

TRUST IN SCIENCE AND THE SCIENTIST

Joos Vandewalle
Erika Vlieghe
Karolien Poels
and others



KVAB POSITION PAPERS

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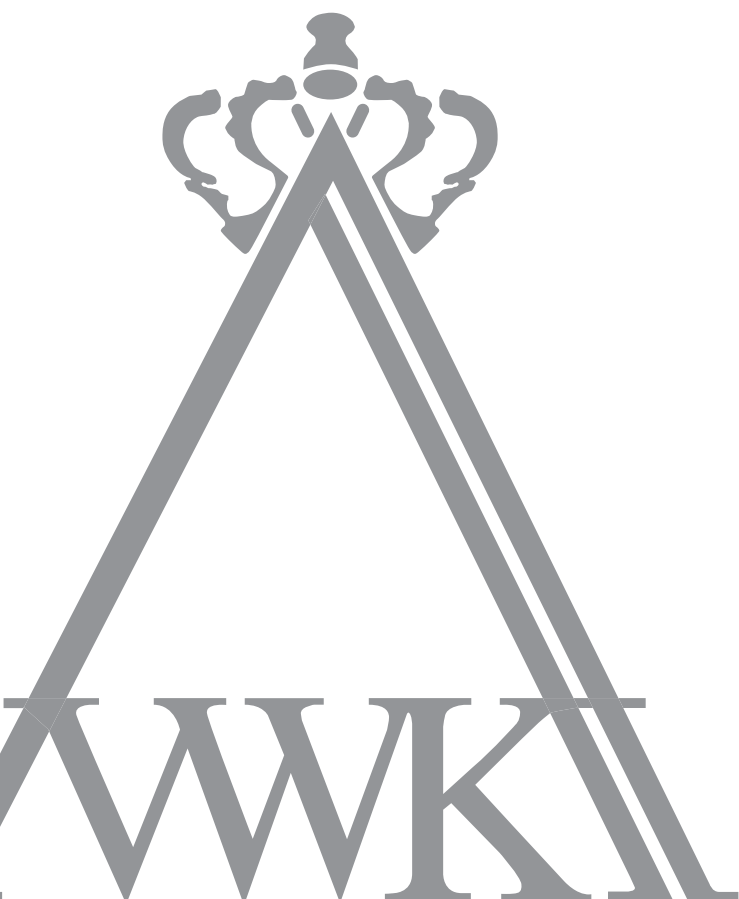
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The drawing of the Palace of the Academies is a reproduction of the original perspective made by Charles Vander Straeten in 1823. The logo of the KVAB was designed in 1947 by Jozef Cantré.

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TRUST IN SCIENCE AND THE SCIENTIST

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Trust in science and the scientist

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Executive summary

This position paper has been written as the result of a unique academic cooperation between the 'Jonge Academie' (JA), the 'Koninklijke Academie voor Geneeskunde van België' (KAGB) and the 'Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten' (KVAB). This cooperation operated through the framework of a permanent reflection group 'Responsible Research & Innovation and Science Ethics'. The Academies offer a platform where active academics, young and less young, and emeriti from different universities and from different disciplines, meet and enter into discussions with each other. They are politically and ideologically independent and strive for more openness of science towards the outside world. Through their prestige, their intellectual strength and their outspoken public engagement, they succeed in involving business leaders, external experts and stakeholders in many of their programmes and working groups. It is a major objective for the academies to contribute to strengthening social support for science, for scientific work and for researchers, regionally, nationally and internationally. For this reason, this position paper focuses on the theme of trust in scientists and in scientific findings from all disciplines. In recent years various factors may have undermined trust in science and scientists. The pandemic, fraud cases, fake news, social media, climate change and world politics are just a few examples. In-depth insights, from the results of a survey and from a historical context, show that this trust is quite good in Flanders. However, this analysis also shows that there is still an important role for the academies, identifying points to be aware of and making recommendations for various stakeholders. The following specific contributions from well-known experts support our conclusions: 1) Communication of scientific results and the relationship with policy by Christoffel Waelkens (Part 3). 2) Scientific insights, and uncertainties in urgent social questions by Erika Vlieghe (Part 4). 3) Use and abuse of statistics/how to conduct science communication with incomplete data, by Geert Molenberghs (Part 5). 4) Social media as a curse and blessing for trust in science by Karolien Poels (Part 6). 5) What have we learned from mistakes and sloppiness in research? by Egbert Lox (Part 7). 6) Scientific integrity and the role of the Flemish Commission for Scientific Integrity by Gert Storms (Part 8). 7) Science communication and fact finding in the media by Tim Pauwels (Part 9).

From this we derive the main recommendations:

1. *For policymakers.* Support societies such as KVAB, KAGB, and JA, which promote transdisciplinary dialogue and which engage in communication with the general public. By keeping the unity and diversity of scientific methods and goals in mind, we can continue to demonstrate that science is worthy of trust. We can also demonstrate that scientists (plural!) together conduct a debate across disciplines in a reasoned manner, supported by facts and scientific findings, and that, together, they form 'science'.

2. *For policymakers at universities, research institutes and research funding agencies.* Reward researchers and research practices that promote trust in science. Let this be a plus point when recruiting and promoting, in addition to the scientific evaluation of the curriculum based on qualitative analyses by qualified scientific experts, supported (but not driven) by quantitative data. Do not let scientific research get caught up in scientific 'hypes' and give slow science a chance. Value a popularizing, informative presence on social media as an important social service.

3. *For education providers.* Teach scientific thinking and trust in science with concrete arguments and examples. Always approach it carefully. Provide basic knowledge (literacy) and identify the core values of science (and democracy) around questions such as 'What is science and how does science work?', 'What is the difference between fact and opinion?', and 'What is a good debate?'. Emphasize, or restore the importance of, philosophy of science in scientific education. Include insights from the history of science, ethics of science, science communication, science journalism and parts of meta-science. This is important for university curricula but can already be initiated during primary education (in world orientation) and continued in secondary education (science, mathematics and ancient culture). The evolution of progressive insight and successive paradigms in the various sciences can also be addressed in secondary education.

4. *For researchers.* Be correct, honest, open-minded and transparent in your own research. Do not conduct research in an ivory tower, but report and communicate attractively, clearly and correctly about your own research in the various media. Make maximum use of open science methods (preregistration, open access, open hypothesis, open data and open hardware, open peer review, citizen science, etc.)

5. *For the media when communicating science.* Provide accurate and attractive stories about science and scientists that also provide the scientific basis of arguments in social debate. It is not easy for the media to present scientific work and scientific results in an accurate, compact and captivating way when they are surrounded by uncertainties and limitations. In this respect, fact-checking methods deserve more attention and support, including support from the government. In major crises, credible interaction on social media should be seen as one of the most important communication channels.

6. *For all those involved in science.* Promote best practices for quality and trust in research from the academic world on the one hand and the industrial world on the other. Avoid unnecessary complexity and strive for simplicity: for example, when designing experimental test setups.

Preface

The Position Papers series, of the Royal Flemish Academy of Belgium for Science and the Arts (KVAB), contributes to a scientifically based debate on current social and artistic themes. The authors, members and working groups of the Academy write in their own name, independently and with complete intellectual freedom. Approval for publication by one or more Classes of the Academy guarantees the quality of the text. This Position Paper, in the original Dutch version, was approved for publication by the Class of Technical Sciences (KTW) of the KVAB on 10 September 2024, by the Young Academy (JA) on 17 October 2024 and by the Royal Academy of Medicine of Belgium (KAGB) on 28 October 2024.

1. Context and societal positioning

In recent years, various factors and phenomena may have eroded trust in science and scientists. The pandemic, fraud cases, fake news, social media, climate change and the state of world politics are just a few examples. The pandemic has led to a flood of sometimes conflicting information about viruses, vaccines and treatments. This can be confusing and frustrating for the public and lead to scepticism about the reliability of scientific findings. Cases of fraud in science, such as Andrew Wakefield's fraudulent research on the link between vaccination and autism, and Diederik Stapel's oft-fabricated data on socio-psychological phenomena, have also tarnished the image of science. Fake news and social media also facilitate the spread of disinformation and conspiracy theories about scientific topics. Climate change is, for example, a complex and controversial topic. The scientific consensus on the causes and consequences of – and on the measures against – climate change is overwhelming, but a small group of dissident scientists sometimes gets the megaphone from the media and from politicians who question the consensus. This can lead to scepticism about science in general. Finally, world politics also play a role. In some countries, scientists who are critical of policy or who challenge the status quo are muzzled or even prosecuted. This can lead to a climate of fear and self-censorship, making scientists less willing to share their findings.

It is important to emphasize that there are also factors that can strengthen trust in science. The development of effective vaccines against COVID-19, the rapid advances in medical science and the increasing focus on scientific integrity are examples of this. Through collaboration between scientists from different disciplines, more global studies of larger systems can be carried out, leading to more convincing and widely supported scientific results. In addition, researchers can disseminate their scientific insights directly to society in outreach activities: science communication, education on the importance of science, explanation about the scientific method, etc. This can lead to broad support for a policy that strives to improve society, the environment, prosperity and health, based on solid scientific knowledge.

The 2023 citizen survey in Flanders indicates that trust in science is still very strong (see the Science Barometer).^[1] A global survey^{[2],[3],[4]} of more than 70,000 people comes to the same conclusion. The citizens surveyed even want scientists to be more involved in policy-making. In 2023, the umbrella academy, International Science Council (ISC), also produced a report with the message that trust in science is necessary for achieving societal goals, such as the Sustainable Development Goals.^[5] In a^[6] 2019 Position Paper of the KVAB, it was argued that there is a basic trust that science can and should play an important role in arriving at sustainable solutions to the big questions we are struggling with.

One can therefore ask whether there is still a need for a common position of KVAB, KAGB and JA on this. There are several reasons why trust in the scientist deserves a deeper analysis and argumentation. First of all, the pandemic and social media have changed the social role of scientists. Urgent questions from society, the media and politicians require a quick response from science. However, science processes are not only thorough and careful, but also slow. There are double-checks of the research results and they often have to go through a lengthy peer review process before communication

with the outside world can take place. This communication with citizens does not always run smoothly, due to the inherent uncertainties, cautions and doubts in the scientific findings and due to divergent insights among scientists. Moreover, social media, with their rather short and unsubtle messages, are not an obvious medium through which researchers can interact with citizens, especially when it comes to debunking fake news or oversimplified slogans. The scientific process itself is also under pressure due to a lack of reproducibility (re-conducting data analyses) and replicability (re-conducting the entire research process, including the production and use of new data) of some research results. Further pressure arises from fraudulent research with possibly fabricated data and from problematic publication strategies in predatory or even fake journals. Fortunately, there is a cultural shift underway within science towards more openness and transparency. Articles, data and software code are being made more widely accessible, thus results and data can be better verified. Citizens are also more often actively involved in so-called 'citizen science'.

In addition to providing opportunities, the generative AI revolution also brings new challenges for research. First of all, generative AI algorithms are highly dependent on the basic data on which learning takes place. In addition, the quality and representativeness of this data are crucial to prevent AI models from displaying bias and creating inaccuracies. The technology can also be misused, for example to create deepfakes or spread disinformation.

