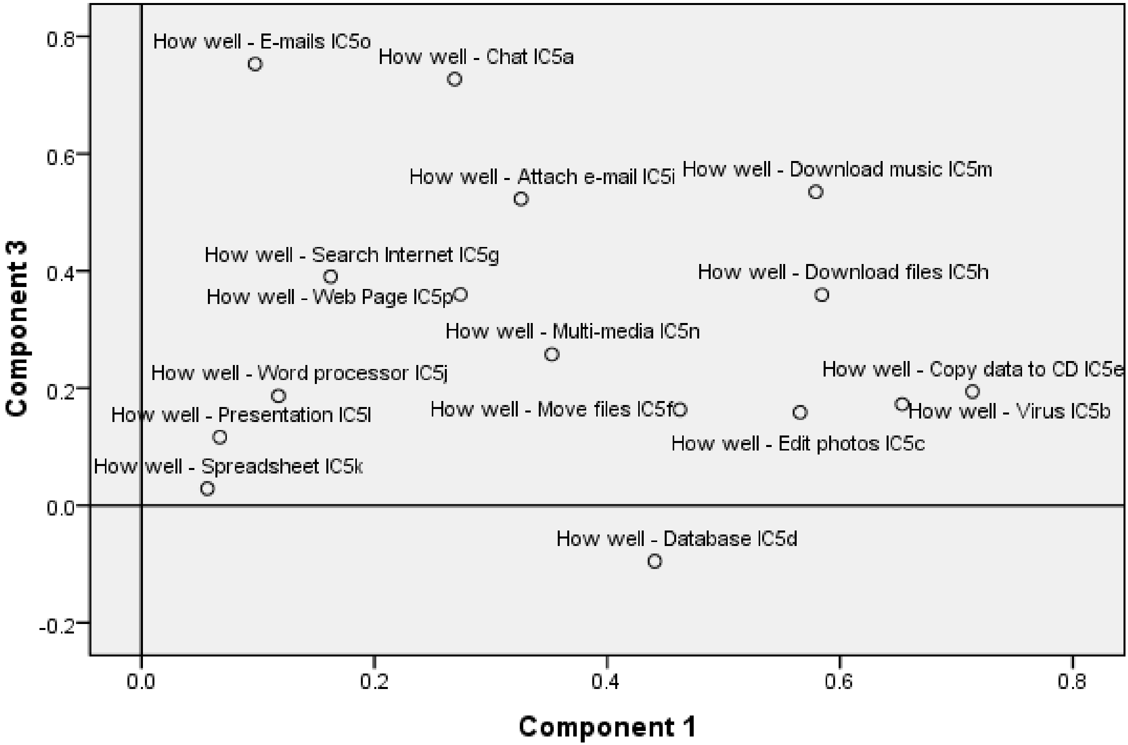


Figure 92: Component plots for factor 1 and factor 3

16.4 Repertory grid analysis

To finish our short introduction to multivariate exploratory data analysis, let us now discuss a more qualitative approach that uses quantitative data analysis methodology. Repertory grid technique (RGT) was invented in the 1950's by George Kelly in the framework of this Personal Construct Theory. RGT is based on the assumption that people's view of objects with which they interact is made up of an idiographic (individual) collection of related similarity–difference dimensions, referred to as personal constructs. RGT has been used in a large variety of fundamental and applied research projects and one of its strength is that it allows the elicitation of perceptions without researcher interference or bias.

A common way to describe the RGT is as the identification of a set of *elements* within a topic (e.g. a set of design languages) which are then rated according to certain criteria termed *constructs*. Elements and constructs can be defined by the researcher, but are usually elicited from the subject by a so-called triadic method. Participants will first name a few elements with which they are familiar, e.g. names of design systems. They have to compare triads of elements, for instance design A with designs B and C, and then state in what aspect two are similar and the third is different. This procedure is repeated with other combinations of elements until no more new constructs are elicited from the user and until all elements can be discriminated in the construct's space.

The output is a grid, which records a subject's ratings, usually on a 5- or 7-point scale, of *m* elements in terms of *n* constructs. This resulting grid can then be analyzed with various data analysis techniques, such as visual inspection, factor and cluster analysis.

We used this technique to analyze idiographic representations of design language researchers, developers and interested "users". We wanted to identify design issues and use cases that the various communities may not be aware of and that analytical methods could not identify. The (simplified) procedure used was the following. Participants were shown a list of educational design systems. A triadic elicitation script was used to extract at least four constructs (labeled aspects). In a next step, ratings for each aspect were adjusted. Next, participants were asked to add more systems and to add new constructs if necessary. Construct names were also adjusted during this process, being usually made more general. At the end, participants adjusted scores by looking at all elements for each construct.

Figure 93 shows a repertory grid created by the author. The figure also includes cluster analysis dendograms for both the elements and the constructs. Values should be read from “left” to “right”. E.g. *Open source*=5 means that we considered Eduweaver, Knowledge Forum, CeLS to be closed source.

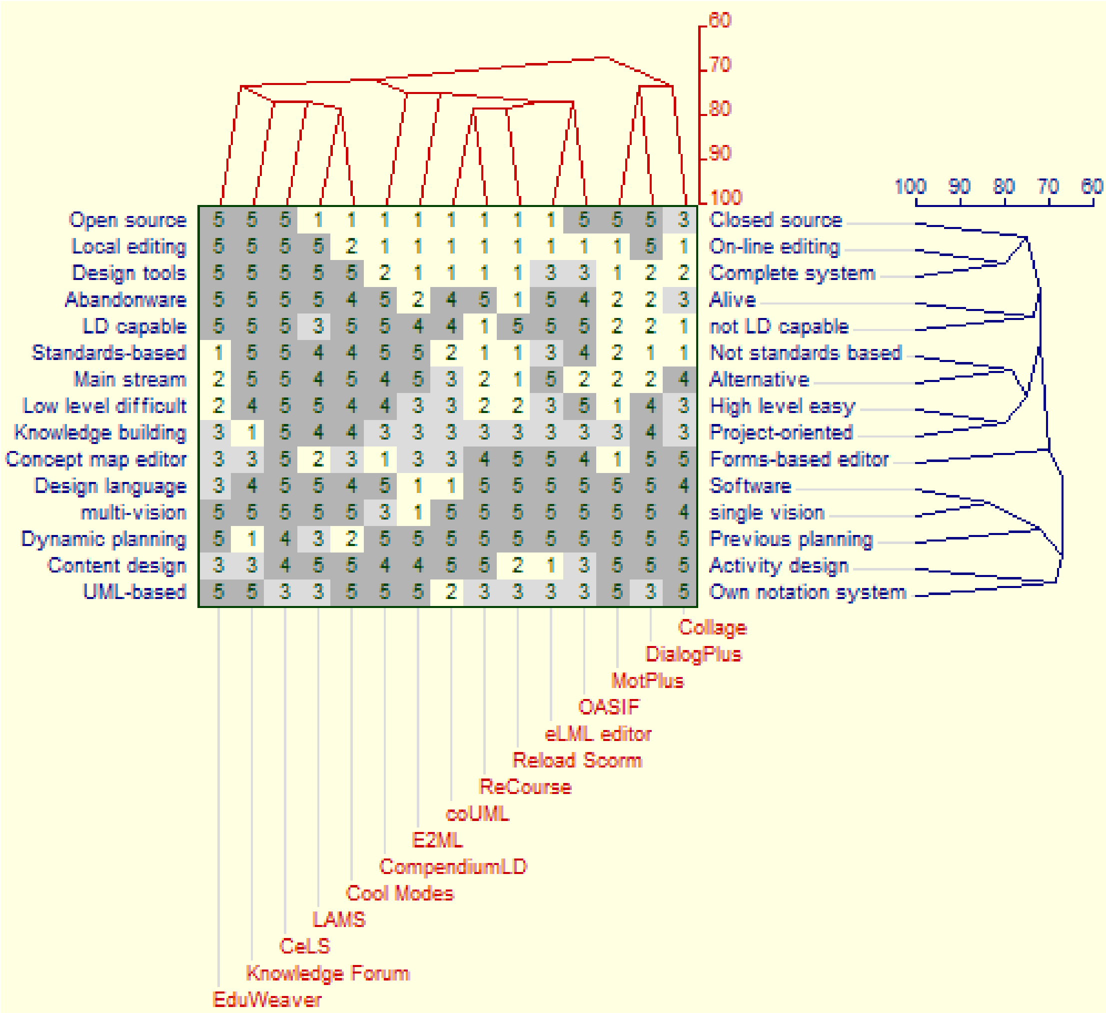


Figure 93: Two-way cluster analysis of a repertory grid

This grid shows a larger variety of clusters and constructs, which is no surprise. It is interesting to notice that *closed source*, *on-line* and *complete systems* appear in the same cluster. *Being alive* and *not LD capable* was another. *High level easy* and *project-oriented* also go together. It is also surprising that systems as different as CeLS and Knowledge Forum and LAMS form a cluster. Or coUML, Recourse and Reload another. Looking at the two principal components it is easy to see why. The most important emerging factor can be named *complete (online) system that allows dynamic planning* vs. *Design tool, LD capable and standards based*. Alternatively and more simply: *fit for real world use*. The second factor opposes design languages vs. closed source on-line mainstream systems. Both factors only explain 52% percent.

