Beyond CP Snow

Many of the challenges we face in the 21st century deal with issues that demand a deepened understanding of the interplay between the biophysical world, humans, society and technology. Research and education stand upon a founding structure with rather distinct borders between the different traditions. As a result, the methods, theories, models, concepts and thought styles that are at our disposal today have mainly been developed to explain, understand and predict phenomena and processes within the different academic spheres (roughly divided into the humanities, social sciences, natural sciences and technology). These spheres can only to a limited extent help us understand the interaction between nature, humans, society and technical systems. A deepened understanding of the interaction between these spheres demands access to theories, methods, models, concepts and thought styles that not only enlighten these spheres but also the interaction among them. We need informed interdisciplinary studies by skilled interdisciplinary scholars.

When speaking about differences among traditions in academia, the concept of “the two cultures” easily comes to mind. Even though CP Snow, when formulating the concept in 1959, referred to the gap between arts and science, the concept has later come to denote The Gap between the humanities and the social sciences on the one hand and the natural sciences and technology on the other. The concept of the two cultures has undoubtedly initiated various interesting discussions, but it has also led to unnecessary and time-consuming fence-building between the parties. This fence-building exacerbates differences and is of no help for those who try to bridge the gap.

The following chapter deals with the common pitching of qualitative and context dependent humanities and social sciences against quantitative and exact natural sciences, as if this was a full description of the academic
landscape instead of a meagre oversimplification thus hindering exchange of knowledge across various gaps. The following is an attempt to help you move to a more nuanced understanding, to a more fruitful position, making it possible to understand and draw on differences.

**Quantitative and qualitative studies**

Most people seem aware that quantitative research means counting, measuring and using statistics and the like, whereas qualitative research is less well known beyond the realm of those who practise it. Many appear to believe that qualitative studies are conducted only in the humanities and the social sciences, and in some quarters it is believed that quantitative studies are conducted only within the natural sciences. Both these apprehensions are misunderstandings: there are without doubt qualitative natural science studies as well as quantitative humanities and social science studies; as developed below, both of these are common and widespread. The words "quantitative" and "qualitative" are used differently and given different connotations in different disciplines, which complicate these discussions since many seem to feel that their interpretation is exclusive while others are ill informed. The differences should not be ignored but there are actually quite a few commonalities that cut across most traditions, commonalities which, however, are seldom explored, discussed or used.

Broadly speaking, qualitative and quantitative research are two different methodological approaches. Qualitative studies focus on the inner quality of things, aim at answering questions such as "how" and "why", and deal either with issues that cannot be quantified or issues where quantification has no meaning. Qualitative studies are common in disciplines such as philosophy, sociology, analytical organic chemistry, political science, taxonomy, ecology and history. Quantitative studies focus on measuring things and aim at answering questions such as "how much", "how fast", and "how long". Quantitative studies are common in economics, hydrology, chemistry, physics, sociology, biogeochemistry, geography and political science.

To illustrate what a quantitative study might be, as compared to a qualitative study, I use an example that cuts across the traditional nature-culture gap.
Few researchers are trained in both quantitative and qualitative methods, and even though one might discern a change with an increasing number of younger scholars who are trained in both, most scholars still act in groups that conduct either qualitative or quantitative research. This either-or division has the unfortunate outcome that qualitative studies with semi-quantitative elements far too often contain quantifications of questionable quality and that quantitative studies with semi-qualitative or qualitative elements rarely are credible in the qualitative parts. This situation unfortunately reinforces the division in either-or. Increasing your methodological awareness will help you combine qualitative and quantitative studies in a credible manner.