During the pandemic in particular, scientists increasingly acted as opinion makers and experts in the media and in the public debate about science. How should the scientist delineate his/her tasks (and time) between finding, verifying and communicating scientific evidence and providing scientific advice to politicians? Scientists are expected to start and develop their research as objectively as possible. However, situations often arise in which a presumption of bias may arise because of a perceived conflict of interest, whether real or not. All these facets and developments require a more in-depth discussion of current problems.

Hence, this is an important theme for the permanent reflection group 'Responsible Research & Innovation and Science Ethics' of KVAB and KAGB. The group wants to map out the deeper grounds and the experiences and insights gained. A well-attended study afternoon on this subject was held on 16 October 2023 at the Palace of the Academies. This was the programme:

- Introduction and welcome by Joos Vandewalle, coordinator of the Permanent Reflection Group RRI and Science Ethics;
- Presentation of the Science Barometer by Hans Verhoeven, iVOX;
- Scientific insights and uncertainties in urgent social questions by Erika Vlieghe, University of Antwerp;
- Use and abuse of statistics/how to conduct science communication in case of incomplete data, by Geert Molenberghs, UHasselt and KU Leuven;
- Social media as a curse and blessing for trust in science by Karolien Poels, University of Antwerp;
- What have we learned from mistakes and sloppiness in research?, by Egbert Lox, general chairman ie-net;
- Debate with the four speakers supplemented by Tim Pauwels (VRT) and Dries De Smet (De Standaard) and with Jan Hautekiet as moderator.

The interaction with the audience and the valuable and enlightening presentations of the speakers constitute the basis for various chapters of this Position Paper. These were supplemented with contributions from members of KVAB and other experts. This was read and updated by the members of the writing group.

This Position Paper is intended to make a substantial contribution to the joint mission of KVAB, KAGB and JA to be the academic voice of science and to represent a moral authority in that area, with regard to scientists, society and the government. Science communication and interaction with the media are an important facet of this. Most of the contributions address the theme from the researchers' own experience, while Part 6 on 'social media as a curse and blessing' provides an integrated communication science approach.

In this paper, we describe 'science', as is customary in Dutch, as the human activity in which targeted research is conducted and knowledge is acquired, both out of curiosity and out of concrete objectives or needs. This description is inclusive. It covers all scientific disciplines including the elements of interdisciplinarity. It recognizes the diversity of different scientific approaches: the natural, the technical, the biomedical and the humanities. We would like to point out that the speakers/authors have partly reflected on the theme based on their own disciplines and that the terminology and trains of thought inevitably adhere to differing scientific approaches. Although we have tried to make the coherence of the contributions as strong as possible in the final editing phase, we have also left differences in emphasis untouched, as this illustrates the richness of 'science'. In the concluding remarks and the recommendations, we have tried to integrate the contributions and thus do equal justice to all scientific approaches. (The term 'scientist' is used universally in this text in the broadest sense of the word, without making a distinction as to the gender or orientation of the persons involved.)

2. The scientific process, the actors, the products, the values and the challenges

2.1 *The historical context*

Over time, science has grown as an autonomous human activity, separate from religion, with which it has had a tense and sometimes changing relationship for many years.[7] The term 'scientist' itself was only coined in the 19th century. If we look at the science process through the centuries, it is a success story in which it has always been possible to build on the discoveries of predecessors. At the same time, the scientific discoveries that had been achieved had to be dealt with critically, in the context of advancing insight, based on creativity and drive and within the openness that was present at that time. This was a process of trial and error, which has had a positive impact on society: better health care, more technical resources, more comfort and better living conditions. The fact remains that our current society is facing more and more major challenges, such as climate change, population growth, social and political instability, the aging population, the environment, etc.

Scientific research itself requires drive on the part of the researcher at the same time as open-mindedness, truthfulness and integrity. Findings intended for publication must be strictly evaluated by competent fellow researchers (*scrutiny by peers*) before they are accepted as reliable results in scientific books or journals. The commercial interests of the publishers of these magazines and books do not always coincide with truthfulness and service to society. For example, there are so-called 'predatory journals' that serve purely commercial interests, and related to this there are also dishonest researchers who let their desire for recognition or gain take precedence over the honesty and truthfulness of their research. This affects the credibility of science. The inability to reproduce or replicate research results is a more subtle factor with the same effect.[8] Human thought is not scientific by nature. In other words, it does not so much look for the cause of a phenomenon or an event, but rather for the purpose or intention behind it.[6] Our intuitive conceptions of how the world functions are often superficial, incomplete, or incorrect. This explains, at least in part, the popularity of conspiracy theories. [9] Scientific thinking and trust in science must therefore be learned and approached carefully. Education and science communication play an important role here.[7] This is a stepping stone to the important tasks of the universities.

2.2 *The role of universities*

The greatest contribution of a university to society, apart from the knowledge generated, is the quality of its graduates. Every academic programme transfers knowledge, but students are also trained in a number of skills and disciplines: abstraction; the critical handling of facts and data; putting the points of view of one's own discipline into perspective and the creativity and skills required to explore and push the boundaries of knowledge and thinking itself. Regardless of their discipline, graduates with these skills are able to make an innovative contribution to the competitive society of the future. These contributions can be achieved in depth (through new knowledge, methods and laws) and breadth (through the use and combination of existing methods in one or more new areas). In order to be able to convey these skills to their students, the professors must themselves be professionally active in advancing knowledge by conducting high-quality scientific research. Perceived this way, the professor is actually a 'master' in

the historical sense of the word; he/she teaches the student all the tricks of a discipline, with scientific research as a means not an end. This fits with the so-called 'Humboldt concept' of what a university is and should be.

2.3 *The scientific process*

Researchers employ a rigorous methodology to collect and validate reliable knowledge. Although there are important differences in the approaches of the different scientific disciplines – compare the way of working of a mathematician with that of a cultural anthropologist – the research process involves several steps that must be carried out carefully and systematically to ensure the quality of the research and to earn the trust of colleagues and society.

In an ideal scientific approach, the researcher first formulates a hypothesis based on previous studies, observations and theories. The hypothesis is a possible explanation that provides an answer to a research question. The researcher then determines the method they will use to test the hypothesis. This includes identifying the relevant variables, selecting reliable measurement tools, drawing up a study design, choosing appropriate analysis techniques and developing a data management plan. The researcher then collects the data needed to test the hypothesis. This can be done with observations, experiments, surveys or other methods. If appropriate, the researcher uses the applicable statistical methods to analyse the data, to determine whether and to what extent the hypothesis is supported. The researcher interprets the results of the data analysis and formulates conclusions about the hypothesis. This may or may not be done by a team. They describe the research activities, results and findings in a manuscript, which is then thoroughly reviewed by external reviewers. When the text is accepted, the researcher can share the findings of the research with the scientific community and the general public in publications, presentations or through other media.

Every step of the scientific process is important to achieve reliable and valid results. The data must be carefully collected and analysed and the interpretation of the results must be based on rigorous processing of that data, not on personal bias. Researchers must be transparent about their methods, data and findings. Research must also be reproducible, which means that other scientists must be able to verify or repeat the study. A distinction can be made here. On the one hand, there is the repetition of the analysis and the processing of the same data, which leads to exactly the same results. On the other hand, there is the repetition of the research that leads to similar but not exactly the same results. Researchers must be honest about their findings and must not draw incorrect or exaggerated conclusions. Finally, scientists must be willing to share their findings with the scientific community and the general public. By following these principles, they can strengthen trust in science and ensure that scientific knowledge is used to improve society.

2.4 *The changes in science*

Three elements of the evolution of science deserve attention here: the transition to digitization, the trend towards open science and the importance of interdisciplinarity in approaching the problems of society. What are their implications for establishing and maintaining confidence in the sciences? Digitization facilitates wide accessibility and sharing of data and information. It therefore also facilitates the smooth dissemination of research products, such as publications, measurement data and metadata.^[10] The open

science movement, for its part, strives to make the results of scientific research freely available (as soon as possible) to both other researchers and to society. This makes the scientific process more transparent, speeds up use of its results and supports further research. This transition is a cultural change that takes time, though in recent years, there has been a clear acceleration.

An important part of scientific activity is driven by the search for solutions to societal problems, such as climate change, poverty, hunger, health, education and security. These often require an interdisciplinary approach^[6]. This implies that scientific research is not so much about the growth or deepening of knowledge in one discipline per se, but about providing broader insights and concrete solutions. Narrow, specific, problem-driven research is often determined and limited by economic interests and often takes a short-term perspective. The complexity of social problems – additionally and increasingly requires people who understand the interconnection of problems at an academic level and who can think in an interdisciplinary or systematic way. ^[11]

Science plays an important role in thinking about the future, foreseeing social changes, and in conceiving medium-term future scenarios:^[12] 'But the more difficult that future is to determine, the greater the need for internationally supported future scenarios. Times of crisis are putting the consistent input of researchers in determining short-term policy into focus, but the role of scientists in drawing up future strategies must become self-evident. We have to work on such scenarios in every social domain. A lack of vision and long-term thinking means the downfall of our society.'

2.5 *Authorship*

It is important to reflect on the authorship of any publications at an early stage of the research, in order to avoid problems later on. The ALLEA Code^[13] states that, in joint research projects, all partners must reach a formal agreement at the beginning of their collaboration on the expectations and standards in the field of scientific integrity and on the procedures for settling disputes and possible cases of misconduct. By making author roles explicit like this, their respective contributions also become clear and can be linked to certain responsibilities that a co-author has in the context of a publication. The CREDIT methodology^[14] provides for 14 different roles for authors. It is always desirable that the entire text of a publication is proofread and approved by all contributing authors. In addition, it is important to draw attention to the specific responsibilities of the corresponding author.^[15] The internationally applicable discipline-specific characteristics of the author roles must also be taken into account. Finally, there are also undesirable practices of authorship, such as ghost authorship, gift/guest/honorific authorship, orphan authorship and forged authorship^[13].

2.6 *Scientific integrity*

In line with the European Commission's Mutual Learning Exercise (MLE) report^[16] on scientific integrity, this concept is understood to mean 'the attitude and practices of researchers to conduct research on the basis of appropriate ethical, legal and professional frameworks, obligations and standards, with a particular emphasis on matters such as authorship, data management, conflict of interest, supervisor responsibilities, data fabrication prevention, data manipulation and plagiarism, reprehensible investigative practices, etc.'

The translation of codes and guidelines to the level of research domains or disciplines is often very important and brings those codes closer to the researchers. The *Survey of Organizational Research Climate*,^[17] a validated instrument developed by Dr. Brian Martinson of the University of Minnesota to measure the research climate in an organization, is one possible tool among others. It can be used as an awareness-raising tool to promote good scientific practices. In June 2019, the Sixth World Congress on Scientific Integrity (WCRI)^[18] formulated five key principles for valuing researchers assessing responsible research practices, valuing complete reporting, rewarding the practice of open science, acknowledging a wide range of research activities, and recognizing essential other tasks, such as peer review and mentoring.

2.7 *The impact of conflicts of interest*

Trust in researchers, and therefore in their research results, can be greatly undermined when the researchers have a financial, commercial or other interest in certain results. Hence, there is a need to indicate possible conflicts of interest, before and at the time of publication. The European Code of Conduct for Research Integrity^[11] requires researchers to disclose any conflicts of interest and any financial or other forms of support for the research or for the publication of the results. The Code of Conduct also stipulates that referees and editors with a conflict of interest should withdraw from situations where decisions are made about publications, funding, appointments, promotions and remuneration. It is desirable that this issue should be part of the mandatory information and training sessions for PhD students, postdocs and new professors. Experienced researchers should also be regularly reminded of it.