The principal components plot in Figure 94 not only shows variables (constructs) as but also individual cases (elements). That kind of visualization is not current in survey research, but very useful when data sets are small and each individual case is of interest to the researcher. In our case, recall that the (red) cases represent educational design systems.

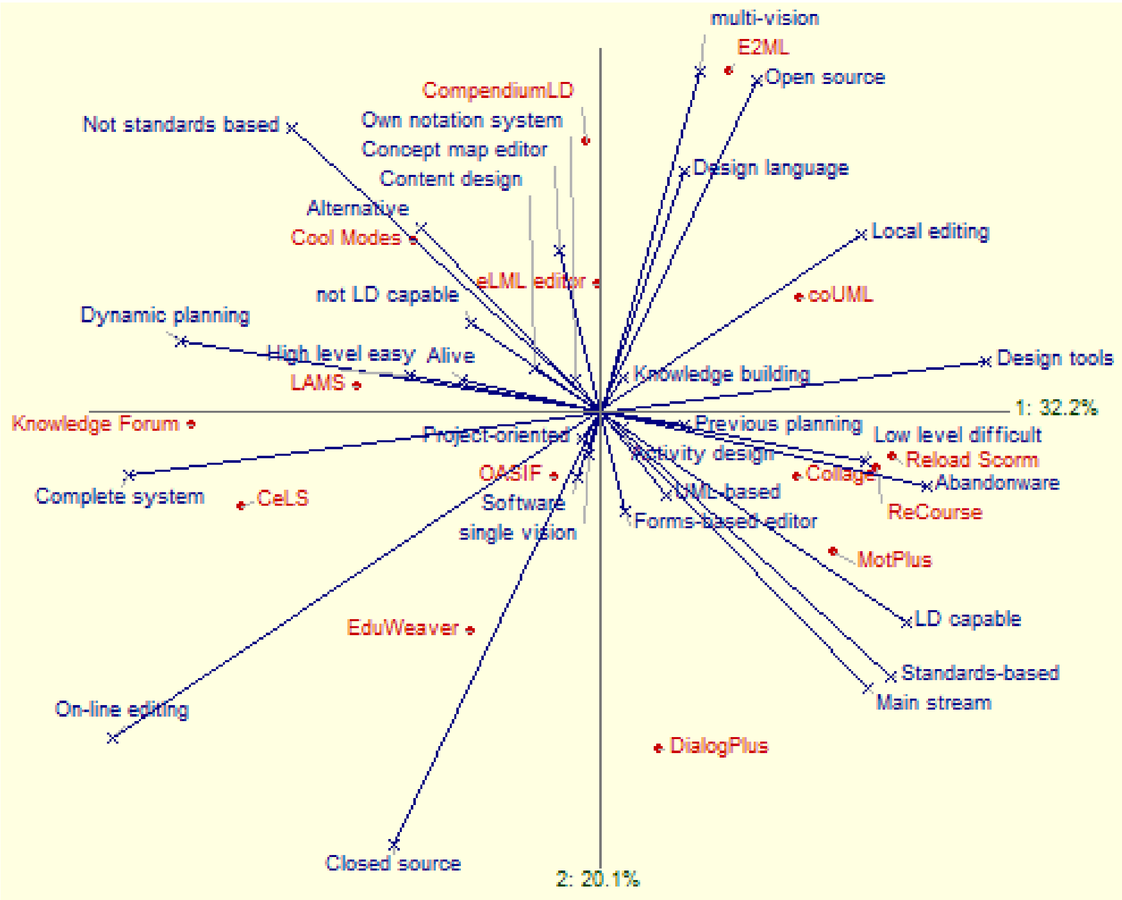


Figure 94: Principal components of a repertory grid

16.5 Summary

The main goal of this chapter was to give you a taste of more complex data analysis techniques. Future researchers should attempt to require these.

Practitioners in educational technology should at least be able to make sense out of research articles and this is why we introduced them here.

Review assignment

1. Download the RepIV software from http://repgrid.com/RepIV/index.html
2. Create a repertory grid about your perception of about ten different web sites in an area of your choice.
3. Try to analyse the results of the two-way cluster and the principal component.
4. Tip: you may read http://edutechwiki.unige.ch/en/Rep_IV for some technical help. This exercise will also test your ability to find extra information that you might need to understand this technique since later you often will be confronted with the request to perform an analysis of certain kind with a new tool and you will have to learn both...

17 Qualitative data analysis

This chapter introduces various aspects of qualitative data analysis. We shall present a “modern” structured approach in which the researcher is expected to code data. These codes will then allow him to conduct various types of analysis of which introduce some examples.

Learning goals:

- Learn how to code data and creating code books
- Learn about some descriptive analysis techniques (including situations and roles)
- Learn about some causal analysis techniques

As we discussed in chapter 10, qualitative data analysis usually implies a series of related and iterative steps. The general principle of most qualitative data analysis methods is the following:

1. Data needs to be ***coded and indexed*** so that you can find it for data analysis. More particularly, information coding allows identifying variables and values. Such systematic analysis of data augments reliability and enhances construction validity, i.e. that you look at all the things that will allow you to measure concepts.
2. You then create ***visualizations, matrices, grammars***, etc. for analysis

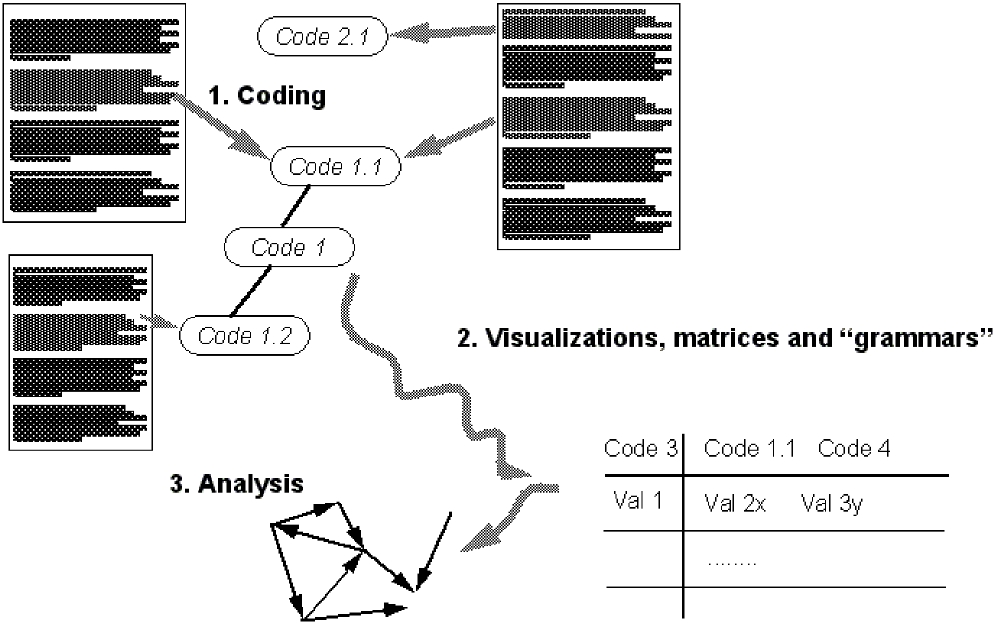


Figure 95: Qualitative data analysis summarized

Before we start explaining coding and analysis, we should mention that you should use a system to keep both documents and ideas safe.

(1) Write ***memos*** to conserve your thoughts. It is useful to write short memos (vignettes) when an interesting idea pops up after looking at something.

(2) Create ***contact sheets*** that allow you remember your field work. After each contact (telephone, interviews, observations, etc.), make a short data sheet that should include:

- A clear tag for indexing purposes (filename or tag on paper), e.g. CONTACT_senteni_2005_3_25.doc.
- Type of contact, date, place, and a link to the interview notes, transcripts.

- Principal topics discussed and research variables addressed (or pointer to the interview sheet).
- Initial interpretative remarks, new speculations, things to discuss next time.

(3) ***Index*** your interview notes:

- Put your transcription (or audio/video files or audio tapes) in a safe place
- Assign a code to each "text", e.g. INT-1 or INTERVIEW_senteni_3_28-1. The same code could be used as filename.
- You also may insert the contact sheet (see above)
- Number the pages if you take notes manually (they can fall down ...)

(4) Do not trust your hard disk. Make frequent backups!

17.1 Codes and categories

The first step in qualitative data analysis is coding. A code is a ***label*** used to tag a variable (concept) and/or a value found in a text. As we said before, the benefit of coding is to enable you finding all information regarding variables of interest to your research. In addition, it will improve the reliability of your research.