When qualitative studies contain sloppy quantifications, it appears to be a question of ignorance of basic statistics. I dare say this is true, whether it is studies in the humanities (e.g. based on in depth interviews) or studies in the natural sciences (e.g. based on analytical chemistry). When conducting studies in which you intend to use quantifications or even semi-quantitative estimates (more than or less than, rather than exact numbers),

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**Example 1**

**Quantitative and qualitative questions**

**Quantitative question:** How many people can this field feed?
To answer this question you could harvest the field, weigh the rice and calculate how many kilogrammes there were per hectare. The number would be more or less exact but would most likely vary between plots and between years. Then you could proceed and analyse the nutritional value of the rice, and estimate how many people the field might feed by combining the harvest information with information on nutrient needs. Another approach would be to estimate how much the rice would be worth on the local, regional or global market and estimate how many persons the income could provide for.

**Qualitative question:** What signifies good rice?
To answer this question you could interview people about their perception of good rice. The perception of good rice might be that it is has a high nutritional value, is easy to store, tastes good, is glutinous, non-sticky, etc. You could also set out to investigate whether or not a specific chemical compound can be tied to the taste, odour or colour of popular rice or if its popularity might be tied to a combined effect of texture, taste and odour.
it is advisable to engage someone who has quantitative training, not only
to crunch the numbers when the study has been conducted but first and
foremost to assist in the design, since a bad design cannot be fixed with
advanced statistics.

When quantitative studies rooted in the natural sciences contain qualita-
tive sub-studies of human or societal issues, it appears to be a question of
what might be called basic methodological ignorance: in spite of the vast
amount of well-written literature in the area, a surprising number of
researchers carry out interviews, surveys and document studies without
even having opened a book on the procedures in question. In contrast, it
never ever happens that a person unskilled in a natural science discipline
would carry out a study of processes or phenomena in Nature. For example,
I do not believe that it is possible to find a historian who has carried out
chemical analyses of old ice cores based on the argument that the ice cores
are historical records and that historians thus have the proper training to
conduct such studies. In contrast, numerous historical studies have been
carried out by natural scientists, engineers or medical researchers, solely
based on the qualification of being personally involved in the historical
events. Personal experience can be a strong asset in research, but it cannot
replace methodological rigour. Work conducted without proper basic meth-
odological competence generally produces questionable results when exam-
ined according to basic criteria for good scholarly work.

It should go without saying that serious interdisciplinary studies demand
that all studies be carried out with equal rigour and be based on sound
methods. If you plan to conduct a study that entails quantitative elements,
you need to be knowledgeable about quantitative design, discuss the design
of your study with an experienced quantitative scholar and not least make
sure you involve someone with know-how on statistical analyses. In exactly
the same way, if you plan to conduct a qualitative study and, for example,
use interviews or surveys, you need to learn how to design a study that
draws on those methods and to make sure that someone with know-how
conducts or supervises the analyses.

Drawing on commonalities

There is a rich literature on qualitative methods within the humanities and
social sciences, but this literature explicitly or implicitly excludes qualitative
natural sciences. The types of studies, which are called qualitative within
the natural sciences, are thus not embraced in this literature. There are
undeniably large differences between qualitative studies in the social sci-
ences and humanities and qualitative studies in the natural sciences. These
differences should not be neglected. But there are also a number of commonalities that it should be possible to draw upon. This is seldom done.

Qualitative natural sciences focus on the inner quality of something, and a great number of the general questions that are dealt with in the qualitative method literature are just as relevant for natural science studies as for the social sciences and humanities. We all carry images of how the world is composed, and these images do, of course, influence our way of conducting research. Textbooks on qualitative methods commonly claim, almost in passing, that this matters only for the social sciences and the humanities and that the knowledge in those books therefore is irrelevant to other fields. I disagree as there clearly is a lot to gain if one manages to elucidate and draw upon commonalities among different qualitative disciplines – across the nature-culture gap. In order to make the knowledge from the general qualitative methods literature applicable in a wider context, these texts need to include rather than exclude the natural sciences, medicine and engineering. While waiting for the literature on qualitative methods to become more inclusive, you can re-write them in your mind by ignoring the limits set by the author and identifying examples from the excluded traditions. Below, I illustrate how knowledge from the qualitative methods literature can be helpful for scholars in field-based observational studies and laboratory-based experimental studies.