3. The communication of scientific results and the relationship with policy

3.1 *The communication of science*

Historically, scientists have been pioneers in the mutual communication of their findings, from Greek antiquity (from Sicily, Archimedes reacted quickly to the heliocentric worldview that Aristarchus had devised far away in Samos) to the development of the Internet in the context of CERN. But, today, when using the expression 'communication of science' we mean something different from 'communication between scientists': it is more about how we translate scientific insights for the wider public.

Is that necessary? Yes, because no one doubts that the insights of science have a major impact on society, partly because of the technology that facilitates and, to a certain extent, manages our lives. But it goes further., Science has played, and continues to play, a not insignificant role in the evolution of society. This evolution confronts us with new problems and even threats that we must address. We advocate here a concrete approach to common challenges within the social model of the democratic rule of law. There is less and less room for scientists who say 'It has to be this way, because I understand it and you may not'. There is an increasing need to convey messages from science in a way that the citizen (i.e. the voter) can understand within their own world, because they decide what the policy priorities should be. However, many researchers are quite reluctant to be active on social media and in opinion articles of newspapers, in particular,

because of social polarization and the accessible nature of this particular medium. It is therefore essential to translate scientific insights on matters of far-reaching social importance for society at large. All the more, because a lot of fundamental and applied research is funded from public funds. Even if it is clear that a research project is a good investment, there remains a responsibility to society. It is also important that society should not only be able to determine whether its investments are paying off, but it should also know why, and it has the right to enjoy the 'miracles' that science reveals. We should include citizens as partners in our scientific story and be grateful for the facilities we are given to satisfy our scientific curiosity.

The foundation of our scientific thinking based on rational arguments owes a lot to the ancient Greek philosophers, in particular to Socrates. It was he who emphasized the distinction between 'being considered right' and 'being right'. The debate he had with sophists like Protagoras was about exactly that. And this is the debate that is resurfacing in the public arena today, fuelled by social media. It is more necessary than ever that we safeguard the 'Socratic function' of our scientific questioning, perhaps even rediscover it. We must guard against populist arguments. We like to say that our universities educate their students to become 'empowered citizens', but shouldn't we focus on providing programmes that train them to make accurate analyses and find workable solutions to complex problems? How is it that the sophists are surfacing again after so many centuries of progress based on the scientific method? We have to recognize that progress itself plays a role in this. Some of the major challenges of our time – such as climate change, controlling the world's population, preserving biodiversity – are a direct result of this 'progress'. Moreover, the challenges have become so complex that no one really has an overview anymore. Finally, it is thanks to science that there are means of communication that also spread nonsense quickly and, on a planet-wide scale. In any case, there is a great responsibility on the shoulders of scientists to inform the public accurately. Many are becoming more and more aware of this.

Today, universities and research-oriented companies attach increasing importance to science communication that benefits the public. Within KVAB, every year there is a special focus on prizes that are awarded to scientists who have made a meritorious contribution in this field. Science communication is a central priority for the Young Academy, with innovative initiatives aimed at various groups within society. It remains important that we recognize that scientists are people, with their talents and weaknesses, and that the institutions in which they work are operating in a competitive world. There are positive sides to this. Participating in the social debate is best done with some sense of the environment in which that debate takes place. A form of competition promotes quality, as long as we continue to realize that our competitors are also our partners. Sometimes things go wrong and that can be very damaging to the credibility of the entire sector. As already indicated, the limited presence of fraudsters taints the reputation of science and complicates the social debate.

Scientists are encouraged by their institutions to communicate about their work to a wider audience. The motivation for this is not only to make new knowledge widely accessible, but also to profile the institutions themselves; science communication as a management tool. This competitive aspect also sometimes has significance for individual scientists, since not everyone has a permanent career in research and some profiling in the media can help. The media themselves like to attract attention with provocative titles and sometimes like controversy more than consensus. None of that is a disaster. The social debate does not have to be boring and some open self-interest can be tolerated. However, that self-interest should not take precedence over the accessibility and accuracy of the messages.

3.2 *Science and policy*

Policymakers in Flanders are aware of the importance of science to support their decisions and are inspired by numerous advisory councils. KVAB's Position Paper series fits into that logic. It is one of the key performance indicators of the covenant with the Flemish Community. The Academy appreciates that it is allowed to choose its topics in complete freedom and that conflicting opinions can be addressed in its debates. A second positive observation is that a healthy balance has been maintained between publicly funded 'fundamental' and 'applied' research projects for several government terms.

Of course, Flanders is not the only level at which policymakers seek advice from ad hoc or other scientific committees. This is good news, but there may also be a certain suspicion that the wheel is constantly being reinvented in many different places. In addition to VARIO (the Flemish Advisory Council for Innovation and Entrepreneurship), there is also a scientific advisory board at the federal level. Within the European Union, there is the large scientific advisory body SAPEA/SAM.^[19] It brings together five important umbrella organizations for academies: ALLEA, for the European academies; Euro-CASE for European engineering academies; FEAM, for medical academies; YASAS, for young academies in Europe; and Academia Europaea, a European member academy. In addition, there is the International Science Council (ICS)^[5] that wants to be 'the global voice of science' and thus ends up in UNESCO waters.

4. How do we restore and maintain trust in science? Lessons from the COVID-19 pandemic

As scientists, we were both adored and hated in the recent COVID-19 pandemic. Neither attitude seems healthy for a critical and well-informed society. Bearing in mind the Dutch saying that 'trust comes on foot and leaves on horseback', it is important for the scientific world to reflect on this in depth and to draw lessons from it. In times of major crisis, which factors have eroded, and continue to erode trust in science among parts of our population and among policymakers?

Perhaps we should make a distinction between (1) social phenomena that have been present for some time and (2) what happens during a major (health) crisis in which scientists and experts are 'suddenly' prominent in advisory bodies and in the media, giving advice on social interventions with a major impact on our personal life. Interestingly, similar social phenomena also occurred during the Spanish Flu pandemic of 1918.
^[20]

Well before the COVID-19 pandemic, 'merchants of doubt' had appeared on the horizon in various scientific disciplines. These had the typical characteristic of discrediting consensus-building around difficult and complex subjects (e.g. climate change, smoking, migration...) and replacing nuanced, fact-based discussion with a mixture of half-truths, conspiracy theories and 'opinions of the moment'. The rise of social media, with stories initially limited to barely 140 characters on Twitter, has stimulated oversimplification for almost two decades. This replaced nuanced stories with witty and provocative one-liners that can spread at lightning speed and many times faster. Then, discrediting everything that is considered 'elitist' or 'mainstream' became fashionable among certain political groups and so the academic world came gradually more into their focus. Yet, we should

not despair too much for Flanders in this context. According to the annual Science Barometer^[1], in 2023 the Flemish population still showed great confidence in science. Only 6% indicated that they had none at all whereas 81% explicitly expressed their confidence. On the other hand, only 48% of Flemish people acknowledged that 'what scientists say is correct'. This percentage remained stable compared to last year but has increased compared to previous years (i.e. 45% in 2020, 39% in 2019).

The COVID-19 pandemic then occurred. After a few weeks, the whole of society was living in a different reality. There was a rapidly increasing number of severely ill people, and established institutions, such as our healthcare system, were in danger of capsizing. There was an urgent need for almost everything: manpower, materials, reliable information, fast solutions and clear planning, with no prepared script. The political reaction was an initially hesitant, wait-and-see attitude, which meant that valuable time was lost. In the meantime, scientists tried to interpret the events with extrapolations, analogies and theoretical frameworks. The policy vacuum suddenly presented them with a great social responsibility: collecting data and insights, putting forward hypotheses, proposing interventions, communicating the science, and issuing warnings and explanations.

After this first phase of contemplation, policymakers reclaimed their place, and this increasingly led to a conflict between the classic, pragmatic politics of compromise and data-driven scientific prudence and risk aversion. Citizens developed an increasing interest in facts and figures about SARS-COV2 and some developed very specific opinions or theories.

The prolonged duration of the crisis increasingly strained the relationship between scientists, policymakers and the general public, with many exhausting months of socially drastic measures and numerous unpredictable twists and turns, such as the emergence of both new variants and the stepwise availability of vaccines. Each new pandemic wave came with a new policy cycle of denial, followed by panic. Scientific advice was 'leaked' and criticized even before it was fully drawn up. Scientists were increasingly accused of having insufficient evidence or not being firm enough in their interpretations. A sad highlight was the slippery slope into personal threats and harassment.

In retrospect, what lessons can we draw from this?

4.1 We need to explain much more how science works (and does not work).

In times when the scientific way of working and the academic world itself are under pressure from societal changes, it is essential that scientists provide their fellow citizens with sufficient insight on how they think and work: formulating hypotheses, collecting data, approaching and analysing it critically and drawing preliminary conclusions that can be rejected at any time. At a time when there was an avalanche of data with rapidly changing interpretations, the concept of 'advancing insights' was put forward from an academic angle as a description of the scientific method. It is about the eternal circle of improvement, how it needs healthy discussion and how relative 'certainties' are.

The concept of 'advancing insight' was also at times misused by policymakers of all kinds to explain a U-turn in their policy (for whatever reason). In doing so, they ignored the fact that science is not a game of mere opinions, but of carefully constructed arguments. During the COVID-19 crisis, the analytical, groping and nuanced world of our knowledge-building was all too often at odds with the fast, fragmented or sometimes even populist method of making political decisions, which is often subject to different rules and customs.

At the same time, it seems contradictory to base socially impactful interventions on uncertain scientific findings. Scientists must therefore explain that there are gradations in the degree of (un)certainty and indicate when there is sufficient certainty to take action. In short, we have to explain how we work. How do you work with 'provisional data'? How do you reconcile divergent hypotheses?

The Science Barometer¹ shows that trust in science and scientists is not too bad in Flanders for the time being. That should not lull us into a false sense of security. Health and broad scientific debate and continued outreach to all groups in society remain very important in order to safeguard understanding of and support for science as the foundation of policy. Independent academic institutions, such as the Royal Academies, also have a role to play in this. They too must continue to explain how scientific insights start to grow.

4.2 *Policy and science cannot exist without each other.*

Policy based on science sounds obvious, a no-brainer. Nevertheless, the marriage of science and policy is often difficult (while remaining necessary), because the set-up and the working methods are very different. Scientific advice can be very solid, in terms of content, and yet unfeasible. Numbers and knowledge are one thing; interpreting them is another. Science also reserves the right to push where it hurts regarding policy, which often provokes defensive policy reactions.

Science and policy need each other. During the COVID-19 crisis we also saw examples of how this could be done. To begin with, sufficient knowledge and understanding of each other's reality, red lines and working methods are essential to be able to work together safely and constructively.

The process of setting up and organizing an advisory body also deserves greater understanding and (especially) transparency. There must be maximum transparency about the selection process of the members, their expertise, their working methods and possible conflicts of interest. The functioning of an advisory body must be completely independent, without (attempted) influence from the policymakers who requested the advice. That is why it can be better for advisory groups to organize themselves (bottom-up) rather than for it to be a top-down initiative from the policymaking body. The advice and data on which the advisory group relies must be complete and easy to find, on a publicly accessible web page, for example.