The coding technique is rather simple in principle:

1. A code is assigned to each (sub)category, i.e. each theoretical variable you work on. In other words: you must identify *variable names*
2. In addition, you can for each code assign a set of possible values, e.g. *positive/neutral/negative*
3. You then will systematically scan all your texts (documents, interview transcripts, dialogue captures, etc.) and tag all occurrences of variables.
4. Three very different coding strategies exist as we shall see later:
   - Code-book creation according to theory
   - Coding by induction (according to grounded theory)
   - Coding by ontological categories

Table 66: Coding principle for qualitative data

The safest and most reliable way to code is to use some specialized software, e.g. Atlas or Nvivo; however, this takes a lot of time! For a smaller piece (e.g. a master thesis), we suggest to simply tag the texts on paper with the following technique:

1. You can make a reduced *photocopy* of the texts to gain some space in the margins
2. Underline or circle the text elements you can match to a variable, then write the code next to it in the margin. Use an erasable pencil.
3. Make sure to distinguish between codes and other marks you may leave on the paper.

Regarding the labeling of codes, we suggest the following:

- Don't use "flat" and long code-books, introduce hierarchy (according to dimensions identified)
- Each code should be short but also mnemonic (optimize). E.g. to code according to a scheme of principal category - sub-category (value) use a code like:

  CE-CLIM(+)

instead of:

external_context -climate (positive)

- Do not start coding before you have good idea of your coding strategy. Either your code book is determined by you research questions and associated theories, frameworks, analysis grids or you really learn how to use an inductive strategy like "grounded theory" (see below).

Coding reliability

Assigning a code to a text segment is not always obvious and coding similar passages exactly the same way even less. In other words, we have a reliability problem.

There are two ways of improving reliability:

- Use clear and operational categories
- Use two or three coders (yourself and a friend) and compute an intercoding index. If it is low, you will have to revise your coding scheme.

There exist several formulas to compute intercoder (inter-rater) reliability. The simplest one is:

reliability =
number of coding agreements / total codes (agreements plus disagreements)

Read the online text by Lombard et al. for a very good introduction.

17.1.1 Code-book creation and management

Code-book creation according to theory

In this coding strategy, the list of variables (and their codes), is defined through theoretical reasoning (e.g. analytical frameworks, analysis grids) and therefore also by concepts that you used to formulate your research questions and/or hypothesis. Below is a part of an innovation study codebook (about 100 codes):

Categories	Codes	Theoretical references
properties of the innovation	PI	.... (Fill for your own code book).....
external context	EC	
demography	CE-D	
support for the reform	CE-S	
internal context	IC	
adoption processes	AP	
official chronology	PA-OC	
dynamics of the studied site	DS	
external and internal assistance	EIA	
causal links	CL	

Table 67: Innovation study codebook (extract)

Before you start thinking about your own codebook, you ***really*** should go through the relevant literature and try to find existing code books (that you then may adapt). E.g. below is an example of codes use to analyze types of job-related problems of Turkish computer teachers (Deryakulu & Olkun, 2007).

a) Role Conflict
b) Inadequate Teacher Induction Policies
c) Lack of Required Technological Infrastructure and Technical Support
d) The Status of Computer Subject in School Curriculum
e) Lack of Appreciation and Positive Feedback from Colleagues
f) Unsupportive Administrators
g) Rapidly Changing Nature of Content Knowledge in Computer Education
h) Lack of Cohesive Computer Curriculum

i) Insufficiency of Pre-Service Teacher Training Programs
j) Large Class Sizes
k) Indifferent Students
l) Inadequate Supervision and Inspection

Coding by induction according to grounded theory

Grounded theory (Glaser, Strauss) refers to a set of approaches that focus on interpretation and theory building, i.e. it is a fully **inductive** approach. The researcher starts by coding a small data set and then increases the sample in function of emerging theoretical questions. Categories (codes) can be revised at any time.

> *Grounded theory begins with a research situation. Within that situation, your task as researcher is to understand what is happening there, and how the players manage their roles. You will mostly do this through observation, conversation and interview. After each bout of data collection you note down the key issues: this I have labeled "note-taking".*
>
> *Constant comparison is the heart of the process. At first you compare interview (or other data) to interview (or other data). Theory emerges quickly. When it has begun to emerge you compare data to theory.*
>
> *The results of this comparison are written in the margin of the note-taking as coding. Your task is to identify categories (roughly equivalent to themes or variables) and their properties (in effect their sub-categories).*
> *Grounded theory: a thumbnail sketch, retrieved October 15 2008.*

One codes phenomena both in isolation and relations (so-called axial coding). One starting point for axial coding could be these big abstract observation categories:

- conditions (causes of a perceived phenomenon)
- interactions between actors

- strategies and tactics used by actors
- consequences of actions

To use this approach you *really* should document yourself since as beginner you likely would fall into various traps, in particular selection and confirmation biases, i.e. you only look at things that will interest you for one or another reason.

Coding by ontological categories

Instead of initially creating a codebook from variables found in your research questions or "inductive" coding à la grounded theory, one can start by creating or using a vocabulary for a given domain. This strategy is a compromise between grounded theory and the theory driven method we presented first.

Below is a table that lists things you could observe in an organization (Bogdan and Biklen, cited by Miles & Huberman:1994 61)

Types	Explanation
Context/Situation	information on the context
Definition of the situation	interpretation of the analyzed situation by people
Perspectives	global views of the situation
Ways to look at people and objects	detailed perceptions of certain elements
Processes	sequences of events, flow, transitions, turning points, etc.
Activities	structures of regular behaviors
Events	specific activities (non regular ones)
Strategies	ways of tackling a problem (strategies, methods, techniques)
Relations and social structure	informal links
Methods	comments (annotations) of the researcher

Table 68: Bogdan and Biklen codes to analyse organizations

In the literature, you may find several other such "accounting schemes". In educational technology, for example, there is a range of relatively simple codebooks for the analysis of conversation and asynchronous discussion groups (forums). De Wever et al. (2006) provide a good overview. Some coding schemes are simple. E.g. Cobos and Pifarré (2008) analyzed “collaborative knowledge construction in the web” with the following coding scheme:

Code	**explanation**	**example**
Explanation	Asks for clarifying some parts of the document	The following link, which appears in your document, doesn't work now, but it worked a week ago?
Support	Express explicit agreement with the document's ideas or information organization	In my opinion this document is very useful and is easy to read
Addition	Suggests additions to the document: ideas, opinions or information organization	I think that an index of the sections of the article should be added
Delete	Suggests deletions from the document: ideas, opinions or information organization	In the summary there are some examples, which perhaps were not necessary?
Correction	Suggests changes to the document. They refer to ideas, opinions or information organization	I think that there is an error in the first paragraph in the conclusion section, where it says 'motor' it should be 'motivation'

Table 69: Code book for “collaborative knowledge construction in the web”

Pena and Nichols (2004) used the following categories for analyzing student interactions and meaning construction in computer bulletin board discussions:

- Questions
- Reply
- Clarification
- Interpretation
- Conflict
- Assertion
- Consensus Building
- Judgment
- Reflection
- Support
- Other

There exist more complex codebooks: As an example we produce a summary of students' messages code book by Eilon and Kliachko (2004).

"Level A" Group	***These categories indicate knowledge construction and a significant contribution to peer learning***
Comprehension	Shows written evidence about the comprehension of the subjects studied by the following categories:
Reproducing- 1	Reproduces the main points, ideas, arguments or messages found in the incoming information with reference to its source and with critical evaluation.
Directing	Directs others to relevant sources for the subjects studied (both printed and online).
Clarifying by questions	Locates ambiguous, difficult or problematic areas in the new material. Describes the context of the question or the reason for asking it.
Clarifying by answers	Gives correct, relevant and comprehensive explanations as answers. Bases the answers on retrieved information while citing its origin.
Reflection	Shows written evidence of metacognitive processes that the learner applies when studying new subjects by the following categories:
Linking/extending	Links the new information with his or her own previous knowledge. Extends the new knowledge to other domains, especially to STS issues.

Critical evaluation	Evaluates the new information critically.
Transformation	Applies the new information in an original and creative way, draws inferences, and gives original examples.
"Level B" Group	**These categories indicate a probable contribution to peer learning, by the following categories:**
Documenting	Documents learning experiences or individual contributions to the group.
Reproducing- 2	Reproduces the main points, ideas, arguments or messages found in the incoming information without any evaluation or original input to it.
Learning outcomes	Presents group and individual learning outcomes.
Technical questions/answers	Questions or remarks about any subject that does not relate directly to understanding the subjects studied.
Personal knowledge	Presents personal knowledge or daily life experiences.
"Level C" Group	**These categories indicate no contribution (or adverse contribution) to peer learning, by the following categories:**
Irrelevant/unexplained questions	Poses questions without giving the context or reason for asking them.
Casual quotations	Includes quotations without their context and without further explanation.
Irrelevant/incorrect answers	Offers Irrelevant or incorrect answers to questions sent by other students.
Emotional/personal comments	Includes personal comments, which should have been sent by e-mail as instructed by the teacher.

Table 70: students' messages code book (Eilon and Kliachko, 2004)

Pattern codes

Some researchers also code patterns (relationships). *Simple* encoding (above) breaks data down to atoms (categories), whereas *pattern coding* identifies relationships between atoms. Pattern coding is also one of the steps in the inductive grounded theory approach. The ultimate goal is to detect (and code) regularities, but also variations and singularities.

