During the still ongoing COVID-19 Pandemic, scientific studies and their interpretation have become the objects of mass-media coverage and public discourse to an unprecedented degree. News presenters read out the latest statistics, experts are asked about their takes on recent developments and even those who deny the validity of scientific results or claim that said results do not to justify certain measures still engage with scientific predictions, albeit to refute or reinterpret them. Science has been the primary and most respected source of knowledge in many parts of the world for a long time, but it has rarely had such a large audience in the general public. And because there is a global crisis that affects the lives of all people on earth, there is a public desire for solutions and crisis- management and in a larger sense a desire for order to return in these chaotic times. It is therefore not very surprising that many expect knowledge about the pandemic to be both certain and exact, so that clear and effective counter-measures can be introduced as quickly as possible. But can our knowledge as a whole even meet these criteria? Or are exactness and certainty false ideals? That is the central question that I want to concern myself with in this essay. In particular, I want to look at knowledge gained through science precisely because the reliability of scientific knowledge is such an important question for the present situation of the world and because, as was stated before, science is the primary source of knowledge for most of the world's population and institutions. So we will examine if certainty and exactness are ideals applicable to scientific knowledge or if they are false and potentially even harmful ideals. Are these reasonable standards that the models and theories produced by science have to meet or do we have to use a different set of standards?

Before we try to answer these questions, we firstly have to clearly define the terms of certainty and exactness. Certainty means that the knowledge we have is definitely accurate and reliable. When the knowledge I have is certain, it cannot be refuted or challenged in any meaningful way. Certain knowledge is unshakable, if I know with certainty that the sky will be blue tomorrow, it will be blue. Exactness is an equally demanding concept. It means that what I know must be a perfect mirror of how things really are and leave no room for vagueness. An inexact statement would be that someone is between one and two meters tall, even if that knowledge is certain. Exact would be the knowledge that this person is precisely 1.73 meters tall. But when the true height of the person is only slightly different, the statement is again inexact, even if the difference is almost immeasurable.

These standards seem to be extremely hard to meet by definition and applying them to the practical reality of scientific research and progress leads to a series of complications. Let us firstly analyse the concept of certainty in science. Natural science relies on empirical evidence and develops theories by using inductive reasoning, looking at a series of similar individual cases and devising a general rule based on what was observed. This core principal of science is however already corrupted by uncertainty. As the Scottish philosopher David Hume already pointed out in the 18th century, inductive reasoning is not logically binding. Just because something always happened a certain way before that does not mean it will always happen this way in the future. Hume famously stated that it cannot logically proven that the sun will rise tomorrow just because it did so every other day before. Therefore, it is not certain knowledge that the sun will rise tomorrow. This concept was advanced even further in the 20th century by the famous philosopher of science Karl Popper. According to Popper, scientific theories cannot be verified, only falsified by empirical evidence. No matter how often a scientific theory correctly predicts certain events, it can never be considered verified because there may always be instances in which it fails to make correct predictions. But when the theory clearly makes a false prediction, it is falsified and must be replaced with a new theory that can also explain the new evidence that falsified the old theory. An example of this kind of development would be the evolution of the atomic model. It went through several stages of development, always encountering new evidence that could not be explained by the old model and therefore developing a new model. Instead of one certain model that could explain and predict everything, revisions were constantly needed to adjust to new discoveries. Wecan therefore not expect knowledge which is gained through science to be certain because scientific progress relies on the falsification and the revision of old theories and models.

But how about exactness? Can our knowledge of the world always be expected to be exact? To a certain degree, the standard of exactness can be met. For example, when we count objects that we can clearly see and distinguish, we arrive at an exact number of objects. I can count that I have five fingers on my hand, not four or six, but five. But not every measurement and every observation can be expected to be exact. In many cases we have some form measurement error, especially when we measure phenomena that are not entirely clear or even completely undetectable for our senses. We know that when we measure amperage or voltage several times under the same circumstances, we get slightly different results. By repeating the experiment over and over again and using mathematics to calculate the measurement error we can approximate a more exact result, but the fact remains that we always have to deal with some level of inexactness because our tools for measuring and observing the world are simply not perfect. So while on a macro-level we may be able to make some exact statements, the scientific analysis of the world as a whole does not always produce perfectly exact results.