4.3 *The Achilles heel: data, data, data*

The now familiar cycle – defining a problem, collecting data and trying to understand it, asking new questions and adjusting the knowledge – forms the backbone of knowledge-building and science. However, many questions remain unanswered. Which data and evidence do we use? Which evidence is reliable and useful, a fortiori during a crisis?

Insights from solid and peer-reviewed research remain the gold standard. However, sometimes we have to rely on small-scale, 'grey' but sometimes very relevant or simply 'best available' data, in anticipation of better to come. What if there really are no data, only theoretical concepts? A lack of good evidence for a particular intervention is not the same as proof that such an intervention is ineffective. The lack of experimental data supporting the use of parachutes is a classic example of this. Sometimes we have to work with a conglomerate of circumstantial evidence, small

pieces of evidence that seem to confirm the theory, while waiting for more systematic and large-scale evidence. One example is the use of masks, ventilation and the other slices of 'Swiss cheese' from non-pharmaceutical interventions that were used during the pandemic. The effectiveness of measures, such as mask-wearing, depends on the context and how well the measures are adhered to. The effect is never absolute but can significantly reduce risk. The Swiss cheese model illustrates how different, imperfect measures can work together. Just as the holes in slices of cheese are almost never in the same place, different interventions complement each other to limit the risk of spreading a virus.

Large-scale, more definitive evidence is methodologically a lot more difficult (or even impossible) to organize and often takes years. Acknowledging and continuing to explain the concept of 'advancing insight' is therefore essential. As we learn more, we must be willing to adjust our insights, by regularly zooming out and performing a post-hoc analysis.

Data collection systems must be set up in 'peacetime', the period between two major outbreaks. In addition, there is an absolute need for more structural and international cooperation. Every small outbreak is useful for testing and adjusting systems so that, in the event of a crisis such as estimating the impact of new variants, it is possible to respond quickly through (near) real-time use of data.

4.4 *Scientific advice is teamwork*

Scientific advice as a basis for policy decisions must, by definition, come from a multidisciplinary team. As much as is possible this enables use of all available evidence in the advisory process. This is also important because many actors are involved in the implementation phase of the policy. It is therefore important to include as many insights as possible. It is important to consider a number of conditions regarding the composition and operation of such a team.

Collaboration across disciplines is crucial. This means stepping out of our individual comfort zones, but also staying within our individual expertise, especially on urgent and new themes. A distinction must be made between scientific and field expertise, and membership of interest groups. The same 'experts' can take on various roles, as scientists and as advocates. It is important to make these roles as explicit as possible, to point out possible conflicts of interest to everyone and to make these public. Providing multidisciplinary policy advice presupposes that you have an eye for the social context. At the same time, scientific advice must mainly bundle scientific insights and remain independent of politics, policy and lobby groups.

It is important to map the existing expertise on certain topics and to bring together experts on themes in 'peacetime', so that they know each other and can switch quickly in moments of crisis. In times of calm, there is a strong need for more structural multi- and transdisciplinary work within the academic world. This can help us to be better prepared for future challenges. It can also be useful to remain agile and flexible and to persevere, even in challenging times.

Such a multidisciplinary advisory team must be capable of sprinting as well as endurance running, depending on the circumstances and the specific assignment. In other words, scientific advisory teams must be able to work quickly and efficiently in crisis situations as well as make long-term efforts to provide long-term advice. In times of (relative) calm, outside of a crisis context, we need basic teams with a pilot light function, teams that can scale up quickly when necessary.

4.5 *The advice: from consensus to publication.*

Depending on the necessity and feasibility decision-making is preferably by consensus, whether or not it is preceded by a formal Delphi process. In the discussions, the available evidence and the precautionary principle must come first. However, an assessment must also be made of the impact of the advice and of the needs or undesirable effects that its implementation may entail. If necessary, and where no consensus can be reached, a partial advice or a range of options must be formulated. There is a dilemma in consensus-building that a more 'diluted' and veiled position will lead to a less vigorous policy. This is certainly a concern for urgent themes that require large-scale action, such as global warming or a pandemic threat.

It is also essential that every advice is written down: *verba volant, scripta manent*. Ideally, the scientific advice should be made public immediately or as soon as possible – transparency and trust go hand in hand. Proactive publishing also prevents fragments of the advice from being strategically leaked by policymakers and journalists, leading to disinformation and mood-stirring. All this can undermine the advice.

4.6 *What should scientists communicate: the facts, the advice or the policy?*

The COVID-19 pandemic has illustrated how complex the interaction is between science, advice, political decisions, implementation and communication. These elements should fit together seamlessly in order to create effective policy and communicate about it to the public. However, scientific discoveries and policy decisions must always be approached with the necessary nuance and restraint.

During the pandemic, we saw scientists act as important communicators (about scientific findings and scientific advice), but also as opinion makers (about policymakers who did or did not follow their advice). This combination of roles caused a confusion that is to be avoided. The need for nuance, for limiting oneself to communicating the science and scientific advice became clearer than ever.

Communicating scientific findings requires clarity about what is currently known and what still needs to be investigated. Transparency about the uncertainties and limitations of the available data is crucial to maintain public trust and prevent unnecessary misunderstandings.

By learning from the experiences during the COVID-19 pandemic and previous epidemic outbreaks, we can develop better strategies for crisis communication. This will help us to better manage future health crises, respecting the science and with a clear, transparent approach.

Finally, freedom of expression plays an essential role in science, especially in times of crisis. Doctors and other health professionals who have the courage to make critical comments and take action are invaluable. Not only do they take the trouble to share their observations, but they often run significant risks. This is not always appreciated and can even be dangerous. Think of the situation in China, where early reports of COVID-19 were suppressed. Consider the health workers in Uganda during the Ebola outbreak who took huge personal risks to warn the world.

4.7 The limits of giving scientific advice

Evidence-based policy is crucial for effective and responsible decision-making. To ensure this, policymakers must rely on robust scientific evidence and on transparent decision-making processes. This means that policies should be based on the best available evidence and that the rationale for policy choices should be clearly communicated. However, the road from research to impact is winding, and scientific discoveries do not always lead directly to policy. Often, a complex process of interpretation, discussion and consensus-building is required. This process should be as transparent as possible, so that the public understands how and why certain decisions are made.

It is important to make the difference between scientific advice and policy decisions as clear as possible. Scientists can provide advice based on their research and expertise, but the final policy decisions are made by political leaders who must also consider other factors, such as economic impact, social consequence, and public acceptance. However, the dividing line between scientific advice and the scientist's own opinion/interpretation is sometimes very thin. This is confusing for outsiders. Of course, every scientist formulates their own interpretation and hypotheses for a number of data. However, without the necessary restraint, nuance or willingness to revise their own opinion, this can become dangerous, especially in a crisis situation, where everything is brought to a head.

By clearly communicating the distinction between the four steps in Figure 1, we can increase trust in both science and policy. Scientists must make clear which recommendations they make and on what basis; and policymakers need to explain how they integrate these recommendations into their broader decision-making framework.

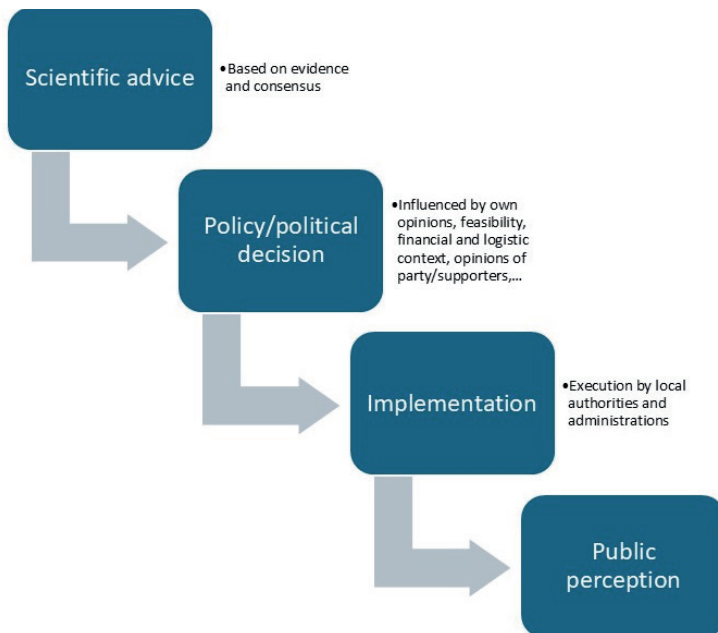


Figure 1 The cascade from scientific advice to the final perception of the measures introduced

4.8 *As a scientist, how do you deal with social appreciation, criticism and hatred?*

During the COVID-19 pandemic, scientific experts suddenly became public personas. One day they were celebrated as heroes, the next day they had become scapegoats. For most scientists, this sudden prominence was an ambiguous gift. They did not want to be portrayed as monsters or 'culprits', but neither was a hero status necessary or desirable. Proper respect for the scientific contribution should suffice.

In 'peacetime' science and the associated debate takes place mainly behind the walls of academia. During the pandemic the entire scientific process – from the hard-won data, to the analysis and mathematical models to the conclusions and recommendations – was the subject of TV programmes, debates, newspaper articles and heated discussions on social media. Scientific debates are essential for the advancement of knowledge and understanding. However, during a crisis, there is also a need for quick and effective decisions. It is thus important to find a balance between continuing to research and debate new data and making decisions based on the best available information. This requires a flexible approach, in which policy can be quickly adapted to new insights, without falling into indecision.

In that environment, it became very difficult to continue to conduct 'neutral' science communication without being drawn into such discussions. After all, the pandemic and all the associated measures had a profound impact on the lives of most people. This led to strong opinion-forming and the emergence of pro/con camps. It also led to misunderstandings and misinterpretations of the advice and the deliberate dissemination of false information to discredit scientists. For example, certain measures, such as wearing masks outdoors or hand hygiene regulations, were accidentally or intentionally misinterpreted and started to lead lives of their own, leading to the further discrediting of the original advice. All this resulted in the growth of sharp criticism of measures taken, the risk of generalization and dismissal of the valuable lessons learnt. This is not only unfortunate, but also dangerous. It raises the threshold for implementing effective non-pharmaceutical measures in the next pandemic. Not every effective vaccine against viruses will be found within eight months. Therefore, we need to find meaningful and feasible ways to reduce and stop the spread of disease.

On the other hand, no matter how much polarization and attacks on scientists can be avoided, criticism in itself is the necessary lifeblood of science. Without well-founded criticism, science ceases to advance. There remains the challenge to conduct debate without the accompanying polarizing question of whether the policy pursued was 'right' or 'wrong'. Such a nuanced debate, based on a correct post-hoc analysis, is very important. However, this seems difficult at the very moment when there is a need for clear instructions and a critical number of people who need to comply with them.

5. Use and abuse of statistics: how to conduct science communication with imperfect data?

Statistics, and by extension biostatistics and epidemiology, like physics and engineering, are strongly mathematics-based disciplines, but they are not an integral part of mathematics. Mathematical statistics, in particular *survey sampling*, teaches us that, with a sufficiently large representative sample, one can make reliable statements about a population. Mathematical statistics also teaches us a proper way to calculate the limits of uncertainty. In a similar way, on the basis of a century of scientific research in design of experiments, we can set up studies, including those of a biopharmaceutical, agricultural, psychological and economic nature, in order to make reliable comparisons between different interventions. Here too, we can quantify the uncertainty.