Some suggested operations:

1. Detection of *co-presence* between two values of two variables
   - E.g., people in favor of a new technology (e.g. ICT in the classroom) have a tendency to use it.
2. Detection of *exceptions*
   - e.g. technology-friendly teachers who don't use it in the classroom
   - In this case, you may introduce a new variable to explain the exception, e.g. the attitude of the superior, of the group culture, the administration, etc.
   - Exceptions also may provoke a change of analysis level (e.g. from individual to organization)

Warning: as in statistical analysis, a co-presence does not prove causality

17.2 Descriptive matrices and graphics

Qualitative analysis attempts to find structure in data (as in exploratory quantitative techniques). There exist two popular types of analysis techniques:

1. A *matrix* is a tabulation engaging at least one variable, e.g.
   - Tabulations of central variables by case (equivalent to simple descriptive statistics like histograms)
   - Crosstabulations allowing to analyze how 2 variables interact
2. Graphs (*networks*) allow to visualize links:
   - temporal links between events
   - causal links between several variables
   - etc.

Analysis = tabulation and visualization

Some advice:

- When you use these techniques always keep a link to the source (coded data)
- Try to fit each matrix or graph on a *single page* (or make sure that you can print things made by computer on a A3 page)
- You have to favor synthetic vision, but still preserve enough detail to make your artifact interpretable
- Consult specialized manuals e.g. Miles & Huberman (1994) for recipes or get inspirations from qualitative research in the same domain as yours.

In this chapter, we cannot cover all possible types of analysis, but we will just provide a **few** examples of what can be done. Before you start doing any sort of analysis, **think** about what you need to answer your research questions!

Remark: In many qualitative studies, in particular in so-called field or case studies, you often will find that researchers just present citations from interviews. These citations have been selected to represent typical thoughts and are arranged in some logical order, e.g. emerging topics in user's perceptions about given issues. Prior to writing the article, these researchers may nevertheless have used some of the data analysis techniques we shall present now.

17.2.1 The context chart

This technique (Miles & Huberman, 1994:102) allows visualizing relations and information flows between roles and groups

Example 67. Work flow for a "new pedagogies" program at some university

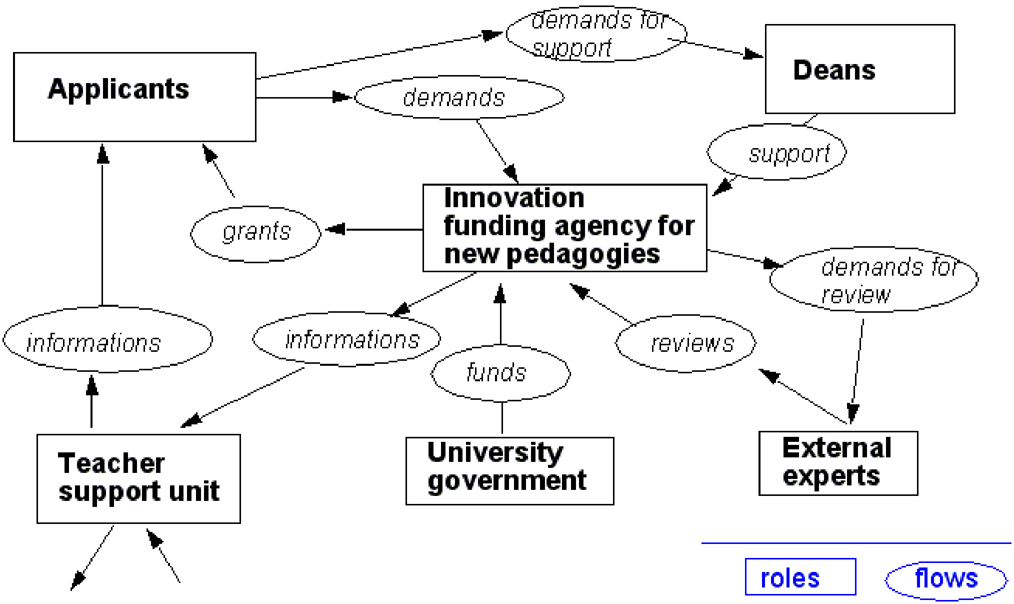


Figure 96: Context chart example

There exist codified "languages" for this type of analysis, e.g. UML or OSSAD

Once you clearly identified and clarified formal relations, you can use the graph to make annotations (like below)

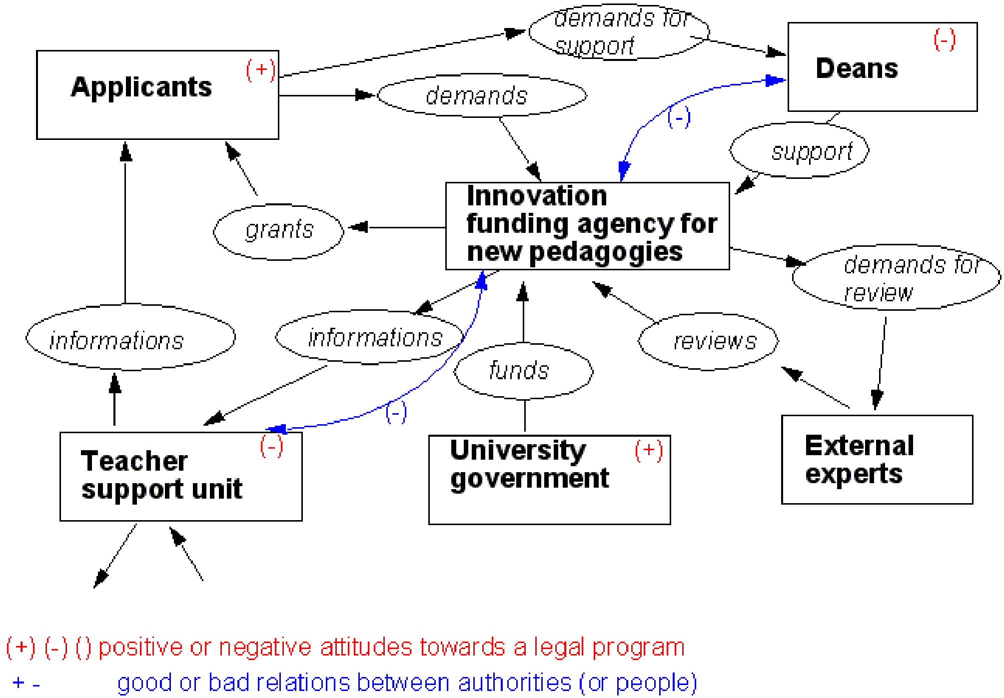


Figure 97: Annotated context chart example

17.2.2 Variable and data tables

You may use qualitative data tables in the same way that you use simple quantitative data matrices (e.g. comparing socio-economic indicators for a list of countries). The following table lists (imaginary) interviewed teachers' answers regarding three questions regarding a new collaboration platform: *needs for support, needs for training* and *need for directives*."

case	var 1	need for support	need for training	need for directives
case 1		important	important	important
case 2		not important	not important	not important

case 3		important	important	important
case 4	xyz	not important	not important	not important
case 5	.....	important	important	important
case 6....		important	not important	not important

We shall discuss later, how to analyze such data in more interesting way.

17.2.3 Check-lists

Checklists (Miles & Huberman, 1994:105) allow making detailed summary for the analysis of an important variable.

Example 68. External support for reform projects

Imagine the following working hypothesis: "*external support is important for succeeding a reform project*". To answer this question, we will tabulate all the information we have from interviews.

External support occurrences	At counselor level	At teacher level
Analysis of deficiencies	Fill in each cell as below	
Teaching training		
Change monitoring		
Incentives		
Group dynamics	adequate: "we have met an organizer 3 times and it has helped us" (ENT-12:10)	not adequate: "we just have informed" (ENT-13:20)
Etc...		

Such a table displays various dimensions of an important variable (external support). E.g. in the example above the values of the variable "external support" are listed in the left column. In the other columns, we insert summarized *facts* as reported by different roles.

Review Question:

- Imagine how you would build such a grid to summarize teachers', students' and assistants" opinions about technical support for an e-learning platform

17.2.4 Chronological tables

Chronological tables (Miles & Huberman, 1994:110) can summarize a studied object's most important events in time

Example 69. Task assignments for a blended project-oriented class

	Activity	Date	imposed tools (products)
1	Get familiar with the subject	21-NOV-2002	links, wiki, blog
2	project ideas, Q&R	29-NOV-2002	classroom
3	Students formulate project ideas	02-DEC-2002	news engine, blog
4	Start project definition	05-DEC-2002	ePBL, blog
5	Finish provisional research plan	06-DEC-2002	ePBL, blog
6	Finish research plan	11-DEC-2002	ePBL, blog
7	Sharing	17-DEC-2002	links, blog, annotation
8	audit	20-DEC-2002	ePBL, blog
9	audit	10-JAN-2003	ePBL, blog
10	Finish paper and product	16-JAN-2003	ePBL, blog
11	Presentation of work	16-JAN-2003	classroom

This type of table is useful to identify important events. Of course, you can add other information, e.g. in this example we added tools used by students

17.2.5 Matrices for roles (function in an organization or program)

Role matrices (Miles & Huberman, 1994:124) consist in crossing social roles with one or more variables. The abstract principle can be summarized as follows (see below for an example):

roles	persons	variable 1	variable 2	variable 3
role 1	person 1	cells are filled in with values (pointing to the source)		
	person 2			
	.....			
role 2	person 9			
	person 10			
.....	.....			
role n	person n			
	.....			