It seems that we cannot use certainty as an ideal for our knowledge because it is antithetical to the ideas of induction and falsification that drive scientific progress. And we also cannot always expect our knowledge to be exact because of the limitations of our gauges and the resulting measurement error. It might be objected that we have only looked at natural sciences and their fallible inductive reasoning, but have ignored the discipline of mathematics which relies on deductive reasoning and does not need testing to produce results, meaning its conclusions are both exact and certain. There is some truth to that objection, even though it is flawed in a very specific way. Yes, mathematical truths are exact because they do not need testing or measurements. There is nothing inexact about 2+2=4. But the claim that mathematical knowledge is absolutely certain ignores the very foundation of mathematics. Mathematical truths are always deduced from a set of axioms that form the ground for everything else that follows. Without using these axioms as a basis, it would be impossible to prove our mathematical statements.

All of this seems damming for the ideals of exactness and certainty. Their standards seem to be simply too high for our earthly knowledge to meet. But that does not mean that we have to abandon them altogether. Just because we know that the results of scientific research are never absolutely certain and not always exact that does not mean that we should not want our knowledge to be as certain and as exact as possible. Scientific research still has the purpose of uncovering the truth, despite its limitations. Therefore, I want to propose a distinction between absolute and relative certainty, as well as between absolute and relative exactness. The basic principle behind this distinction is that absolute certainty and exactness means that knowledge meets these two criteria on its own without a frame of reference. Relative certainty and exactness on the other hand, means that knowledge meets the criteria within a specific frame of reference. The frame of reference is nothing more than the background that led to the formulation of specific conclusion. In the case of inductive reasoning, the frame of reference would be the various instances in which a phenomenon occurred the same way that led to the theory that it will always occur this way. The deductive reasoning of mathematics is definitely stricter and harder to dispute because of its reliance on logically binding conclusions, but it still has the axioms as frame of reference on which all of these conclusions rest. A hypothetical alteration of the axioms would mean a changed frame of reference and therefore changed conclusions. The knowledge about what tools we use to make measurements and how they can produce measurement errors is also a vital part of the frame of reference because it gives the necessary context of how the input that led to the formulation of the theory was generated.

Let us now summarize what we know about the application of both the absolute and the relative criteria. Firstly, absolute certainty is something we cannot expect from our knowledge. Because scientific research is a process that relies on the testing and falsification of theories, certain and unchangeable knowledge is not the result of this research. Even mathematics only establishes certainty within the boundaries of its axioms. Absolute certainty is definitely a false ideal, that our knowledge simply cannot meet. And it is not just false, but also harmful to the credibility of science. When the idea persists that science is meant to produce infallible, absolute conclusions, the enemies of the scientific method can claim that the method is simply wrong and does not work because it fails to provide us with absolutely certain knowledge. This kind of naive scientism might lead to a backlash against the scientific method and the people advocating its use, similar to the one we are partially experiencing at this very moment during the pandemic. We should not advocate an ideal that will lead to our method looking ineffective and disappointing.

Absolute exactness is not as unapplicable or as dangerous as absolute certainty. Mathematical statements are absolutely exact and our observations and measurements on a macro-level can also meet this ideal. But using it on all of our observations and measurements would be a mistake. Especially when using other tools to measure phenomena, we simply to do not receive absolutely exact results. Again, we should raise the standards to a degree that our results cannot meet.

But relative certainty is an ideal which can be used for our knowledge. By looking at the evidence and using it as a frame of reference, scientists can produce theories that account for all the observations currently available. Of these theories, developed through induction, it can then confidently be said that they are relatively certain according to present evidence. Mathematical statements can likewise be considered relatively certain, relying on the truth of their axioms. Similarly, we can use relative exactness as a standard for our theories because by analysing the observations we have, we can come up with models that are as exact as possible, given what instruments and methods we used to conduct experiments.

Relative certainty and exactness present scientists with the achievable task of finding the most certain and exact theory with the given evidence that forms the frame of reference, but at the same time they keep the door open for new evidence and criticism of existing theories. The progress of science does not just consist of developing new theories, but also of expanding the frame of reference, that means repeating experiments, collecting new evidence and refining the gauges. If there is evidence that contradicts theories that previously seemed to meet our criteria, revisions will be necessary. Through this method, theories can be developed that reach some standards of exactness and certainty without contradicting Popper's idea of falsification. As a result, there is constant progression through an expanding frame of reference that leads to our knowledge becoming more and more sophisticated and accurate, but not absolutely certain and exact.