5.1 *About representativeness, randomization and observational data*

Theory often assumes ideal situations in which assumptions made are valid in full, where samples are sufficiently large ('going to infinity'), etc. In practice, pragmatism is needed and requires a great deal of additional knowledge, insight, experience and practical research – such as computer simulations – in order to determine the exact impact of assumptions that have not been (entirely) met. Examples of such deviations are obvious: not everyone who is contacted for a study is willing to cooperate; those who participate in a study with repeated measurements over time may drop out in some cases; responses to questions are not always correct because people are not willing to give a truthful answer and choose instead to answer in a socially desirable way; when compiling a representative sample, it is sometimes difficult to reach certain groups within society to a sufficient degree, etc.

Questionnaires derive their legitimacy from the representativeness of the sample used, and experimental studies lead to valid comparisons by applying randomization techniques. However, there are many circumstances in which the scientific question is a comparison but a designed experiment is not possible. This may be because it is unethical, would be too slow, etc. Here is an example: an experimental study with a human sample to show that smoking causes lung cancer is ethically unjustifiable. In such a case, observational studies are used, among other things, in which a group of smokers is compared with a group of non-smokers. The smoking behaviour is not determined by the experimenter but is established from the behaviour that people show anyway. At first glance, one can then determine the link between smoking and lung cancer. The big problem, however, is that of the so-called 'other variables'. While people differ in smoking behaviour and smoking behaviour influences the development of lung cancer, people will differ from each other in other characteristics. Think of age, gender, drinking behaviour, eating habits, sporting activities, working conditions, socio-economic status, level of education, etc. These factors help to determine the risk of lung cancer. In other words, many phenomena, such as lung cancer, have multifactorial causes. These other factors are called 'confounders' when they disrupt the relationship we wish to study ... by not taking them into account. In epidemiology and public health, where there is often the need to study harmful effects, scientists are constantly confronted with this problem. It poses major challenges for the science communicator. Those who are not familiar with the phenomenon experience it as unnatural. Moreover, we are never sure that we have included all confounders in our statistical analysis.

Randomization, as is common in experimental studies, circumvents this problem by comparing two or more roughly equal groups which differ only in the experimental factor. For this reason, seemingly paradoxical results can arise. For example, randomized clinical trials can show that a vaccine is very effective in preventing hospitalization, while observational data during the vaccine rollout could show exactly the opposite: i.e., that those who have been vaccinated are more likely to end up in hospital. The latter phenomenon can occur, even when we have information about everyone in the population. After all, for an infection whose severity increases sharply with age, it is logical that vaccination coverage also increases with age. The comparison is skewed by comparing younger unvaccinated people with older vaccinated people. Analysis methods need to be corrected for age, by stratification for example; the comparison between vaccinated and unvaccinated people in each age group is made separately (in age bands of 5 or 10 years, for example), which will then show how well the vaccine works for each age group. These results are then bundled into a result for the entire population.

Sometimes the opposite is done. Rather than starting from groups of smokers and non-smokers and determining over time who has developed lung cancer, the researcher starts from a group of patients with lung cancer and then chooses a control group who are free of lung cancer but who have the same characteristics (age, sex, etc.). We call this a retrospective study. It is possible to control for confounders on an individual level. For each cancer patient ('case'), one or more controls are chosen who do not have lung cancer but have the same background characteristics. This eliminates or at least drastically reduces the influence of confounders. For cases and controls, it is then recorded whether or not they smoke, and a reliable comparison can be made on this basis. However, here too the validity of the results still depends on how extensively confounding was corrected for.

The broader communication problem is that a simple analysis of observational data does not usually produce accurate results and that a correct analysis is quite complex and less intuitive. This often gives rise to doubts about the validity of the data analysis and even about the honest intentions of the analyst.

5.2 *During the pandemic*

This problem deepened during the pandemic, in relation to various matters including : (1) vaccination in the post-marketing phase, even though the vaccines had been studied through standard clinical trials; (2) the efficacy of face masks; (3) the usefulness of a curfew; (4) the usefulness of a COVID safe ticket (CST).

For example, it has often been pointed out that no randomized trials were undertaken to substantiate the usefulness of face masks during the COVID-19 pandemic. First of all, such studies are not impossible, but they are quite difficult and they are time consuming. This can be done at an individual level. However, if a group of people wears face masks and they are effective, the risk also decreases for non-wearers, a phenomenon that is specific to communicable diseases. If one applies randomization at the area level, one gets ecological effects; differences between areas are not necessarily the same as the effects one would see at the individual level. It is therefore more promising to make use of all possible elements of evidence, for example: the effect of face masks in laboratory conditions; effects already demonstrated in sufficiently similar conditions, such as in other respiratory diseases, etc. Finally, it is best to opt for the precautionary principle; if there is any remaining doubt, this will be the least harmful solution, pending further research results. The problems with the COVID Safe Ticket and the curfew were possibly even greater because there was little or no usable evidence from similar circumstances.

When data is incomplete, all the issues listed are exacerbated; they even appear in experimental research. Suppose we have two properly comparable groups, but that people in the control group give up because they experience little improvement, while in the experimental group it is precisely the side effects that cause dropout, even though the drug works and the side effects are reversible. De facto, our experimental study will then look more like an observational study, with all the problems already mentioned, as groups become progressively fewer and less comparable.

Even in situations where we register all available information about a certain phenomenon, there is no guarantee of unbiased results, and careful interpretation and analysis are still required. We see this in the figures below, which show both the number of confirmed cases and the number of hospital admissions for 2020–2021. Hospital admissions are reliably registered. The same applies to the number of test-confirmed infections. However, not everyone is tested and the fraction of infections determined by a test varies over time when compared with the total number of infections. This is particularly evident at the beginning of the pandemic in the spring of 2020, where we see a large peak in hospitalizations, but, when compared to later peaks, only a limited peak is evident in the number of confirmed cases. This has everything to do with the fact that diagnostic tests first had to be developed and made deployable on a large scale. In the autumn of 2020, there is good agreement between the two indicators. But even when testing is up to speed, the fact remains that every time viral spread increases, in the run-up to a peak, the testing lags more and more behind the actual spread.

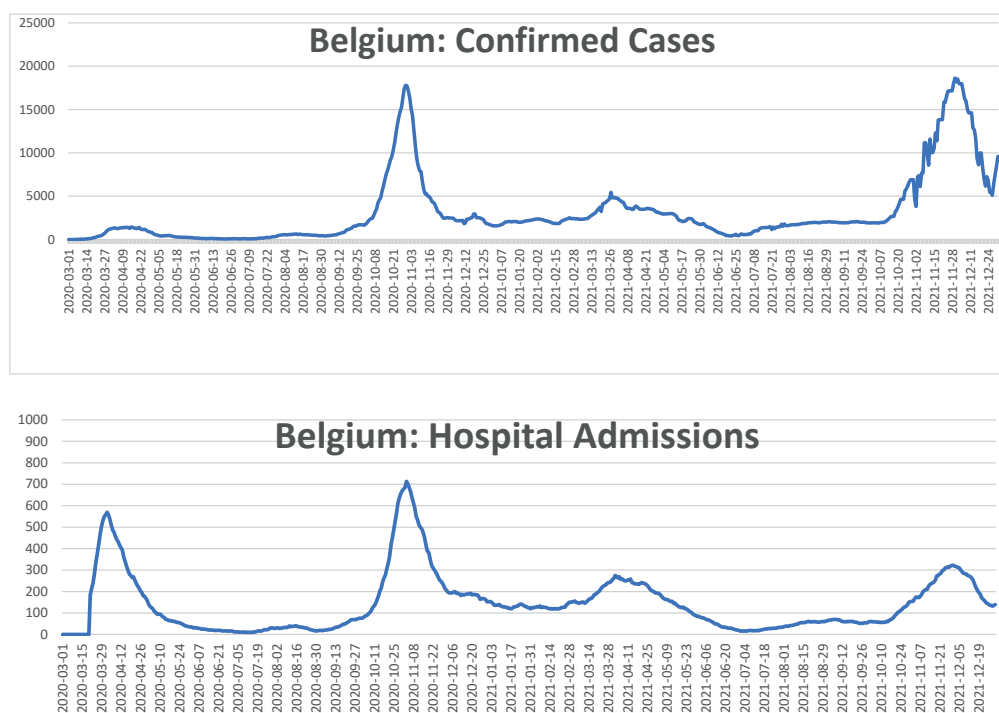


Figure 2 This figure shows the number of confirmed cases and the number of hospital admissions. Hospital admissions are reliably registered. The same applies to the number of test-confirmed infections (top figure). However, not everyone is tested and the fraction of infections detected by a test varies when compared with the total number of infections over time. Both are very similar, except for the early days when good tests were scarce.

Such phenomena present us with particular challenges in terms of communication. The reliability of an indicator, such as test-confirmed cases, is frequently questioned with the a priori assumption that it is not. This is not a yes/no question, but an issue that requires careful qualification. The indicator value is not equal to the total number of cases – this is due to the so-called ‘dark number’, the number of cases that are not confirmed by a test. Nor can we simply read the growth rate of the epidemic from them. However, the actual number of infections and growth rates is related to both the observed number of infections and the observed number of hospitalizations. On the basis of mathematical models, in which biological and virological knowledge is brought together with partly incomplete data from various indicators, an estimate can be made of the total number of cases. For other purposes, such as determining whether there is growth or contraction and whether growth is accelerating or slowing down, the curve can be used – it is a *marker* of what is going on. This is sufficient to formulate policy measures and inform the public, despite the incompleteness of the data.

Yet, the use of imperfect data complicates science communication based on it. The nuances about what can and cannot be done with the data are often lost in an all-or-nothing debate and the associated scepticism. It does not mean that we should not use the data, but it makes sense to supplement them with a representative sample from the population (a sentinel survey) from which epidemiological information is collected on a regular basis (infections, antibody build-up, vaccination, etc.). The registration systems are sufficient for other indicators of endpoints that occur less frequently but are easier to determine (such as hospitalization and mortality).

6. Social media as a curse and a blessing for trust in science

Citizens come into contact with science through news media, through searches on the internet and on social media, etc. This is done both selectively (when they are looking for concrete information about social themes, their own health, etc.) and incidentally (when others share something, when they read the news of the day, etc.).

6.1 *From an institutional to a networked model*

The classic model of science communication²⁴, the so-called ‘institutional model’, is characterized by linear flows of information between professional gatekeepers, each of whom fulfils its role. Scientists develop the knowledge, formulate the research questions and lead the scientific research. Policymakers formulate their policy on the basis of scientific insights and are responsible for its implementation. News media let policymakers develop their policy and ask critical questions. In this model, citizens come into contact with (a limited part of) scientific insights mainly through the news media and (to a lesser extent) through policymakers.

For the past half-century, science communication in Western European societies has relied primarily on this model. We relied on science and scientists as institutions for knowledge creation, on the government and its (elected) officials as institutions for policymaking and on media and journalists as institutions for meaning-making. The three are aimed at constructing common knowledge, common ground and common sense. The institutional model is based on shared assumptions about who to trust, what to trust, and how trust is built. Naomi Oreskes explains that we trust scientists, not be-

cause of their authority as individuals, but as members of a professional community that develops common knowledge and collective wisdom.