You also can create tables that cross roles with roles and that will show relationships between roles.

	role 1	...	role 3
role 1	fill in all sorts of information about interactions		
...			
role 3			

Example 70. Evaluation of the implementation of a help desk software

Actor	Evaluation	assistance provided	Assistance received	Immediate effects	Long term effects	Explanation of the researcher
Manager	-	-	-	demotivating	threatened the program	Felt threatened by new procedures
Consultant	+	Help choosing the right soft. involved himself	-	contributed to the start of the experiment	-	....
Help-desk	+/-	debugging of		better job	slight	is still

worker?		machines, little help with software		satisfaction because of the tool	improvement of throughput	overloaded with work
Users	+/-	A few users provided help to peers with the tool	debugging of machines, little help with software	Were made aware of the high amount of unanswered questions	slight improvement of work performance	....

Below is a crossing between roles example to visualize relations:

	role 1	**trainers**	**role 3**
role 1			
trainers		don't coordinate very much (1)	doesn't receive all the information (2)
role 3			

17.3 Techniques to study relations

Often qualitative analysis stops with simple descriptive analysis. However, you also may use qualitative data to do some kind of "correlation analysis"”as you typically do in quantitative data analysis. We shall present some example techniques.

17.3.1 Matrices ordered according to concepts (variables)

Clusters (co-variances of variables, case typologies), i.e. the idea that certain values should "go together": Hunt co-occurrences in cells

Example 71. Correlation between needs for support and needs for training

Let us formulate the following research question: "Can we observe a correlation between expressed *needs for support* and expressed *needs for training* for a new collaborative platform (data from teachers' interviews)?"

The following data matrix shows e.g. that *need for support* and *need for training* seem to go together, e.g. cases 1,3,5 have association of "important", cases 2 and 4 have association of "not important".

case	**var 1**	**need for support**	**need for training**	**need for directives**
case 1		important	important	important
case 2		not important	not important	not important
case 3		important	important	important
case 4	yyy	not important	not important	not important
case 5	.....	important	important	important
case 6....		important	not important	not important

In order to carry out an analysis, it is a good strategy to create cross tabulations of variables. E.g. to show precisely how *need for support* and *need for training* go together, we could create the following table:

training needs * support needs		need for support	
		yes	no
need for training	yes	3	1
	no	1	2

We can observer a correlation here: "blue cells" (symmetry) is stronger than "magenta"!

In addition, one could create a typology with the same data:

	Type 1: "anxious"	**Type 2: "dependent"**	**Type 3: "bureaucrats"**	**Type 4: "autonomists"**
case 1	X			
case 2				X
case 3	X			
case 4				X

case 5	X			
case 6		X		
Total individuals per type	3	1	0	2

We can observe emergence of 3 types to which we assign "labels"

Review question:

Can you explain how we created these four types?

Hint: Look at the values of the data table.

Remark: If you have more than three variables, you should quantify the data and use a cluster analysis program.

Example 72. Effect of different types of pressure on ICT strategies

The table shows co-occurrence between values of 2 variables. The idea is to find out what effect different types of pressure have on ICT strategies adopted by a school.

	Strategies of a school				
Type of pressure	**strategy 1:no reaction**	**strategy 2:a task force is created**	**strategy 3:internal training programs are created**	**strategy 4:resources are reallocated**	**strategy 5: .....**
Letters written by parents	(N=4)(p=0.8)	(N=1)(p=0.2)			
Letters written by supervisory boards		(N=2)(p=0.4)	(N=3)(p=0.6)		

newspaper articles				(N=1)(p=100%)	
type ...	.....	....			

Interpretation of crosstabulations

Let us recall the principle of crosstabulation that we already introduced in the chapter on quantitative data analysis. Its purpose is to estimate the probability that a given value of the independent (explaining) variable entails a given value of the dependent (explained) variable.

The procedure recalled:

1. Calculate the percentage for each value of the independent variable. This can be either the line or the column depending on how you orient your table.
2. Compare the percentages in the other direction

Review question

- Fill in the percentages in the table below.
- Then, complete the sentence

	Variable y to explain = Strategies of action			
Explaining variable x	**do nothing**	**send a mail**	**write a short tutorial**	**Total**
Students making indirect suggestion	4 (__%)	1 (__%)		5 (___ %)

Students explicitly complaining		2 (__%)	3 (__%)	5 (___%)

Interpretation: If students explicitly complain, the tutor will react ___________ strongly and engage in more helpful activities

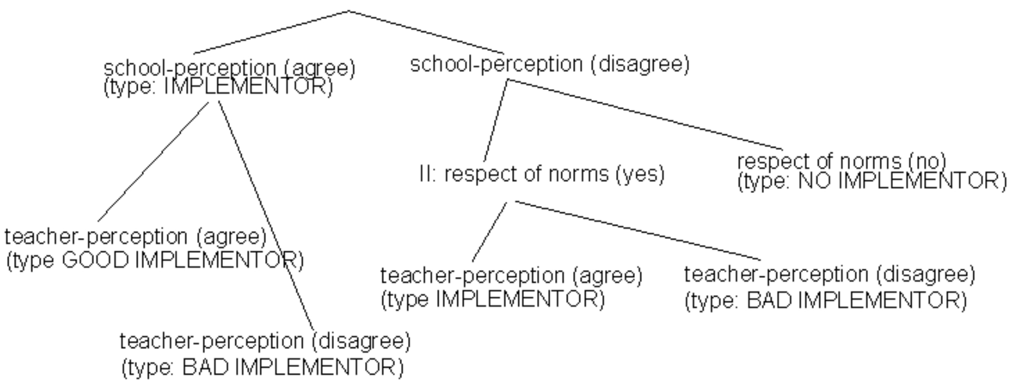
17.4 Typology, activity and causality graphs

There are no limits of what you can draw. Such analysis just uses a more or less precise language to draw concept maps. Below we just show two examples.

17.4.1 Typology graphs

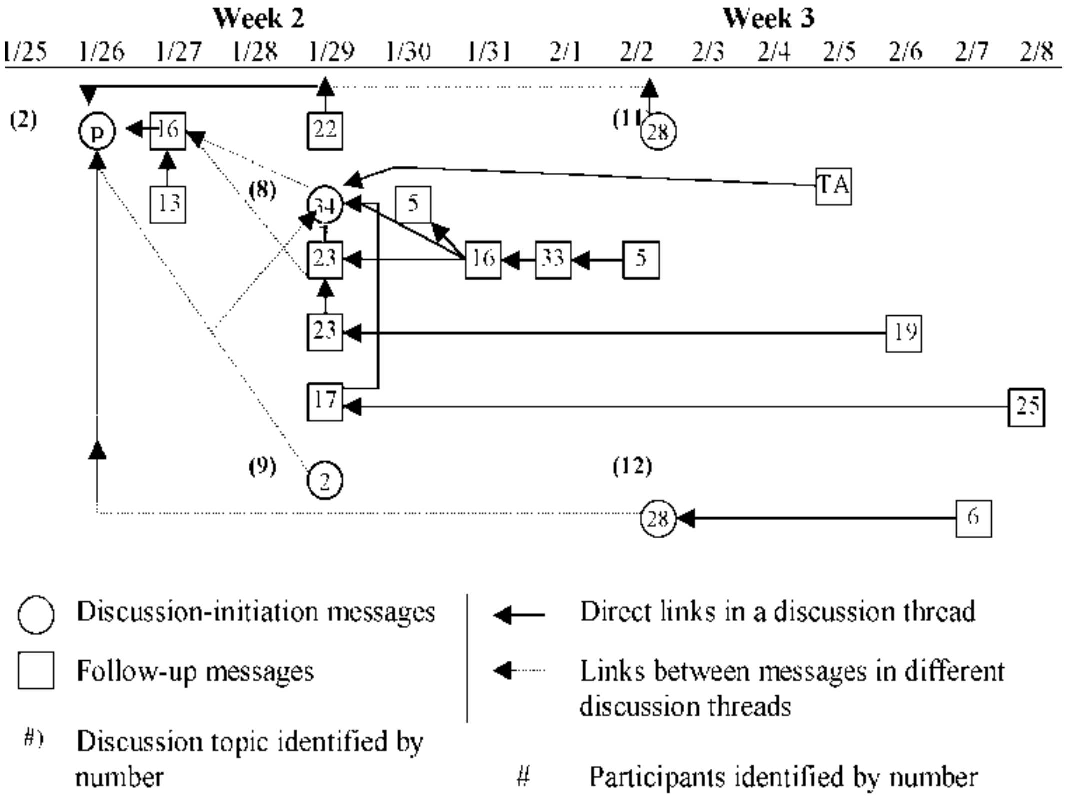
Typology graphs display attributes of object types in a tree-based manner

Example: Perception of a new program by different implementation agencies (e.g. schools) and its actors (e.g. teachers)



17.4.2 Dialog and message structures

Message structure can be rendered with "message maps" (e.g. Pena-Shaff and Nicholls, 2004).