We can however imagine a particular exception where even the criteria of relative certainty and exactness do not apply. That is when nature itself does not conform to these principles. There are a number of noteworthy examples of this phenomenon from the area of quantum physics. In the double-slit experiment it is impossible to tell through which one of two slits a light particle will go, so in this case certainty is impossible. The movement of the particles can only be described through statistics after several repetitions of the experiment. And because we already mentioned the atomic model, more recent versions of it cannot provide a concrete position for the electrons and only speak of probabilities where an electron might be. That way, making exact statements about the position of an electron is also impossible.

In both of these cases, our traditional conceptions of how we should describe the world do not work. These quantum phenomena can only be described through statistics and probability, which is better than no description at all, but in both cases it cannot provide us with any certainty or exactness. What does that mean for our method of trying to find theories and models that are relatively certain and exact? Should we disregard it as inadequate? Or should we even try to order the chaos we find in the universe by all means necessary? I suggest that we must avoid both of these extremes and instead modify our ideas to fit these limitations. When it comes to classical physics and also the other sciences, our previous ideal is still useful because we can develop and test theories with relative certainty and exactness. But we apparently cannot

always use it. Perhaps it is not even necessary to always use strictly the same methods for describing the universe. The philosopher of science Paul Feyerabend developed the concept of methodological pluralism to reject the idea that science should only have one continuous and fixed method and instead famously proclaimed that anything goes in the realm of science. Such a rejection of the scientific method as a whole is undesirable and irrational because following Feyerabend, science and pseudoscience or non-science become completely indistinguishable. Even in quantum physics, we still gain our knowledge through empirical evidence and mathematical calculations. Empirical observation and mathematical proofs help us to better understand the world and abandoning them would only lead to catastrophe. It would mean losing any distinction between the arguments of scientists that have proof and studies to back their claims and the ideas of conspiracy theorists and madmen. But we can use Feyerabends methodological pluralism and apply it to areas where it can have a constructive effect. We must change the standards that we apply to our theories when there is no other way to describe what we observe. Here, some pluralism is necessary. In the case of quantum physics, we use statistics that are still scientific, being based on experimentation and calculations. In the end, nature has the last word on the ideals we use for our theories because we want to describe it the way it is and not the way we want it to be.
But for the most part, relative certainty and exactness are realistic and useful standards that we can apply in many fields of scientific inquiry. In these cases, we can establish a frame of reference and arrive at the best possible theory within that frame. In some specific cases theories can even be absolutely exact. The only exception to this general rule is a natural lack of certainty and exactness that leads to the formulation of less strict theories, mostly in the form of statistical interpretations. We have completely rejected the idea of our knowledge always being absolutely certain and exact. For some people, this might seem confusing and disorienting. How can we live our lives with our knowledge about the world being imperfect? The answer to this question and another important criterium for scientific theories can be found in a philosophical school of thought that was codified in America in the 19th century and was called pragmatism. Pragmatism states that our knowledge should be measured by the practical effects it has in our everyday life. It does not require grand ideals like absolute certainty and exactness, only practical results. Just because our knowledge about the laws of physics is not absolutely certain, our computers do not stop working and our water does not begin to boil at a completely different temperature. If we analyse the practical results, meaning the technical development that was based on scientific progress, we will see that theories that only meet the ideals of relative certainty and exactness and even that not always, still are very useful in our lives, constantly providing us with new innovation and technology.

In conclusion, it can be said that the ideals of certainty and exactness that we wanted to analyse in this essay are mostly incompatible with what science actually is and how it works. The very essence of science is critical thinking and constant gathering of new evidence. This is antithetical to any kind of absolute knowledge that exists only in dogmatism. For there to be true progress in research, the frames of reference need to be acknowledged and need to be challenged, so that theories can continue to be refined and to evolve. In this context, we can expect relative certainty and exactness, unless nature dictates otherwise, in which case we must adjust our ideals to the subject of our research. But trying to apply absolute ideals to the process that is scientific research is just another case of harmful rhetoric against science. Especially in a crisis like the current pandemic, we need accurate communication and understanding of science from both sides. Those who present the results of science must not present these results as absolute or beyond criticism and revision. And those to whom these results are presented must understand that these results, while not absolute, are still the best conclusions within the frame of reference and can be practically used to achieve what we want to achieve. Only then, with sufficient communication and understanding of what it is and what its ideals are, can science be properly appreciated as the best epistemic method we have and a great tool to improve the lives of all people on earth.

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