From the inception of Facebook in 2004 to its mass adoption in 2010, this classic model of science communication has been under pressure due to the advent of social media. Through social media, information comes to users unfiltered, from all kinds of sources and it is difficult to evaluate which channels are reliable. Anyone can spread information, even with intentions that do not (only) serve the purpose of informing people. For example, content creators on social media are often driven by commercial motives. These media use their own kind of images and language (memes, videos ...) that are very popular and whose information comes in easily, although it is not necessarily the case that only this information is believed. 'Experts and institutionally embedded science professionals no longer have a monopoly on informing politicians and mass media, as social media platforms provide a communication channel for every citizen and non-expert. Non-expert voices gain influence through the posts and videos they post, as well as the automated likes, shares, retweets, and recommendations powered by platforms; "Friends" and non-experts seem to be able to communicate scientific information on an equal footing with institutes or experts.' [22]

The business model and commercial logic of social media also ensure that each piece of information is initially assessed for its commercial value. Engagement-driven algorithms are created in this way; anything that creates a lot of likes, clicks and shares is pushed to the forefront. The chance that these are emotion-driven, sensational and/or polarizing messages is greater than the likelihood that they are nuanced, complex scientific interpretations. Politicians also go along with this story. Moreover, the news media themselves are dependent on social media and an increasing share of people get their news via social media. Social Media and Society^[24] have documented a shift to a 'networked model of science communication'.

6.2 *Towards 'different' science communication*

On the other hand, some recent examples (e.g. Dear Pandemic) show^[23] that, if the right tone is found, social media are also ideal channels for disseminating scientific information quickly and on a large scale. 'Dear Pandemic' is an example of a promising new paradigm for communication and intervention in public health. The contributors deliver content in ways that are personal, practical, actionable, responsive, and *native* to social media platforms. The guiding principles of the project are a model for public health communication that focuses on future infodemics. They can bridge the gap between the scientific community and the practical, day-to-day decision-making needs of the general public.^[22] At the same time, scientists themselves can share scientific knowledge among peers via social media.

In conclusion, it can be said that media use continues to evolve, even when it concerns media through which citizens come into contact with science. A new generation of young media users is growing up with their own media and language use and logics.^[24] To gain (or restore) trust, institutional actors will have to adapt appropriately to the dynamics of social media and to the logics of the networked model. Policymakers and regulators must also continue to consider the power of technology companies and the role they play in disseminating (un)reliable information. There is an important role for sensitizing and educating basic knowledge (literacy) and core values of science (and democracy), with questions such as: What is science? What is a good debate? The role of (traditional) media outlets, such as public broadcasting and news companies, is certainly not played out either.

7. What have we learned from mistakes and sloppiness in the research?

Scientific insights are generated at universities, knowledge institutions and beyond, in industry for example. The processes, timelines and mechanisms used to ensure their quality differ between knowledge creation at universities and knowledge institutions on the one hand and those used in an industrial context on the other. The following three insights are based on many years of experience in research and development in the field of inorganic functional materials technology for a globally active supplier to the automotive industry.

A first insight is that even highly educated and good scientists can sometimes make a scientific mistake. One cause may simply be time pressure that does not allow for preparation, such as the insufficiently detailed and critical study of the operating manual of complex analytical devices. This can lead to a situation where these devices are unknowingly misused and produce results that have no scientific significance. Another reason is that experimental setups have become very complex. It can therefore happen, in all ignorance, that important details are lost: the scientist can't see the wood for the trees. To reflect, we recall how groundbreaking scientific insights in physics came about in the last century, such as the discovery of nuclear fission, about a hundred years ago. The laboratory set-up used by Lise Meitner and Otto Hahn can still be admired in the Deutsches Museum in Munich and impresses to this day with its simplicity and clarity. A lesson that can be derived from this is that the scientist must always think carefully and critically about the essence of the scientific question to be evaluated experimentally and then ask themselves what is the simplest and most minimal experimental setup to deal with the question. Both aspects are well captured with the acronym KISS (Keep It Simple, Stupid). It is an advice that is still valid today.

A second important insight is that there is a fundamental difference between research at universities on the one hand and research in an industrial context on the other. This difference can be seen in the mechanisms by which the quality of scientific insights is guaranteed – at least in the field of materials technology. In simplified terms, it can be said that quality assurance of university research relies heavily on the finality of the publication of the research results in renowned, internationally accessible journals, after a strict peer review process. From the perspective of a researcher and product developer active in industry, it can be said that this method of progress deserves complete respect and trust in terms of the deductive part of the scientific work, the steps that start with the experimental results and go all the way up to the scientific insights. But experience in the industry feeds doubts about these previous steps and about the quality of the experimental results. The author of these lines has the personal insight that 'paper is patient'. In the context of industrial research and development, the role of publication is less eminent. In this process of knowledge creation other feedback mechanisms are active. One of these is the repeated and external evaluation of the performance of the product that was developed on the basis of the scientific insights generated. This evaluation is done by the potential customer, who compares the performance with alternative products proposed for the same application by professional, global competitors. In other words, 'the proof of the pudding is in the eating'. We can also say that the economic preconditions of research and development in industry have ensured that a high degree of efficiency is built into the experimental part of the process. This means that, today, it has become the industry standard that experimental work is done according to externally certified, internationally recognized, quality assurance processes. We can say that industry has invested more in the first step of knowledge creation.

Finally, a third insight is that, in the industrial process for knowledge acquisition, there are many more repeated experiments. A sample of a promising product is synthesized several times in order to provide various customers with enough copies for their validation work. After successful validation by customers, the synthesis of the new product is brought to an industrial standard, which also provides an ultimate check on the accuracy of the acquired knowledge. A further example is that industrial, analytical laboratories regularly participate in so-called 'proficiency analysis', as one of their quality assurance measures. In this process, samples of the same material are made available to different laboratories for analysis, after which the results achieved by each lab are compared with each other. This is a good practice which can have great value as a source of inspiration for academic experimental research, in the sense that the same scientific question would be posed to several academic laboratories in parallel and the results critically compared, before new scientific knowledge is cemented in publications.

8. Scientific integrity and the role of the Flemish Commission for Research Integrity (VCWI)

Throughout history, the importance of science for society has increased enormously. Part 4 of this Position Paper provides an example – the role that research played during the COVID-19 pandemic. Scientific insights show that the Earth is warming up and warn of the consequences if we do not stop that warming. Not a day goes by without a scientist being interviewed on the radio or television about a subject that dominates current events, whether it is about natural disasters, about the consequences of excessive public debt or about excessive screen use. But if we only look at the successes of science, we are not telling the whole story. Science is always presented as advancing insight that is the result of a strictly rational process in which the physical and natural worlds are systematically investigated. This view overlooks the fact that research is done by humans and humans are not strictly rational beings. Scientists also operate in a social context that is characterized by everything that is human. Nothing human is strange to them ...

8.1 *Gatekeepers under discussion*

Of course, researchers can make mistakes, which means that erroneous findings, conclusions or interpretations can influence scientific literature. Errors are an essential part of the scientific process; follow-up research and substantive discussions should reveal such errors and bring us closer to the truth. However, scientific literature is not only distorted by honest mistakes. Just as the sports world is riddled with doping and bribery scandals and just as the economic sector has to contend with unfair use of insider information in share transactions and with tax evasion, science also has to deal with violations of scientific integrity. After all, scientists are not fundamentally different from other people. In addition to their drive to find out and understand things and to find solutions to intellectual, practical and social problems, researchers can be driven by self-interest, ambition, vanity and greed. Meta-research – that is, research about research – has shown that, in recent decades, such 'all too human' factors have influenced scientific literature much more strongly than previously thought.

Scientists like to refer to two gatekeepers that protect scientific literature from both honest errors and violations of scientific integrity; the peer review process and the need to be able to replicate or reproduce findings. (See Part 2 on the scientific process.) The

peer review process means that (usually anonymous) experts assess research reports on their quality. They must detect possible errors and imperfections before a manuscript is accepted for publication. However, that assessment process turns out to be much less reliable than is usually assumed. It is also under pressure because editors of scientific journals are finding fewer and fewer researchers willing to carry out this often-time-consuming work, which is associated with little appreciation or prestige. Some researchers even find ways to circumvent fair reviews by setting up so-called review carousels or by suggesting non-existent colleagues, so that the requests for review (via deceptive e-mail addresses) end up back with them.[²⁵]

Replication research, the other gatekeeper, is also far from flawless, mainly because it is not worthwhile for a scientist to check published findings. After all, replication research rarely leads to publication. In the field of psychology, only one per cent of published articles contains replication research; in economics, that percentage is much lower. [²⁶]

The fact that scientific literature is contaminated by unreliable reports, resulting from malicious intent, has become especially clear in the past decade. In a recent,[²⁷] anonymous survey among almost 7000 researchers in the Netherlands, one in twelve scientists admitted to having falsified or fabricated data in the previous three years. Of the more than 50,000 unreliable papers currently listed in the database of Retraction Watch, [²⁸] a large majority were retracted due to violations of scientific integrity. Depending on the source, the estimates of the percentage of forged papers ranges from 2% to more than ten times as much.

A detailed examination of forty well-documented fraud cases showed that the two traditional gatekeepers were rarely effective in detecting the fraud. The fraud only came to light in one of these forty cases after problems were experienced in replicating the results. No more than four of the remaining cases were discovered during the peer review process. The majority of the forty cases would have gone unnoticed without the whistleblowers who disclosed the fraud.[²⁹] However, speaking out to expose scientific fraud is not without risk; whistleblowers often experience negative consequences.[³⁰] It is therefore important that they receive protection in the research institutes where they work.[³¹] It should be noted that in a number of cases it is becoming increasingly possible to detect and prove scientific fraud with the help of sophisticated image analysis and other detection software. The development of these techniques demonstrates the increasing attention to integrity but may lead to the false illusion that the problems are under control. Proving (scientific) misconduct or fraud may sometimes take years because existing investigative methods are imperfect or because those responsible for misconduct lack (ethical) insight, usually for opportunistic reasons. It is always crucial that accusations of the violation of scientific integrity are investigated in an impartial manner and that appropriate measures are taken when violations are identified.

8.2 *Initiatives for protecting scientific integrity*

As early as the 1980s, a number of high-profile fraud cases in the United States made it clear that the peer review system and replication research were unable to protect science from deception. In the aftermath of a report by a parliamentary committee of inquiry into violations of scientific integrity, a law was passed in 1989 that required American universities and research institutions to report scientific fraud. Three years later, the Department of Health and Human Services established the Office of Research Integrity (ORI), which is tasked with overseeing scientific integrity in research.

Similar initiatives took longer in Europe. In 2003, the Royal Netherlands Academy of Arts and Sciences, the Netherlands Organization for Scientific Research and Dutch universities set up the National Board on Research Integrity (LOWI), which is an independent advisory body that deals with complaints about possible violations of scientific integrity. In 2007, the European Network of Research Integrity Offices (ENRIO) was established, which aims to unite committees and institutions working for scientific integrity. This way they can also advise each other. Not all European countries have such committees or institutions; for example, Spain and Portugal have none. That is why the European Federation of Academies of Sciences and Humanities (ALLEA) advocates the establishment of committees in these countries. [32]

Around the same time, Flemish universities saw the need to pay attention to violations of scientific integrity. At KU Leuven, Ghent University, University of Antwerp, Vrije Universiteit Brussel and Hasselt University, committees for scientific integrity (CWIs) were established in 2007, 2009, 2010, 2012 and 2013, respectively. They have the task of investigating reports of breaches of scientific integrity in an independent and fair manner and providing advice to rectors. In this way, the CWIs complement a university's initiatives to promote scientific integrity in research: by training young researchers, by facilitating a positive research culture and by demonstrating good practice.

