Research Methodology

Part 2: Research Designs and Methods

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1 A recapitulation

Remark 1.1 (Summary of previous class)
Last time, we had a bird's eye view on the research process. We reminded ourselves why science is awesome (people were able to calculate the circumference of Earth, more than 2,000 years ago!) We defined a few key concepts, like *science* or *theory*, and we compared those to pseudoscience (vs science) and hypotheses (vs theories). Then we considered the research process according to the *scientific method*

1. Define a general question
2. Gather information and resources (e.g., literature review, theory building)
3. Form a hypothesis
4. Perform an appropriate experiment (or make appropriate observations) and collect the data
5. Analyze the data to derive the results of your study
6. Interpret the results and draw conclusions (this may serve as a starting point for a new hypothesis)
7. Publish results

Importantly, this process should be thought of as a cycle – once you have interpretable results, those should naturally give rise to new research questions. Towards the end, we briefly addressed each of these items (e.g., how to operationalize your research question to formulate a hypothesis). We finished while discussing about the publication process; let us resume that discussion.
Disclaimer. Most of the following content is based on Ref. (1).

Group Exercise 1.2 (The publication process)
The way how research is summarized and published and presented can vary considerably between fields. In computer science it is common to publish findings in conference proceedings; in the natural sciences it is common to publish in journals; and in the humanities it is common to publish books. So, how does the publishing process in your field look like? What is the typical length of a research output? How would the review process look like, and how would you address the comments of reviewers? How are different publishing venues ranked?

Group Exercise 1.3 (Does all research follow the scientific method?)
While the scientific method is a useful template for the research process, not all research is done according

to that template. For example, for some research projects, the aim is not to verify/falsify a hypothesis, but rather to create a prototype or to come up with an algorithm that is more efficient than all existing algorithms. Similarly, in mathematics, empirical results (e.g. from simulations) play a negligible role and are only used to formulate conjectures (if at all). Here, research is done by defining relevant objects, and by formally proving interesting relationships between them (by logical deduction). To which extent do you see the research approach in your own field reflected by the scientific method?

Definition 1.4 (**Research / Research methods / Research methodology**)
Let us end this short recapitulation by defining a few more concepts that we haven't defined yet:

Research. *Research is the systematic process of collecting and analyzing information to increase our understanding of a phenomenon (under study).* [Oxford Concise Dictionary]

Research methods. *These are the methods and procedures a researcher employs to accomplish a research task. These procedures include the research techniques, data collection methods, statistical techniques, how the results will be evaluated etc.* [Ref. (2)]

Research methodology. *Research methodology is the systematic study of the research process starting from the planning process to reporting the results.* [Ref. (2)]

In the following, we now address some of the steps of the scientific approach in more detail. In this session, we focus on the *research question* and on the *research design*.

2 Formulating a research question

Group Exercise 2.1 (**Good research questions**)
Please discuss the following questions in your group, and come up with suggestions:

1. **Group 1:** How do you get ideas for the next important topic to tackle?
2. **Group 2:** Which aspects should one keep in mind when deciding whether or not a topic is good?

Here are some of my own impressions:

1. **Systematic ways:** Read papers and think about which important aspects are missing; get inspired by going to conferences, reading books, blogs, or opinion pieces; ask the natural follow-up question of your present research (or of your supervisor's present research); extend or generalize some other previous work; test theories; be open when colleagues approach you with ideas (but not too open!)
   Unsystematic ways: Go for a run; take a shower; sit on the couch and listen to music – put yourself in a scientific mindset and let your mind wander around.

2. **Aspects that have to do with yourself:** **(1)** Do you have the expertise to do this? Or at least, do you know a natural collaboration partner to approach? **(2)** Does the topic allow you to transition into an interesting field? Could you transform this topic into your research agenda? **(3)** The topic should excite you. You should enjoy thinking about it.
   Aspects that have to do with the topic: **(1)** Minimum requirement: There is something new about

what you do, and the question should be feasible (answerable, and not too broad). **(2)** Useful additions: Is the topic timely? Is there a reason why it is hard to interpolate from previous work to your new study (e.g., is there some kind of trade-off)? Does the research have the potential to change how we look at things? Has it been difficult to approach the problem in the past, but you have some neat trick? Does the problem have practical applications? Does it simplify the way how people/researchers can do/compute something in future? [those would exactly be the aspects that you would also highlight in the intro of your paper]

Group Exercise 2.2 (Is this a good research question?)
Let us jointly evaluate whether the following are good research questions:

- *Is it right to have capital punishment?* [Not empirically testable, non-scientific]
- *Are teenagers who play violent computer games more likely to be aggressive in real life?*
- *Urban decay and gangs* [Set of variables, not questions]
- *Does police affect crime* [Perhaps too vague; however, for a research paper that pretty much asks a similar question, see Ref. (3)]

Remark 2.3 (Research question vs research design)
The kind of research question you have has a considerable impact on which research method is relevant.