There is a relatively clear demarcation between the field-based and the laboratory-based natural science traditions, where the former mainly depend on observation and the latter depend on experimentation (Chapter 8). Qualitative as well as quantitative studies are conducted in both areas. Most of the field-based natural science traditions originate from natural history, where Sweden can pride itself in having produced scholars such as Elias Fries and Carolus Linneaus. Natural history stems from the idea that observation makes it possible to increase our understanding of the biophysical world. In the 18th century, Nature was depicted through detailed drawings in combination with illustrative descriptions. The focus was on describing the inner character of various phenomena with the aim of furthering the understanding of relationships, to explain rather than predict. During the late 17th and early 18th centuries, natural history was closely related to natural theology; the idea was that through the understanding of Nature one would be able to form a deeper understanding of God, of one's own existence and its inner meaning. Descriptions of Nature were mainly qualitative but contained some quantitative elements: annotations of temperature, precipitation, numbers of bird or plant species, etc. Various field-based natural sciences have developed from this tradition, such as hydrology, ecology, meteorology, natural geography, climatology and geology, in addition to systematics (how various species are related). Most
of these traditions still entail both qualitative and quantitative elements. I use biodiversity as an example where the term "diversity" suggests a quantitative approach. The most common way to describe biodiversity is to measure species abundance. Biodiversity is, however, a complex and intricate concept which, among other things, entails four levels: genes, species, populations and ecosystems. In addition, the term signals both the present situation as well as the ability to withstand or absorb future changes. Biodiversity is thus a concept that is meant to describe an area's inner features, its qualities from a certain perspective. In order to cover the meaning of the concept, various tools have been developed, some of which are based on statistical models. Quantitative tools are thus used to describe a qualitative concept.

The laboratory-based experimental natural sciences rest upon a different heritage as compared with the field-based natural sciences. Among other things, the roots can be traced to alchemy rather than natural history. The aim of alchemy was to figure out how, through manipulation and experimenting, one could achieve a certain goal, as for example creating gold from lead or finding the formula for the universal cure for all diseases. Just as in natural history, there was no clear border between religion and science, at least not until the 19th century.

Among the laboratory-based sciences are the so-called "exact sciences". As can be deduced from the name, the "exact sciences" conduct research in which exact answers are sought, and often possible to find. For example, a specific chemical compound has a specific structure irrespective of the quantity. A compound is either lead or gold. If the structure is changed, the compound is no longer the same. Another example is illustrated in Figure 4, which depicts carbon monoxide and carbon dioxide. Both are gases, but carbon monoxide is comprised of one carbon atom and one oxygen atom, whereas carbon dioxide has two oxygen atoms.

Carbon dioxide is a non-poisonous gas that is essential for photosynthesis and exhaled by humans and many other organisms. Carbon monoxide is also a gas but in many respects differs from carbon dioxide, for example by being poisonous for humans, causing suffocation if inhaled. Identifying a molecule as carbon dioxide is exact, as it either is or is not carbon dioxide.

Figure 4 A visual representation of carbon dioxide (CO₂) and carbon monoxide (CO).
At the same time it is a qualitative task, as it is a way to define and identify the intrinsic properties of the gas – its qualities.

Both the field- and laboratory-based natural sciences often use technical equipment that delivers numerical data. Diagrams, numbers, illustrations or equations based on such numerical data are often used to describe various inner qualities. The use of technology, or artefacts as it is often called in the literature, and its role in the production of knowledge is in itself an extensive discussion. Here, I confine the discussion to pointing out that the use of numerical data as one of several tools to describe qualitative features most likely is the root of the perception that the qualitative natural sciences are quantitative.

Below, I provide a highly simplified example of how numerical data can be used to describe a qualitative feature. We can distinguish the colour red from blue by the use of visual experience and then describing the two colours by examples of things that usually are red or blue, respectively, or by describing the feelings we experience when looking at the two colours. Another approach is to describe the two colours by their wavelength spans. When the length of the light waves is around 650 nm, the colour we see is called "red" and when the length of the light waves is around 450 nm, the colour we see is called "blue". The number, here illustrated by the wavelength, is a way of naming, denoting but not quantifying the colours. Using a quantifiable unit (in this case the amount of millionth millimetres) to identify a quality is thus not the same thing as quantifying the thing that carries that quality.