Following the example of LOWI, the five Flemish universities – in collaboration with KVAB, KAGB and FWO (the Fund for Scientific Research – Flanders) set up the overarching Flemish Commission for Scientific Integrity (VCWI) in 2013. It was given a double task: issuing general advice in the field of scientific integrity and giving a second opinion on the handling of complaint files that had previously been dealt with at a university or another research institution. In addition to the institutions that formed the basis for the establishment of the VCWI, the committee is currently also recognized by: the Flemish Institute for Technological Research (VITO); imec; the Flemish Institute for Biotechnology (VIB); Flanders Make; the Institute of Tropical Medicine; the Flanders Marine Institute; the Institute for Agricultural, Fisheries and Food Research; the Research Institute for Nature and Forest; the Heritage Agency; the Meise Botanic Garden Agency; the University College Ghent (HOGENT), and Vlerick Business School.

As far as their first task is concerned, the VCWI has issued four general recommendations to date: on plagiarism in project applications, CWI procedures during the COVID-19 pandemic, the recommendation to accept the ALLEA code as a generally applicable document for scientific integrity and an advice to clarify the contributions of authors to scientific publications. The VCWI received 43 requests for second opinions between 2014 and 2023 and dealt with 27 cases. The other requests were inadmissible or were not dealt with, for example, because the committee saw no reason to deviate from a clear CWI advice.

We can ask the question, to what extent the combination of the peer review system, the execution of replication research and the various reporting points for integrity violations succeed in maintaining the reliability of the scientific knowledge base. In 2022, the committees of four of the five universities received a total of 36 reports of integrity violations, of which 19 were declared admissible. (No data were available for one university.) The large discrepancy between the estimated prevalence of scientific misconduct on the one hand and the limited number of cases investigated at the CWIs and the VCWI on the other shows that only a very small minority of the violations are reported. Sometimes victims prefer not to report to a CWI, for strategic reasons.

Science is indisputably advancing. At the same time, it is advisable to keep in mind the imperfections of the researchers. That science is a strictly rational process is a persistent myth that overlooks the fact that research is a human activity.

9. Science communication and fact-finding in the media

Of course, media and journalism have their limitations. One of them can be summed up as 'the three solas of the media': *sola resulta*, *sola concreta*, *sola practica*. The media are very focused on the result of a scientific debate, on what actual changes are brought about by that result and what the practical consequences are for the viewer, reader and listener. There is nothing wrong with that in itself, but inevitably one aspect is suppressed; how did scientists actually come to their conclusion and why do scientists think they know what they think they know? It may well be a criticism of the media (and sometimes also of science itself); the media like to report on scientists reaching the summit, but they are far less interested in explaining the mountain.

Readers, viewers and listeners may be left with the impression that science is a closed world where the result is final and based on authority rather than on a process. However, science should actually be a constant debate. Even worse, almost everything that is served with a vaguely scientific sauce on the net or on social media claims an equally legitimate right to be considered as scientific truth. For these reasons we would like to make a plea for a new journalistic genre that emphasizes the method: Why do scientists think that the climate is changing under the influence of humans?, what is the evidence for that?, why are scientists convinced that corona vaccines have saved human lives? Such articles will rarely reach a high readership peak on any particular day and this may make them less commercially interesting but they can last a very long time. With a sensible approach, they can also continue to rank highly in search engine results for a long time. Universities and media could work together on this.

Even then, in the best case, we might only reach the people who are willing to enter such search queries into browsers. But that's more than you might think. Don't underestimate how many people treat the internet as their 'university'. However, unfortunately, there are more and more people, especially young people, who get their information from social media. They often expect that the information does not have to be searched for at all: 'The news will find me.' This means that information that answers the question 'why do scientists think they know this?' must also be available on social media in manageable formats. This is a result of the evolution in media use; a publication will never stand alone. Today, information must be offered simultaneously on different platforms and in various formats. scientific method on Instagram or X? It's certainly possible. Media makers have quite a bit of in-house experience to bring to this. But it requires work, collaboration with scientists and, above all, money.

Social media users also often assume that if something is not true, the correction will automatically appear in their feed. As a result, they don't bother to check anything. If there is no response then it might just be true. For that reason alone, it is important that scientists themselves are also active on social media. There are quite a few scientists who do that in a really clever way. The question is whether or not universities always realize that this is an important form of social service, which should be honoured as such. However, it remains important that scientists who do this make a clear distinction between science and opinion.

Because users of social media assume that corrections will follow spontaneously, it is important that fact-checking organizations are also active on social media. In Flanders, three media organizations currently have recognition from the International Fact-Checking Network: *Knack*, VRT NWS and the independent www.Factcheck.Vlaanderen. This last was set up by professors and other teachers of journalism courses in higher education. These three partners work together in www.deCheckers.be, which aggregates and promotes fact

checks on social media. However, Factcheck.Vlaanderen and deCheckers have a great need for structural funding. Oh and, just for the record, who checks the fact-checkers? Potentially, this is a role for every reader because in a fact-checking article, written according to the rules of the trade, the method is explicitly mentioned and the publicly accessible sources are linked in the article.

A final important element seems obvious but is nevertheless very important: social media are ... social. Information on socials gets most traction and impact through interaction. Universities, journalistic media and governments often still consider their socials as a publication channel, while they are essentially an interaction channel. Journalistic media are not used to interacting with their audience but it is an important way to strengthen the relationship with your reader or viewer. Interaction with your readers and viewers can be crucial to keeping their trust in a virtual world where every information carrier, no matter how unreliable, seems to be equal to the other. However, interaction is labour-intensive and therefore costs money. Still, in a major epidemic, it is pointless to have a telephone desk, such as www.coronavirus.be had in Belgium, but not a social media desk. Moreover, it is not such an exotic idea to make your desk for socials three times larger than your desk for telephone interaction.

All that, of course, will cost money. In 2018, in an advisory report^[33] to the then Minister for the Digital Agenda, Alexander De Croo, a group of experts on disinformation proposed organizing a structural consultation with all internet platforms. Since platforms represent a major disruption to the traditional revenue model of media, especially in smaller countries or language zones, it is only fair that part of their profits would return to support the quality of the public debate in the community they disrupt. KVAB also published a Position Paper^[34] and Thinker's Report with specific suggestions.

Incidentally, there are platforms that take responsibility and invest in, for example, independent fact checks. Unfortunately, Marc Zuckerberg has recently announced that he will stop doing this, especially in the United States. The consequences for fact-checking in Europe are unclear today. Nevertheless, there are many fact-checking initiatives, but they lack scale and structural funding. It is high time that a critical dialogue is started with platforms in which all the players involved join forces to counter disinformation more and better than we do today.

10. Final reflections and remarks

What is remarkable about the perspective of this Position Paper, in comparison with other KVAB Position Papers, and about the contributions of the symposium 'Can the scientist be trusted?' from 2023, is that science (or the scientist) itself is the object of study. Moreover, the word 'trust' in both titles refers to a characteristic of science (or of the scientist) that falls outside the realm of the common natural sciences approach to science.

'Trust' is a remarkably 'soft' concept to attribute to science; it is akin to 'faith'. In the Greek translation of the Old Testament, the word '*pistis*' refers to trust.^[35] *Pistis* is needed to be able to believe, the highest form of certainty. In Greek mythology, *Pistis* was even personalized as a female deity. Her Roman counterpart 'Fides' is an important figure in Roman culture and rhetoric; the root of her name can be found in the English word *fidelity*. The English word *faith* also contains this mixture of trust and belief.

How do we arrive from Pistis or Fides to science? Where do Pistis and Fides come from?

10.1 On to sociology, psychology, and statistics

We could use the scientific method itself to answer these questions. That is, we use science to study science. That is the domain of meta-science.^[36],^[37]

What do sociology, psychology or statistics have to say about trust in science? The Science Barometer^[1] is actually an application of survey methodology from sociology, in this case to investigate trust in science. With a survey, we can describe the trust in science among the general population and determine which factors are associated with trust and distrust. By repeating the survey annually, we can also map out changes over the years and the most important trends.

In psychology, one focuses additionally on the scientist or scientific activity as a form of human behaviour. Within psychology, mutual trust is considered a foundation of quality human interaction. As a characteristic of individuals, it is nurtured in a warm and caring attachment relationship during the first year of each child's life.^[38] If that basis is absent, it can have serious consequences for later development, in some cases even leading to paranoid personality disorder. If we extend this line to the scientist and their audience, then trust in science is a foundation for all scientific activity and communication. In other words, if there was no trust in science, then the basis of all scientific activity and communication would disappear. An important task is therefore reserved for parenting and education. If trust in the scientist is pursued, then the scientist must be worthy of it from the start and that trust must not be betrayed.

According to psychology, 'doing scientific research' can therefore be considered a form of human behaviour. In that respect, all behavioural principles, as we know them from general psychology, also apply to scientific activities. As we have already written in Section 8, nothing human is alien to the scientist. For example, we know that behaviour that is rewarded, has an increased chance of being repeated. This can cause scientific research to stray from the ideal of truth-finding towards research that quickly yields a positive result, achieves publication in a prestigious journal, guarantees a professional appointment or brings more promotion opportunities. Questionable research practices and certain cases of data or publication fraud can be understood and addressed from this perspective.

These methods and insights from the social and behavioural sciences can help us to learn more about the phenomenon of 'science' or the person of 'the scientist'. Statistics is also a discipline par excellence with which to study trust (or its counterpart: uncertainty). The application of statistics in the social and behavioural sciences can be seen as an attempt to get a grip on uncertainty by quantifying trust through the use of methods such as a frequentist confidence interval, a Fisherian fiducial interval, or a Bayesian credible interval. Notice how the words 'confidence', 'fiducial', and 'credible' resonate with trust.

10.2 *The importance of the philosophy of science*

However, these methods and insights from meta-science fall short in a fundamental way. If you use the scientific method to study trust in the scientific method, then you already assume a prior trust in that scientific method. This means that science is supported by ... science. That is not possible. We also need principles or rules that lie *outside* of science as a means to reflect on science and scientific findings. A similar phenomenon occurs in statistics. We can construct a confidence interval to estimate a mean, but we also need confidence in the method to arrive at that confidence interval. This is only possible by making the plausibility of certain model assumptions acceptable. We could try to quantify the uncertainty about those assumptions, but to achieve that goal, you need yet another method. You can go on like this ad infinitum. Somewhere the purely scientific justification stops, and you must work with a collection of assumptions and rules in which you put your trust.

If science itself does not have the last word on trust in science, where can that last word come from? It is more important to ask the question than it is to answer it. Nevertheless, there are many possible answers. These can take other forms depending on differences in world view, image of mankind, intuitions and views on what reality looks like and how it corresponds to our experience of it (from 'facts' and 'observations'), to values and norms, to culture and zeitgeist. With this question, we end up in the domain of the philosophy of science, which considers questions such as: What is science? How can we distinguish science from pseudoscience? What criteria must sound scientific research meet? Philosophy of science is more important than any other discipline for teaching us something about trust in science.