Source: Student Interaction and Meaning Construction in Computer Bulletin Board Systems (BBS) http://www.sloanconsortium.org/conference/proceedings/2004/ppt/1087.ppt.

17.4.3 UML activity diagrams

The Unified Modeling Language (UML) is a non-proprietary, object modeling and specification language used in software engineering. UML includes a standardized graphical notation that may be used to create an abstract model of a system: the UML model. Some educational modeling languages are also described as UML diagrams. For example, the semantic information model of IMS Learning Design (and former EML) has been expressed in UML as we have seen in chapter 11. Another example is coUML (Derntl & Motschnig, 2007), a multi-purpose educational modeling language that can be used to design or analyze courses from global to detailed level.

UML activity diagrams are a popular tool in learning design research. There are three kinds of nodes in activity models:

1. ***Action nodes*** operate on control and data values that they receive, and provide control and data to other actions. In more simple terms, action nodes tell what agencies (e.g. a human) does at some point. 

2. ***Control nodes*** route control and data through the graph. These include constructs for choosing between alternative flows (decision points), for proceeding along multiple flows in parallel (forks), and so on.
    - Decision and merge control node are represented by a lozenge 
    - Forks and joins are represented by a horizontal or vertical line (and incoming and outgoing flows). One or more activities can fork and one or more activities can join. 
    - The initial node is represented by a fat black dot. There can be only one initial (starting) node 

- Final nodes are represented by a fat black dot inside a circle (bull's eye symbol). A circle with an x represents the end of a flow (not the whole activity)  

3. Object nodes represent data as they wait to move through the graph.

4. Finally, another important concept is so-called "swim lanes". Activities can be drawn in columns that represent different actors.

Example 73. UML Activity diagram for problem-based learning

This example has been taken from the IMS LD Best Practice and Implementation Guide Revision 2003 (http://www.imsglobal.org/learningdesign/ldv1p0/imsld_bestv1p0.html) and it shows how a typical problem-based learning model could be defined. The diagram in was built with the help of narratives like the following ones:

> *At Penn State, students in Information Sciences and Technologies are involved in courses, which emphasize problem-based learning. In any given course, a number of problem-based learning activities are completed. Preparation for these problems includes an introduction to course objectives, policy and structure, principles of problem-based learning, and sample group problem-solving activities. For any given problem-based learning activity, students are assigned to teams and presented with a problem description, objectives, document and presentation requirements, an outline of associated topics, and evaluation rubrics. Students are then assigned a number of discrete learning tasks, which address all areas of the overall problem. These tasks include participation in discussion activities, access to subject matter experts, reviewing online content and resources, and online quizzing. Once students have completed all of the discrete tasks, students are evaluated by delivering their problem solution in the form of an in-class presentation and a response document, together with discussion activity participation, self- and peer-assessment, and online low-stakes quizzes.*

A narrative also can be presented in list form as in the following example that we also took from the same specification with slight modifications.

- The coordinator for the course makes a problem description available to the group
- Each of the students in the group reads the problem (on the website), as does the facilitator.
- The students decide who is going to be the chairperson - the spokesperson for the group, responsible for recording key group decisions, and the chosen representative is appointed as such by the facilitator.
- The groups then communicate amongst themselves to clarify the problem, using each other and the facilitator to discuss and clarify terminology and any open issues, eventually arriving at their own succinct statement of the problem at hand.
- The chairperson writes this problem description down and the group continues by identifying possible solutions or explanations for the problem.
- These possible explanations are clustered into a small number to be explored further by the students.
- The explanations to be pursued are listed in an online text
- The group then identifies the learning goals of the problem and individuals embark on the required research.
- Eventually, the groups meet up face-to-face or online to discuss their findings, again assisted by the facilitator.
- The chairperson summarizes the findings in an on-line text.
- Subsequently, an Evaluator and the Facilitator discuss the performance of the group and the Evaluator provides an Evaluation of the group

There are five different actors: Evaluator, Facilitator, Chairperson, Student and Coordinator.

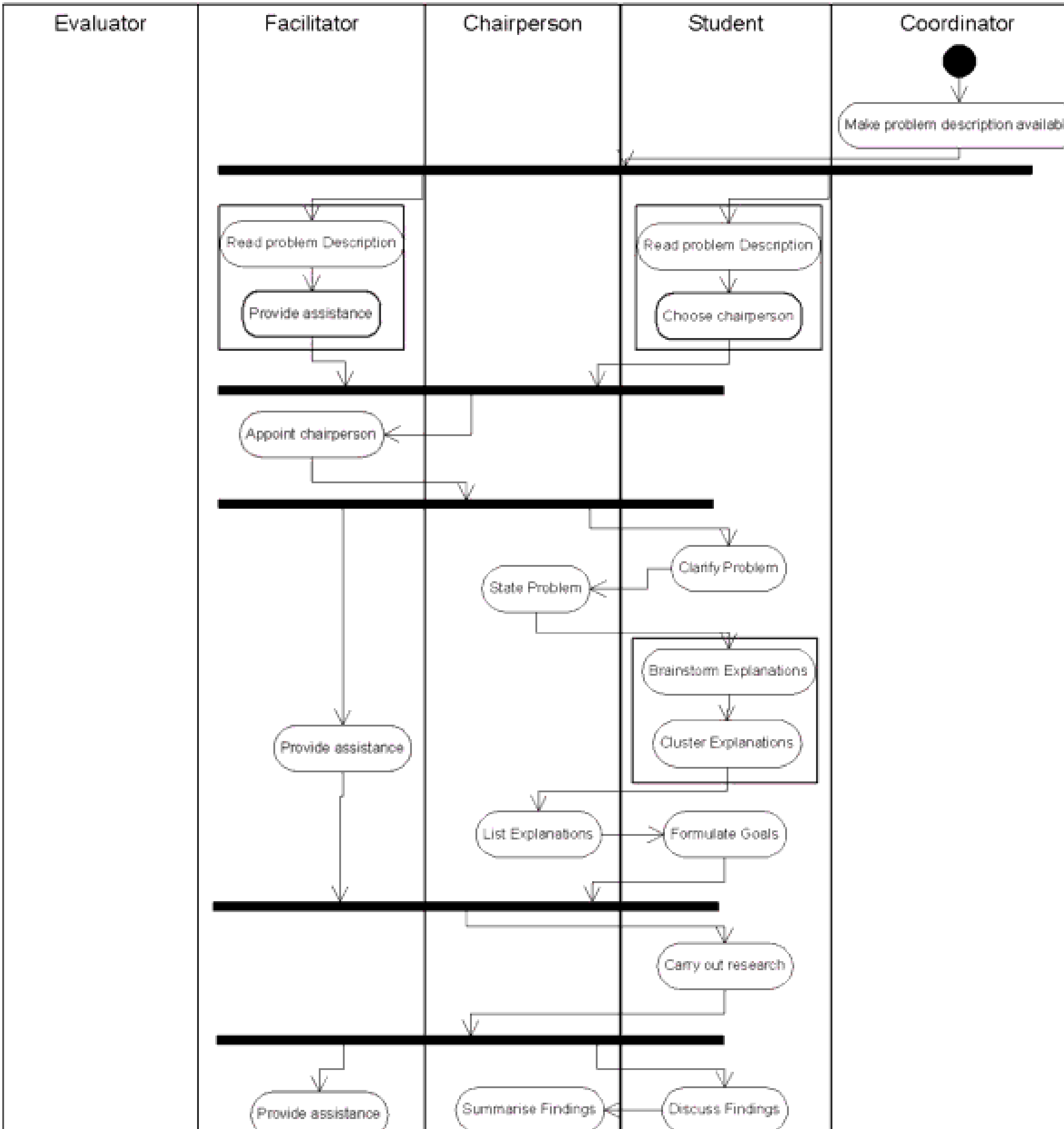
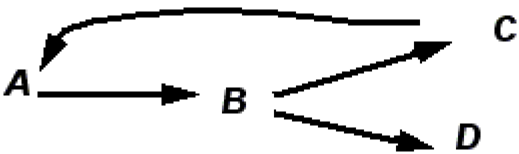

Evaluator
Facilitator
Chairperson
Student
Coordinator
Make problem description availabl
Read problem Description
Provide assistance
Read problem Description
Choose chairperson
Appoint chairperson
Clarify Problem
State Problem
Brainstorm Explanations
Cluster Explanations
Provide assistance
List Explanations
Formulate Goals
Carry out research
Provide assistance
Summarise Findings
Discuss Findings

Figure 98: Activity Diagram for Problem Based Learning (Source: IMS)

Other UML languages can be useful for qualitative data analysis and we will not discuss these for space reasons. Of particular interest are use case diagrams and class diagrams.

17.4.4 Subjective causality graphs

A simple causality graphs relates variables (concepts) with directed arrows.