Question type	**Example**	**Explanation**
Descriptive	*What's the general satisfaction among IT:U employees?*	Interested in the general characteristics of a given population
Correlational	*Is there a relationship between occupational background (scientific vs administrative) and employee satisfaction?*	Interested in statistical associations between different variables
Causal	*Do cookies increase employee satisfaction?*	Interested in establishing causal relationships

In addition, there are several other question types (e.g., comparative, exploratory etc). Moreover, there are additional distinctions for the type of data that one would obtain (e.g., qualitative vs quantitative research). To do hypothesis-testing, you will need some kind of quantitative data. Moreover, as a rule of thumb, to establish a causal relationship, you will need to run an experiment (for other types of questions, you could also use non-experimental/observational methods, such as ethnographic studies or surveys).

3 Non-experimental approaches

Remark 3.1 (Correlational research)
In correlational research, your main interest is to determine whether two (or more) variables covary. However, you do not make any attempts to manipulate variables; you observe them as they are. For example,

you might ask whether scientific staff members are more satisfied at IT:U. To this end, you could compare some measure of satisfaction (e.g., number of smiles) across employees. Note that even if there were significant differences, we would not be able to assume a causal relationship. In general, there are two difficulties when trying to infer causal relationships from merely correlational observations: **(1)** Third-variable problem: There could be a third variable that affects both of the considered variables (e.g., people with a high tolerance for frustrations might be both happier on average, and more likely to become scientists). **(2)** Directionality problem: Does A cause B or does B cause A?

Remark 3.2 (An overview on some non-experimental research designs)

1. **Naturalistic observation.** Naturalistic observation involves observing your subjects in their natural environments without making any attempt to control or manipulate variables (either directly or with cameras, etc). One special case of such an approach are ethnographic studies where a researcher is immersed in the social system being studied. This technique is mostly used to study aspects of the respective culture through a study of social interactions. Study subjects could be foreign villages, but also local milieus (e.g., prisoners, gang members, PhD students, etc).
2. **Case studies.** A case study is a descriptive technique in which you observe and report a single case in depth (e.g., in management science, or in medicine).
3. **Archival research.** This strategy involves studying existing records. These records could be historical accounts of events, census data, court records, police crime reports, published research articles, medical records, social media information, etc. This kind of data analysis could be combined with content analysis – analyzing written or spoken records for the occurrence of specific items (e.g., using social media data to detect misinformation).
4. **Surveys.** Here, you obtain data through questionnaires. Questions can be of several types. Open-ended research questions allow people to formulate answers in their own words, whereas for restricted questions, the researcher provides options (a special case of such a question is to provide a rating scale).

Note that all of these methods might provide you with both qualitative and quantitative data.
Question: With which of these methods could you approach the question *What's the general satisfaction among IT:U employees?*

Remark 3.3 (Design choices in non-experimental/observational studies)

- How to clearly define *behavioral categories*? (How do you operationalize behaviors like *satisfaction*, *aggressiveness*, etc?)
- How to quantify behavior? (e.g., How frequently was some behavior observed? How long did some behavior last on average?)
- When it is non-trivial to classify behavior, you may designate several observers. An interesting quantity is then the *interrater reliability*, how often two or more observers agree in their classification. You would like to take measures that this reliability is high.
- Observer bias. This bias occurs when observers know the aim of the study and if their assessments are influenced accordingly. The solution is to use (hire) observers that are blind to the research hypothesis.

- Observing by participating or non-participating? Should observation be overt or covert?

Remark 3.4 (Why correlational research)
Even though correlational studies do not yield causal relationships, there are at least three reasons why they are useful: **(1)** These days, there are many big data sets publicly available. **(2)** Especially in the early stages of a research project, correlational evidence may provide useful directions. **(3)** In some cases, variables would be hard/impossible to manipulate (e.g., whether or not someone has a scientific background), or it would be unethical to do so (e.g., does bullying affect suicidal thoughts).

4 Experimental approaches

Remark 4.1 (**Setup of an experiment)**
In an experiment, the researcher systematically varies one or more variables to explore their effect on some outcome variable. The variable under control is called the *independent variable*; the outcome variable is the *dependent variable*. For example, a researcher interested in the effect of cookies on student participation might systematically vary the availability of cookies in the classroom. In the simplest case, there are only two possible comparisons made (two treatments): one with cookies and one without. In that case, we call the treatment without cookies (the baseline) the *control group*, and the treatment with cookies the *experimental group*. We note that in this example, student participation might also depend on a number of other variables (e.g., daytime, content of class, etc). These are *extraneous variables*. They also affect the experimental outcome, but they are not of interest to the experimenter. The task of the researcher is to either keep the values of extraneous variables constant across treatments (e.g., always do lectures at the same daytime), or to randomize these variables across treatments (e.g., for each given lecture, it is randomly determined whether it belongs to the control or to the experimental treatment). Only when we control for variation in extraneous variables in this way, we can be sure that differences between treatments are indeed caused by the variable we explicitly manipulated.