Unfortunately, little attention is paid to philosophy of science in scientific curricula and the number of courses on offer has even been reduced in recent decades. A recent editorial in *Science* unequivocally demands; 'Teach philosophy of science'!^[39] The editor of *Science* also explicitly makes the link with trust in science:

'Much is being made about the erosion of public trust in science. (...) Resetting the public's understanding of how science works will be a big job, but a good place to start is with students who get science degrees. Unfortunately, most programs are full of didactic classes about scientific principles, with few, if any, requirements on the history and philosophy of science. Because many undergraduate science majors pursue careers outside of science, including medicine, a shift in curricula would ultimately produce a public that is more literate in the way that science works.' (p. 141).

'Trust in science' is therefore the theme par excellence in which the classical humanities, social and behavioural sciences, biomedical sciences and natural and technical sciences meet and need each other.

11. Conclusions and recommendations

The Academies offer a platform where active academics, young and not so young, and also emeriti from different universities and from various disciplines -- meet and discuss with each other. They are politically and ideologically independent and strive for more openness of science towards the outside world. With their prestige, their intellectual strength and their strong public commitment, they succeed in involving people in positions of responsibility in companies, external experts and stakeholders in many of its programmes and working groups. Based on this task description, it is an important objective of the Academies – international, national and regional – to contribute to strengthening public support for science, scientific work and researchers.

To this end, they wish, in particular, to strengthen the trust that society can give to sciences and scientists (see box 9 of the KVAB evaluation 2024). This theme is therefore central to the activities of the permanent reflection group of KVAB and KAGB Responsible Research & Innovation and Science Ethics. This Position Paper was developed in collaboration with the Young Academy as a consolidation and deepening of the successful study afternoon held on 16 October 2023. It offers in-depth insights into the philosophical, sociological and psychological basis, the historical evolution and the scientific and statistical underpinnings of trust in science and the scientist.

Trust arises as a human two-way relationship between partners and has a specific dynamic and a fragility that is often formulated as a Dutch saying; 'Trust comes on foot and leaves on horseback'.

Trust in researchers and research results is based on a number of values and basic attitudes of researchers and the processes that they set up. First of all, it is crucial that the various steps of the research process are correctly documented, are transparent and that the researchers are open about their work. Attention must also be paid to minimizing the risk of bias in scientific results resulting from (conscious or unconscious) personal or political interests, to ensuring mutual control, to the search for consensus between different scientists, to the recognition or awareness of one's own position as a researcher and to the independence and freedom of scientific research.

Objectivity is not set as a universal goal here. It is a loaded term in the history and philosophy of science. According to many human scientists, objectivity is an impossible ideal to achieve in all the substeps of the scientific method. Is the choice of a topic or a research question objective? Is the formulation of the problem objective? Is the selection of the background literature objective? Is my observation of reality objective? Is my interpretation of the results objective? Is my policy advice objective? In the biomedical sciences, this is sometimes overcome by talking about minimizing the risk of bias rather than talking about unbiased. In the human sciences, people will talk about 'intersubjective controllability' or recognizing one's own 'positionality'. Researchers must also take responsibility for the study results and declare any actual or perceived conflicts of interest. The same open-mindedness and correctness are required for scientific advice to the government and to the innovation chain. In the valorization processes of scientific inventions, real dilemmas can arise, in which scientists should adopt a reserved attitude. Start-ups and cooperation with the business community, such as the pharmaceutical industry, are an added value for society. At the same time, there is always a risk that the public, due to real or perceived conflicts of interest, will develop a form of distrust in the scientist and the scientific findings.

Of course, any form of fraudulent behaviour is unacceptable; consider the fabrication, falsification and manipulation of data, plagiarism, incorrect reporting and sloppy or un-

fair reviews. But there are also much more subtle forms of unacceptable or unethical behaviour by researchers. Finally, even with highly educated and very good scientists, unconscious mistakes are possible; to err is human. Scientists must then honestly admit those errors rather than hide them and retract or correct their publications that contain the errors. For example, there is a tendency in experimental research to use increasingly complex experimental test setups. This increases the risk of unwanted and also undetected erroneous experimental results.

The scientific world encompasses many disciplines with many different cultures and customs that have developed and grown internationally, each of which has its specific value for safeguarding the quality of research in that discipline. Many methodologies can also be used in other disciplines and research groups worldwide. For example, there is a fundamental difference in the quality assurance of experimental work at universities and knowledge institutions on the one hand (exploratory work, low Technology Readiness Levels [TRL]) and in industry (development work, high TRL) on the other. Repeated experiments and quality control in the treatment of measurement results are common in the industrial context of development work, but are applied less systematically in academic, rather exploratory work. The process of fact-checking is common in journalism and the media world and very valuable for confirming or disproving the accuracy, factuality, and accuracy of the reporting and the claims. There, the journalistic and scientific approaches run parallel.

Recommendations

1. *For policymakers.* Support societies such as KVAB, KAGB, and JA that promote transdisciplinary dialogue and engage in communication with the general public. The increasing specialization of science into sub-disciplines allows us to make great scientific progress in certain sub-domains. However, this should not lead us to lose sight of the broader framework and fundamental trust in science. By keeping in mind the unity and diversity of methods and goals of science, we can continue to demonstrate that science is worthy of trust and that it is the scientists (plural!) together who conduct the adversarial debate in a reasoned way, supported by facts and scientific findings and across disciplines. Together they form 'science'.
2. *For the policymakers of the universities, the research institutes and the research funding institutions.* Reward researchers and research practices that foster trust in science. Make this a plus in recruitment and promotions, in addition to the scientific evaluation of curricula based on qualitative analyses by competent scientific experts, supported (but not exclusively directed) by quantitative data. Consider introducing a quality management system according to international standards (ISO) and use valuation frameworks, such as The Declaration on Research Assessment (DORA) <https://sfdora.org/> and Coalition for Advancing Research Assessment (CoARA) <https://coara.eu/> for the evaluation of all scientific research in order to guarantee the quality and use of the results. Consider using the appropriate Next Generation Metrics^[40] appropriate to the type of evaluation (individual researcher, research group, institution, and goal). Don't let scientific research get carried away by scientific 'hypes' and give slow science a chance. Appreciate the popularizing and informing presence on social media as an important form of community service.
3. *For the education providers.* Introduce scientific thinking and trust in science with concrete arguments and examples and approach the theme carefully. Provide basic knowledge (literacy) and core values of science (and democracy) based on questions

such as: What is science and how does science work?, What is the distinction between facts and opinions?, What is a good debate? Attach more importance to (or restore the importance of) philosophy of science in scientific education. This can also include insights from the history of science, science ethics, science communication, science journalism and parts of meta-science. This is important in university curricula but can already be initiated in primary education (in the subject of world orientation) and continued in secondary education (in subjects such as science, mathematics and ancient culture). The principle of advancing insight and the successive paradigms from the various sciences can also be addressed in secondary education.

4. *For the researchers.* Be accurate, honest, open-minded and transparent about your own research. Do not conduct the research in an ivory tower, but report and communicate about it in an attractive, clear, and accurate way in the various media. Make maximum use of the methods of open science (preregistration, open access, open hypothesis, open data and hardware, open peer review, citizen science ...)

5. *For science communication in the media.* Tell correct and attractive stories about science and scientists and also mention the scientific basis of arguments in the social debate. It is not easy for the media to present scientific work and scientific results accurately, compactly, and engagingly when they are accompanied by uncertainties and limitations. The methods of fact-checking deserve more attention and support from the government and from the public. The government must understand that disinformation will never be a commercially viable model and that their support is needed in refuting factual errors in manipulative campaigns. The recommendations of the committee of experts deserve renewed attention in this regard. In major crises, credible interaction on social media should be seen as one of the most important forms of communication.

6. *For all those involved in science: promote best practices in terms of the quality of and trust in research.*

- Combine the best scientific quality assurance practices from the academic and industrial worlds. The practice of ring analyses, customary in analytical labs, could be inspiring for experimental work; research structurally one and the same scientific question in parallel in several independent laboratories and exchange conclusions.
- Do not use a sledgehammer to crack a nut. Strive for simplicity when conceiving experimental test setups. Conduct an in-depth analysis of the scientific question to identify the essence of the experimental task and limit the experimental work accordingly.

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13. Postscript

After the publication of the Dutch version of this Position Paper in December 2024 and before the finalization of this English version two reports and an opinion article have appeared in the international scene on strongly related topics.

-The National Academies Press in the USA published an extensive 409-page report entitled: 'Understanding and Addressing Misinformation About Science', <https://www.nationalacademies.org/our-work/understanding-and-addressing-misinformation-about-science>.

The core of this report is dealing with the problems of "fake scientific news" or "misinformation based on alleged scientific evidence". It mentions 'trust' 221 times. The report has 13 important recommendations, some of which are specific to the US situation. However, it is noteworthy that several recommendations are in line with those of this Position Paper.

- In January 2025, a Eurobarometer survey on trust in science in the 27 countries of the EU concluded that 83% of the EU citizens think that the overall influence of science and technology is positive and 67% also agree that science and technology make our lives easier, healthier and more comfortable. This too is in line with this Position Paper. <https://europa.eu/eurobarometer/surveys/detail/3227>

- Related to the discussion in Section 8 a recent opinion article balances the large numbers of retractions against the trust in science 'Does the glut of retractions mean science is in crisis? Hardly', Leslie McIntosh, René Aquarius and Dorothy Bishop, 31 January 2025. <https://www.timeshighereducation.com/opinion/does-glut-retractions-mean-science-crisis-hardly>

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Three Flemish academies: the 'Jonge Academie' (JA), the 'Koninklijke Academie voor Geneeskunde van België' (KAGB) and the 'Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten' (KVAB) have joined forces to take stock of the state of trust in science and the scientist in Flanders. This is an initiative of their permanent reflection group Responsible Research & Innovation and Science Ethics and it is aimed at the wider public, the educational world, the media and the various policy bodies. It was written by a multidisciplinary group of leading researchers from these three academies. Since it is believed to have value outside Flanders, an English version is published.

In recent years, there have been several events and evolutions that may have affected trust in science and scientists. The pandemic, fraud cases, fake news, social media, climate change and world politics are just a few examples. In-depth insights, concrete experiences from the authors, survey results and a historical context show that our trust is quite good, but at the same time the analysis also shows that the academies, the media, the research institutions, education still have an important role to play, with items of attention and recommendations.

It is recommended that the policy continues to support societies such as the KVAB, KAGB, and JA, which promote transdisciplinary dialogue and engage in communication with the general public.

The policymakers from the universities and the research institutes and funding institutions such as the FWO are encouraged to reward the researchers and research practices that promote trust in science. Education providers are requested to carefully teach scientific thinking and trust in science with concrete arguments and examples such as 'What is science and how does science work?', 'What is the distinction between facts and opinions?', 'What is a good debate?'.

When it comes to science communication, the media are requested to provide correct and attractive stories about science and scientists, that also provide the scientific basis of arguments in the societal debate. The methods of fact-checking deserve more attention and support, also from the government. All those involved in science are encouraged to apply best practices for quality and trust in research.

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