Another example is the case of carbon dioxide and carbon monoxide mentioned above. To identify the gas, you may let the gas bubble through water and then taste it. If it tastes acidic, we can conclude that it is likely to be carbon dioxide, as this gas will form carbonic acid when dissolved in water, a common ingredient in carbonated drinks. Another way to identify the gas is to use an instrument (called a gas chromatograph) that measures how fast the gas diffuses, since the rate of diffusion depends on the weight of the gas, among other things. Carbon monoxide will travel faster than carbon dioxide because it is less heavy. The time needed for carbon dioxide to move through the instrument is registered and reported by the use of numbers (minutes and seconds), but these numbers cannot be used to quantify the gas, only to distinguish different gases from each other.

If we wish to move from the qualitative, that is identifying the colour or the gas, to quantifying the intensity of the colour red or the flux of carbon dioxide in the surrounding air, we need additional information. The former case, moving from the qualitative to the quantitative, will involve determining the intensity of the light, a rather simple task. When moving from identifying the gas to quantifying the flux from the soil to the atmosphere in a forest, the study becomes considerably more complicated and we have
to elaborate our methodology substantially if the results are to be solid enough to serve as a basis for reliable conclusions.

**Context dependence and quantification**

Moving from a qualitative analysis and description to a quantitative estimate is always easier said than done and requires careful consideration to avoid various pitfalls. In this sense, there is nothing that separates the carbon dioxide example from any other study in which you wish to use a qualitative study as the basis for a quantitative study. To use in-depth interviews with four twelve-year-olds regarding their religious beliefs to draw conclusions regarding twelve-year-olds in general is intricate and extremely difficult, many would argue impossible. To use the results from four air samples that have been carefully analysed for their chemical composition to draw conclusions regarding the composition of air in general is likewise intricate and extremely difficult, many would argue impossible. The former type of studies is seldom done, not even after careful consideration, great hesitation and lengthy discussions. In contrast, it is easy to find examples of the latter type of studies, even in highly respected journals. The only way to understand this discrepancy is that the former group is familiar with general qualitative methods literature whereas the latter group are not (including editors and reviewers).

It is often argued that the exactness of the natural sciences in combination with the fact that the results are globally valid is what makes them more reliable, as they deliver exact answers whereas the social sciences and humanities are always context dependent. This is not the case. The exact sciences (which are only a sub-component of the natural sciences) are often able to deliver exact answers *under ideal conditions*, which actually exist only in theory. With the use of laboratories, it is possible to get close to ideal conditions, and it is possible to achieve almost exact answers, but only rarely is it possible to create conditions which allow for truly exact answers. Outside the laboratory, in more complex environments, the exact sciences can provide only approximations. If exact knowledge is to be useful in a complex context, it must consequently be considered in light of that very context.

Discussions on the context dependence of the natural sciences quite often start (or end) with someone lifting a mug or a box of matches and asking whether or not it may be disputed that the object will fall if dropped. Sadly the core issue is overlooked, since most interesting situations are considerably more complex than a falling mug. Even in such a simplified situation we are only able to draw conclusions only about the fall, and
hardly even then: we cannot with certainty know whether or not the mug will break and, if so, if it will break into small or large pieces. We do not actually know if the person in question will let the mug fall, as an act of will is needed to make the fall happen. The only thing we are able to deduce with certainty is the time it will take for the mug to fall, based on an idealized model that assumes free fall without friction, wind, etc. To claim that the exact sciences are context dependent, is in other words to claim that everything must be put into context to have a meaning, which is something completely different from denying basic physical laws under ideal conditions.