Group Exercise 4.2 (**Causal versus correlational study)**
Suppose you wish to study whether the amount of sleep affects memory performance.

1. **Group 1:** Propose a research design if you want to address this question as a **causal study**.
2. **Group 2:** Propose a research design if you want to address this question as a **correlational study**.

Note that both tasks require groups to operationalize 'memory performance'.
[In the first case, explicitly manipulate the sleep participants get the previous night, by having them sleep on site. In the second case, do a survey to ask people how much they slept the last, say, 2 nights. In both cases, let them then, say, try to memorize 30 words by looking at them for 1 minute].

Remark 4.3 (**Internal and external validity)**

- *Internal validity* reflects to which extent the ability of the experiment to test what it was supposed to test: that variations in the independent variable (and only in that variable) caused the variation in the dependent variable. When there is another (extraneous) variable that was not controlled for, we speak of a *confounding variable* (e.g., if the cookie lecture was always in the morning and the control always in the afternoon). This would give to potential *rival hypotheses*. To ensure internal validity the experiment needs to be carefully designed, to avoid any possible confounds.

- *External validity* asks to which extent the finding of the experiment generalizes to other settings (e.g., from the lab to a natural environment, from student participants to the general population, from an artificial task to a more natural task).

In the following, we discuss two more design choices that the researcher needs to make when conducting the experiment.

Remark 4.4 (Lab vs field experiments)
In a lab experiment, you conduct the experiment in a specific environment that is artificial relative to the setting in which the behavior normally occurs. Lab experiments usually have the advantage that they tend to be cheaper, and that the researcher has more control on extraneous variables (enhancing internal validity). Instead, field experiments are conducted in the environment in which some behavior naturally occurs (e.g., testing how people react to littering in a public train station, see Ref. (4)). By their design, field experiments tend to have better external validity.

Question: Is there a best of both worlds?

- *Simulations:* Here, you attempt to re-create (as closely as possible) a real-world situation in the lab (e.g., using virtual reality, or driving simulator).
- *Lab-in-the-field experiments:* Here, you take a standardized experiment but you target relevant populations in naturalistic settings (e.g., do economic experiments in the kindergarten, or in different small-scale societies (5)).

Remark 4.5 (Between-subject vs within-subject design)
When you use a between-subject design, you use different sets of participants for the different treatments. For example, when you interested in the effect of distractions on driving performance, you might expose some of your participants to a calm podcast and some other participants to an upsetting podcast.
When you use a within-subject design, participants take part in all treatments sequentially. Note that such a sequential design could confound the experiment if it was always true that, say, the calm treatment follows the upsetting treatment (*Why?*) To avoid this confound, you would randomize the order of treatments. A within-subject design has the advantage that with the same number of participants you get more data, and that you naturally keep the extraneous characteristics of the participant constant.

Remark 4.6 (Summary)
In this class, students should have learned the following:

- how to generate research ideas, and what makes an idea a good one,
- how to find an appropriate research design for a given research idea,

- what is the difference between correlational and causal studies, and which design choices need to be made in each study.

5 Some bonus material

Remark 5.1 (A reflection on the research process)
Obviously the research process according to the 'scientific method' is an idealization; in reality, things often are a bit more messy. In particular, the way from research to research article can often follow a non-monotonic trajectory. To illustrate this point, we take a look at the research process for one of my own papers (6).

References

[1] Bordens, K. S. & Abbott, B. B. *Research Design and Methods: A process approach* (McGraw-Hill, New York, 2022).

[2] Thomas, C. G. *Research Methodology and Scientific Writing* (Springer, Cham, Switzerland, 2021).

[3] Di Tella, R. & Schargrodsky, E. Do police reduce crime? Estimates using the allocation of police forces after a terrorist attack. *American Economic Review* **94**, 115–133 (2004).

[4] Balafoutas, L., Nikiforakis, N. & Rockenbach, B. Direct and indirect punishment among strangers in the field. *Proceedings of the National Academy of Sciences* **111**, 15924–15927 (2014).

[5] Henrich, J. *et al.* In search of homo economicus: Experiments in 15 small-scale societies. *American Economic Review* **91**, 73–79 (2001).

[6] Hauser, O., Hilbe, C., Chatterjee, K. & Nowak, M. Social dilemmas among unequals. *Nature* **572**, 524—527 (2019).