There exist many variants. One older method is operational coding (Axelrod, 1976) and is somewhat popular in political science. It allows computing outcomes of reasoning chains

Example: Teacher talking about active pedagogies, ICT connections, Forums

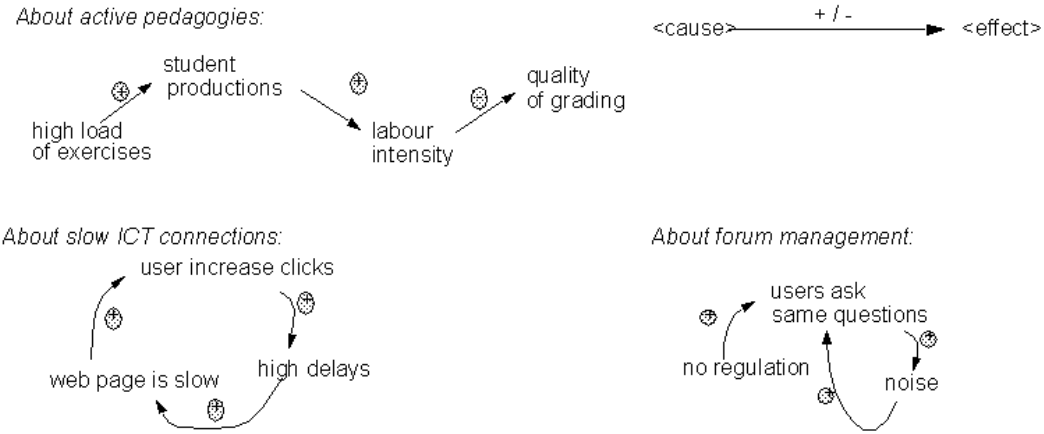


Figure 99: Causality graph examples

17.5 Summary

There is a huge body of qualitative data analysis techniques and some of these have little in common except the general principle:

1. Data used are rich. They are obtained through various qualitative data collection methods and/or from documents and online traces of user activities.
2. Such data generally needs to be coded.
3. Data analysis often relies on visualization techniques, but one also may use simple lists, just use quotations, or rely on quantitative exploratory data analysis techniques.

Review Questions

1. What is the purpose of a codebook?
2. What is the name of a popular tool to model student activities in learning design research?
3. Can you name a qualitative approach that uses quantitative exploratory data analysis techniques

Review case study

1. Download Xornam S. Apedoe (2007). Investigating the use of a digital library in an inquiry-based undergraduate geology course, *Canadian Journal of Learning and Technology*, 33(2) http://www.cjlt.ca/index.php/cjlt/article/view/18/16
2. State the central research problem
3. Create a list of all research methodologies used. For each method, describe the type of data analyzed and the analysis method.
4. Which data collection method and analysis type seemed to be the most important?
5. Summarize the lessons for instructors in 5-6 sentences.

PART V – BIBLIOGRAPHY AND RESOURCES

Research methodology cannot be mastered after a single course. An introductory course will get you started. You will learn the rest from experience, from intensive reading of the research literature and from advanced methodology manuals and web sites.

Introductory research methodology is well documented. There are many good books. However, educational technology is an inter-disciplinary field and you may get much contrasted advice. Therefore, also read research papers to find out how similar problems are solved. In addition, you should identify a research journal that publishes papers in your area of interest and then browse through its contents.

Become a member of a scientific society, e.g. AECT (http://www.aect.org/), AACE (http://www.aace.org/) or ISLS (http://www.isls.org/).You will get a free journal and access to online resources.

You likely will need additional resources for learning specific research methods and techniques. If so, you may first try to find online tutorials, but do not neglect your local library. Finally, you may have to buy a book or consider taking a summer school course in research methodology, for example at Essex or Michigan.

The author's wiki also may help you finding extra information:

- http://edutechwiki.unige.ch/en/
  - http://edutechwiki.unige.ch/en/Research_methodology_resources
  - http://edutechwiki.unige.ch/en/Educational_technology
  - http://edutechwiki.unige.ch/en/Essential_reading

Finally, study the bibliography and the online references chapters presented hereafter..

Good luck with your studies! - DKS

18 Bibliography

This bibliography includes first a few selected general purpose textbooks for further reading. We also include some specialized introductions as well as references for the examples we used.

18.1 General

These books should be suitable for beginners. *Leedy and Ormrod* is probably one of the best books to start with since it introduces research design as a whole.

American Education Research Association (2006). Standards for reporting on empirical social science research in AERA publications. Educational Research, 35(6) 33-40.

Bell, Judith (2005). Doing Your Research Project: A Guide for First-Time Researchers in Education and Social Science, 4th edition, Buckingham: Open University Press, ISBN 0335215041

Bolker, Joan (1998). Writing Your Dissertation in Fifteen Minutes a Day: A Guide to Starting, Revising, and Finishing, Holt Paperbacks, ISBN 080504891X

Cohen, Louis , Lawrence Manion , Keith Morrison (2007). Research Methods in Education, 6th ed. Routledge, ISBN 0415368782.

Creswell, John W. (2002). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (2nd Edition), Sage Publications, ISBN 0761924426

Creswell, John W. (2004). Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research, Prentice Hall; 3rd edition. ISBN 0136135501 - Companion web site

Järvinnen, (2004), On research methods, Tampere: Opinpajan Kirja. (Methods book for ICT-related issues, good but difficult and dense reading])

Leedy, P. D., & Ormrod, J. E. (2005). Practical research: Planning and design (8th ed.). Upper Saddle River, NJ: Pearson Education. ISBN 0131108956 (This is our recommended general purpose textbook about research design)

Newman, Lawrence (2003). Basics of Social Research: Quantitative and Qualitative Approaches. Allyn & Bacon, ISBN 0205355781

Newman, Lawrence (2005). Social Research Methods: Qualitative and Quantitative Approaches, 6th edition. Allyn & Bacon, ISBN 0205457932

Peters (1997) Getting What You Came For: A Smart Student's Guide to Earning a Masters or Ph.D.

Steiner, E. (1988). Methodology of Theory Building. Sydney: Educology Research Associates.

18.2 Quantitative approaches

Quasi-experimental research

Campbell, Donald T. and Stanley, Julian (1963). Experimental And Quasi-experimental Designs For Research, Rand McNally, Chicago ISBN 0395307872. (Very old, but still relevant)

Cook, Thomas, K. and Campbell, Donald T. (1979). Quasi-Experimentation: Design and Analysis Issues for Field Settings, Houghton Mifflin Company, ISBN-10 0395307902

Experimental research

Box, George E. P.; William G. Hunter; J. Stuart Hunter and William Gordon Hunter (2005). Statistics for Experimenters: Design, Innovation, and Discovery, 2nd edition. John Wiley & Sons, ISBN 0471718130. (Rather difficult reading).

Survey research

DeVellis, R. F. (2003). Scale development: theory and applications. Applied social research methods series Volume 26. Thousand oaks, London, Delhi: Sage Publications.

Fowler, Floyd, J. (2001) Survey Research Methods, Sage Publications, ISBN 0761921915

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Statistics

Elementary Concepts in Statistics (Statsoft), retrieved 12 March 2009 from http://www.statsoft.com/textbook/stathome.html

Field, A. P. (2005). Discovering statistics using SPSS (second edition). London: Sage publications. ISBN 0-7619-4452-4. (Good introduction to statistics book for beginners, and help with SPSS too).

Garson, G. David (n.d.) Scales and Standard Measures, from Statnotes: Topics in Multivariate Analysis, Retrived 18:24, 12 March 2009 (UTC) from http://www2.chass.ncsu.edu/garson/pa765/statnote.htm.

Garson, G. David (n.d.) Testing of Assumptions, from Statnotes: Topics in Multivariate Analysis, Retrived 18:24, 12 March 2009 (UTC) from http://www2.chass.ncsu.edu/garson/pa765/statnote.htm.

Hinton, D. P. R. (2004). Statistics Explained: A Guide for Social Science Students (2nd ed.). Routledge. ISBN 0415332850 (This is a good technical-mathematical introduction to statistics)

Tukey, John Wilder (1977). Exploratory Data Analysis. Addison-Wesley. ISBN 0-201-07616-0.

Case study research

Merriam, Sharan B. (1997) Qualitative Research and Case Study Applications in Education, Jossey-Bass, ISBN 0787910090

Stake, Robert Earl (1995). The Art Of Case Study Research, Sage Publications, ISBN 080395767X

Yin, R.K. (2002) Case Study Research - Design And Methods. Third edition. Sage Publications, ISBN 0761925538 (first edition was in 1984).

Evaluation

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Frechtling, J., Frierson, H., Hood, S. & Hughes, G. 2002. The user friendly hand-book for project evaluation. NSF. Retrieved May 2009 from http://www.nsf.gov/pubs/2002/nsf02057/nsf02057.pdf

18.3 Theory of science

Kuhn, T.S. "The Function of Dogma in Scientific Research". Pp. 347-69 in A. C. Crombie (ed.). *Scientific Change*

18.4 Qualitative research

Coffey, Amanda, Holbrook,B. Atkinson, P., Qualitative Data Analysis: Technologies and Representations, School of Social and Administrative Studies, University of Wales, Cardiff. http://www.socresonline.org.uk/1/1/4.html

De Wever, B.; T. Schellens, M. Valcke and H. Van Keer. Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education* 46 (2006) 6-28

Denzin, Norman K. and Yvonna S. Lincoln (eds) (). The SAGE Handbook of Qualitative Research, Sage Publications. ISBN 0761927573

Dey, I. (1993). Qualitative Data Analysis. Routledge, London.