By studying processes in the laboratory it is (often) possible to create a (close to) exact understanding of how various physical and chemical phenomena and processes act under ideal or close to ideal conditions; the results can be used to extrapolate to environments outside the laboratory. The laboratory environment makes it possible to minimize and sometimes eliminate natural variation. When conducting an experiment designed to find an exact answer, variation is an unwanted result of the variability of the instrumentation. This stands in stark contrast to environments outside the laboratory where natural variability is an inherent, central and information-carrying feature of the system. Variability is different in different environments and its characteristics hold crucial information. For example, when it comes to biodiversity, an area with one hundred different plant species and ten plants of each species will differ in many aspects from another area, which also holds one hundred different plant species but one thousand plants of one species and only two of the other ninety-nine. An exact answer may thus not be sufficient and may even be misleading when you describe a complex field, as additional information is often needed. To use an oversimplified example: imagine a person holding one hand in a bucket with icy cold water and the other in a bucket with boiling water. It is possible (and easy) to make an exact estimate of the average temperature which is objective, replicable and globally valid. No-one will argue, however, that such an estimate will provide a fair description of the situation the person is experiencing.

Exact information must consequently always be interpreted to be of any use. To interpret any information, however exact, in light of a complex context, is both intricate and complicated. A useful answer concerning a complex question cannot and should not be exact since the exactness will be misleading. I use an example to illustrate that results (the answer to a research question) may be both globally valid and exact or neither globally valid nor exact, depending on the context. I use the following question as my example: "How much will addition of 0.5 ml of nitrous acid decrease the pH of water at a temperature of 20 degrees Celsius?"
In the first case in Table 1, where water stands for “pure water”, the answer is undeniably both globally valid and exact, provided that the instrumentation and purification methods have been calibrated and the method/instrumentation variation is negligible. Analyses of pure water at any laboratory should give the same result. It is not valid for “water” in general, however, but only for “pure water”, in other words distilled, deionized, filtered water, which is only found in laboratories, provided that ideal conditions are prevailing at the laboratory.

In the second case in Table 1, where water stands for “a surface water sample”, the variation among replicates of the same sample will be larger than for purified water, since natural water is more heterogeneous than purified water. If a sufficient number of samples are analysed, the average value will give a fair picture of the water from which the sample was drawn – more analyses will not change the results. Hence, providing an exact estimate of the average is sufficient provided that the variation is small. An estimate of the variability should also be provided to make it possible for the outsider to determine whether the variability is relevant or not. The answer can thus be said to be (rather) exact, but it is not globally valid; as discussed in the third case a sample from a different lake or river will give a different result and a sample from the same surface water sampled at another time or at another location may actually also give a different result, since the water quality in the same water body varies with time and space.

In the third case, water denotes “surface water in a region”. If we set out to determine the effect on surface waters in a region, we will find that the variation among samples from different surface waters will be considerably

<table>
<thead>
<tr>
<th>Sample (Water = ?)</th>
<th>Globally valid?</th>
<th>Exact?</th>
<th>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure water</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>A surface water sample</td>
<td>No</td>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td>Surface water in a region</td>
<td>No</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>Water</td>
<td>Yes</td>
<td>No</td>
<td>4</td>
</tr>
</tbody>
</table>
larger than the variation among replicates of the same sample due to the heterogeneity of the biophysical world. An exact answer will, in this case, be misleading since the variation among the samples describes the situation and should consequently be included in the answer. The variation in itself carries information. The variation is thus not an indicator of accuracy. The answer is not globally valid, since the results depend on which region is sampled.

In the fourth case, water stands for any water sample. If we set out to achieve a picture of how the pH would change after addition of the acid to any water, we will need to collect a large number of samples. As in case three above, we need to include information about the variation as it describes the heterogeneity, i.e. what reality "out there" looks like. And reality in complex fields is seldom linear or normally distributed. Since our aim is to describe the response of any water sample, the sampling should be designed in such a manner that the results are globally valid, but they will certainly not be exact.