Glaser, Barney G. (1992) Basics of grounded theory analysis: emergence vs forcing. Mill Valley, Ca.: Sociology Press.

Henri, F. (1992). Computer conferencing and content analysis. In A. R. Kaye (Ed.), Collaborative learning through computer conferencing. The Najadan Papers (pp. 117-136). London: Springer-Verlag.

Lombard, Matthew; Jennifer Snyder-Duch and Cheryl Campanella Bracken (2008). Practical Resources for Assessing and Reporting Intercoder Reliability in Content Analysis Research Projects, Retrieved from http://www.temple.edu/sct/mmc/reliability/, accessed 7 October 2008.

Marshall, C. & Rossman, G. B. (1995) , Designing Qualitative Research, second edition, Sage, London

Miles, M. B. & Huberman, A. (1994). Qualitative Data Analysis: An Expanded Sourcebook. Sage. ISBN 0803955405 (This is still **the** cookbook for structured qualitative analysis.)

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18.5 Design research

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Boot, Eddy W.; Jon Nelson, Jeroen J.G. van Merriënboer, Andrew S. Gibbons (2007). Stratification, elaboration and formalisation of design documents: Effects on the production of instructional materials, *British Journal of Educational Technology* 38 (5), 917-933. doi:10.1111/j.1467-8535.2006.00679.x

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Nielsen, J. (1993), Usability engineering, Boston: AP professional.

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Jakob Nielsen, Usability Inspection Methods, CHI ’95 Tutorials, http://sigchi.org/chi95/proceedings/tutors/jn_bdy.htm

18.6 Examples

Below are the references of various articles and other papers used as examples. Our choice of example was guided by didactic principles, e.g. we chose these to illustrate a principle or in the case of review assignments for their simplicity and on-line availability. In other words, this selection is not representative of research in educational technology.

Apedoe, Xornam S. (2007). Investigating the use of a digital library in an inquiry-based undergraduate geology course, *Canadian Journal of Learning and Technology*, 33(2) http://www.cjlt.ca/index.php/cjlt/article/view/18/16

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Dolmans, D.H.J.M.; H.A.P.Wolfhagen, A.J.J.A. Scherpbier & C.P.M. Van Der Vleuten, (2003). Development of an instrument to evaluate the effectiveness of teachers in guiding small groups, Higher Education 46: 431-446,

Eilon, Batia and Kliachko, Sarah (2004). The Contribution of a Substance-Oriented Forum to the Study of Human Biology in Science Teacher Education, *Journal of Technology and Teacher Education* (2004) 12(1), 5-24.

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Lockhorst, D., Admiraal, W., Pilot, A., & Veen, W. (2003). Analysis of electronic communication using 5 different perspectives. Paper presented at ORD 2003 (in Heerlen).

OECED (Organisation for Economic Co-Operation and Development) (2009), PISA 2006 TECHNICAL REPORT. ISBN 978-92-64-04808-9. Also available as PDF from the PISA website.

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19 Online research methodology resources

These online research resources include some useful on-line tutorials and methodology web sites.

There exist many useful websites and shall just present a very small selection here. You may use the author's http://edutechwiki.unige.ch/en/ to explore concepts and techniques of educational technology and related fields.

19.1 Links of links and meta research

Links of links

- http://edutechwiki.unige.ch/en/Research_methodology_resources (maintained by the author of this text).

Research in educational technology studies

- What We Know about Research in Instructional Technology: Interviews with Research Leaders by Marshall G. Jones et al. presentation at the annual conference of the Association for Educational Communications and Technology. St. Louis, MO. February, 1998. http://www.gsu.edu/~wwwitr/docs/leaders/index.html
- Randolph, Justus J. (2007). Multidisciplinary Methods in Educational Technology Research and Development, HAMK Press. This is the only book that specifically focuses on educational technology, and it's **free**!

http://www.archive.org/details/MultidisciplinaryMethodsInEducationalTechnologyResearchAndDevelopment

19.2 Tutorials

General introductions to research methodology

- Bill Trochim's nice Knowledge Base. This web-based text-book is a good place to start for quantitative research (including statistics) http://www.socialresearchmethods.net/kb/index.htm
- Research Methods, by Christopher L. Heffner. This ten chapter research methods text is written for both undergraduate and graduate students in education, psychology, and the social sciences. It focuses on the basics of research design and the critical analysis of professional research in the social sciences from developing a theory, selecting subjects, and testing subjects to performing statistical analysis and writing the research report. http://allpsych.com/researchmethods/index.html
- Shields, Patricia and Hassan Tajalli. 2006. Intermediate Theory: The Missing Link to successful Student Scholarship. Journal of Public Affairs Education. Vol. 12, No. 3: 313-334. http://ecommons.txstate.edu/polsfacp/39/

Statistics

There are many tutorials on the web. If you are not happy with this little choice, consult http://www.slais.ubc.ca/resources/research_methods/quantita.htm for example.

- StatSoft Electronic Statistics Textbook. **Very good and fairly suitable for beginners**, from StatSoft the makers of Statistica ! http://www.statsoft.com/textbook/stathome.html

- HyperStat Online Textbook by David M. Lane at Rice University. Centered on Anova and testing. Look at its humor links to take a break. http://davidmlane.com/hyperstat/index.html
- PA 765 Statnotes: An Online Textbook by G. David Garson, NC State University. **Very good Hypertext with many detailed "chapters", not always suitable for total beginners**. Also makes references to SPSS procedures. http://www2.chass.ncsu.edu/garson/pa765/statnote.htm
- Statistics Hell. Dr. Andy Field's slides and handouts (with some dripping blood). Some of his stuff is really recommended, in particular the introductory texts on factor and cluster analysis. http://www.statisticshell.com/
- Wikipedia Statistics. The Wikipedia has become a very good resource for some issues and models (2006). But not always for the faint hearted. http://en.wikipedia.org/wiki/Statistics
- NIST/SEMATECH e-Handbook of Statistical Methods Exploratory Data Analysis, retrieved 5 March 2009

Qualitative Research methods

- Lombard, Matthew, Jennifer Snyder-Duch and Cheryl Campanella Bracken (2005). Practical Resources for Assessing and Reporting Intercoder Reliability in Content Analysis Research Projects, retrieved May 2008 http://www.temple.edu/sct/mmc/reliability/
- Bob Dick, Grounded theory: a thumbnail sketch, http://www.scu.edu.au/schools/gcm/ar/arp/grounded.html, retrieved April 2009.

Design methodology

- Design Methodology. Slides by Maria Hakansson, IT-University. http://www.viktoria.se/~saral/design_isd.htm

Software

- The Impoverished Social Scientist's Guide to Free Statistical Software and Resources by Micah Altman. This is probably the best list of free quantitative software on the Internet http://maltman.hmdc.harvard.edu/socsci.shtml
- Choosing Qualitative Data Analysis Software: Atlas/ti and Nudist Compared by Christine Barry, Sociological Research Online, vol. 3, no. 3. Note: this on-line journal has other good "quali" articles. http://www.socresonline.org.uk/3/3/4.html
- WEXTOR is a Web-based tool that lets you quickly design and visualize laboratory experiments and Web experiments in a guided step-by-step process. http://psych-wextor.unizh.ch/wextor/en/index.php
- Questionnaires can be administered over the Internet. The main advantage is cost reduction. On the other hand, you may get a higher sampling bias. A recommended free survey server-side software (that you can install with most Internet providers) is LimeSurvey (php/mysql-based) http://www.limesurvey.org/

19.3 Data and Theory

Data and Question Archives

- The Impoverished Social Scientist's Guide to Data Resources by Micah Altman. A good starting point for major data resources as well as many

international and US databases.
http://maltman.hmdc.harvard.edu/data.shtml

Finding research articles on the Internet

It is increasingly easy to find academic materials on the Internet. However, for many resources you (or your institution) has to pay.

- Google Scholar is the best overall search engine for academic materials.
- Social Reference managers, Citation indexes, social bookmarking sites, etc. also can be useful

Open access journals

Most universities have institutional subscription for many journals, but some do not. Luckily, there exists an increasing set of so-called "open-access" on-line journals and that you can consult without any fees.

- Directory of Open Access Journals, http://www.doaj.org/

Good open access journals in educational technology are:

- Journal of Interactive Media in Education (JIME), http://www-jime.open.ac.uk/
- Innovate - Journal of online education, http://innovateonline.info/
- Australasian Journal of Educational Technology (AJET), http://www.ascilite.org.au/ajet/ajet.html
- Canadian Journal of Learning and Technology, http://www.cjlt.ca/

- International Journal of Emerging Technologies in Learning (iJET), http://www.online-journals.org/index.php/i-jet
- Contemporary Issues in Technology and Teacher Education (CITE), http://www.citejournal.org/vol9/iss1/
- E-Journal of Instructional Science and Technology (e-Jist), http://www.usq.edu.au/e-jist/ (now merged with AJET)
- Educational Technology & Society http://www.ifets.info/