In summary: most complex issues dealing with environment, health or security are far more complicated than the water example above. Hence, when the aim is to achieve a deeper understanding of a complex field, it is rarely if ever possible to delimit the study to questions to which there are exact answers. This is for two reasons, as already explained. First, exact answers are valid only under ideal conditions that prevail only in theory and sometimes in the laboratory. To be valid in a more complex context, the answer must be interpreted. For example, the exact effect of nitrous acid added to pure water is globally valid, but only in a laboratory context, since pure water does not exist outside laboratories. Second, (close to) exact answers are possible only when the natural variation has been minimized or eliminated. Environments outside the laboratory are characterized by their heterogeneity and the variation is a central and information carrying feature. Even the most exact findings consequently do not have any meaning in a complex field if they are not put into context.

**Interpretation and context**

The above serves to illustrate that anyone who studies complex issues is likely to benefit by reflecting upon how the context influences which conclusions may be drawn from a specific study – context is thus relevant not only to students in the humanities and social sciences but to also students in the natural sciences and technology. As mentioned above, there is a rich literature on qualitative methods, which commonly discusses challenges
emanating from the context. Many of the questions that are discussed in this literature are of a general character and even though not spelled out, many of the issues discussed are general and highly relevant across The Gap. There is yet another body of literature that describes and discusses the production of knowledge in science. This literature is also written for (and mostly read by) students who study sociology, philosophy and history of science, and not for students studying science.

It is sometimes argued that the natural sciences and engineering differ from the social sciences and humanities in that the former see the whole as the sum of the parts whereas the latter emphasize the need to study the parts and the whole interchangeably. In the philosophy of science literature, the former approach is often called reductionist whereas the latter is a prominent part of a hermeneutic approach. The latter approach builds upon the idea that the whole is more than the sum of the parts whereas the former builds upon the idea that the whole can be understood as the sum of the parts. Hermeneutics was originally a method that dealt with the interpretation of texts, mainly religious, but it has later come to denote an approach rather than a method. In simplified terms, a hermeneutic approach means that you believe that nothing can be understood without interpretation and that it is therefore necessary to remain open to other potential ways of interpreting the phenomenon under study. Furthermore, the understanding that the parts and the whole are interchangeably dependent on each other makes up a crucial part of the interpretation process. Since hermeneutics to a large extent deals with the interpretation of texts, it comes as no surprise that computer communication, especially artificial design, draws upon such knowledge.

The importance of studying the parts and the whole interchangeably, as well as the need to understand that data must be interpreted to be given meaning (also called a holistic approach) are applicable to all research that deals with complex issues. There are numerous examples of research traditions within the natural sciences that emphasize the need to focus on the parts and the whole interchangeably to understand an issue, since it is impossible to understand the whole as simply the sum of the parts, especially in the field-based traditions mentioned above. Basic textbooks in disciplines (i.e. hydrology, hydrochemistry, ecosystem ecology, limnology and eco-toxicology) generally emphasize the necessity to study the system and not only the parts, since the sum of the parts, due to the numerous feedback loops and related complexities, will not add up to the whole. It is stressed that the information is context dependent, but the literature rarely if ever discusses the challenges of context dependence on a general level and it seldom draws upon the rich method literature from the humanities and social sciences.
Notes

1  Charles Percy Snow 1993.
3  See, for example, *The SAGE Handbook of Qualitative Research* by Norman K. Denzin and Yvonna S. Lincoln (eds) 2005.
4  In order for a study to be called qualitative in the humanities and social sciences, many demand that the study in one way or another contains a reflection on the meaning of what has been studied, a demand that is rarely or ever fulfilled in qualitative natural science studies.
5  See, for example, Roger Strand 2002.
6  See, for example, Daniel Sarewitz *et al.* 2002; Lorraine Daston and Peter Galison 2007; Lynn White Jr 1974.
7  See, for example, articles in the journal *Science, Technology and Human Values*.
8  For a discussion on the fact that all knowledge is and must be contextualized, see Ludwik Fleck’s *Development and Genesis of a Scientific Fact*, originally published in 1936, reprinted in 1979.
9  See, for example, Ludwik Fleck 1979; Thomas Kuhn 1970; Bruno Latour 1987 and Donna Haraway 2008, to mention a few.