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Wellcome Global Monitor

Understanding what people around the world think and feel about science and key health challenges

Questionnaire development report

Contents

Foreword

In 2018, the Wellcome Global Monitor will ask more than 140,000 people around the world to share their thoughts about science and key health challenges as part of the Gallup World Poll. How do different people relate to science? Who do they feel science benefits? How do they weigh up different sources of evidence? Do they trust scientists?

At Wellcome, we want to see a world in which health is improved through the generation of knowledge, the translation of research into impactful interventions, and through changes in policy and practice. We believe that we will be more successful in our mission if people are empowered around the world to understand, engage with and use science.

This ambitious study is the first of its kind, designed to gain a representative snapshot of how people in 140 countries think and feel about science and research and how they understand the interaction between science and society. While there is a good evidence base of public attitudes in high-income countries, far less is known about other parts of the world.

The study will complement our existing work in the UK on the Wellcome Monitor and Science Education Tracker, and by partnering with Gallup World Poll, we are drawing on the deep expertise and insight of a team that has been running a global longitudinal study for 13 years. We also thank the external advisers who have shaped our work and thinking so far.

This report details the questionnaire development process. We are looking forward with interest to the findings in 2019.

Dr Simon Chaplin
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Executive Summary

This report summarises the first phase of a project that will ask more than 140,000 people around the world what they think and feel about science and key health challenges. It describes the testing and design process for a comprehensive questionnaire on attitudes to science, which will be used in over 140 countries.

The questionnaire development process started with a literature review on the subject to make sure all the main ideas were carefully considered, and the relevant ones incorporated in the questions. To gain further insights, eleven academics and interested stakeholders were interviewed on the topic. Gallup's experts on questionnaire design, incorporating previous work on the subject, combined with Wellcome's expertise, developed the first draft of the questionnaire. This was subject to repeated reviews and refinements to prepare for cognitive testing.

Twelve cognitive tests in each of seven countries were conducted in order to assess whether the questions would be well understood across the various demographic groups. This stage focused on low- and middle-income countries as there was a shortage of similar surveys in these countries. Many surveys have been conducted in high-income countries and findings from these were incorporated, where relevant, in the questionnaire development process. The cognitive tests resulted in insightful and important refinements to the first draft. This was followed by pilot testing in ten countries (50 pilot tests in each county), including higher income countries, and further cognitive testing was conducted to finalise the questionnaire.

The final product includes some 30 questions on a variety of attitudinal aspects towards science, including:

- Knowledge of and engagement with science and health
- Trust in science and scientists
- Science and society
- The intersection of science with religion
- A focus section on vaccines.

Understanding of the word 'science' and 'scientific research'

A key finding from the cognitive testing of the first draft of the questionnaire was that it is essential to provide a simple definition of the word 'science' so that it is understood uniformly across the world. In general, low education and under-privileged respondents had difficulty in finding alternative words to describe what they understood by the word 'science'. Even if they understood the notion at one level, it was difficult for them to offer an opinion or engage on the subject. Many respondents indicated that they '*do not think about those things as they are for rich people*'.

The notion of 'scientific research' was not clear to many people interviewed, including low education and under-privileged respondents. The expression 'scientific research' was therefore simplified in the final questionnaire to 'the work that scientists do'.

Furthermore, when people were asked if they thought that subjects like physics, chemistry, biology, literature, history, or others constituted science or not, many respondents thought they were being tested and felt uncomfortable. They answered in a way they thought would make them seem knowledgeable ("social desirability effect"). This was the case despite including brief explanations of what each subject meant in the question itself. It was therefore decided to delete

these questions and any others that made respondents feel tested, and variants of the statement 'this is not a test and there are no right or wrong answers' were inserted at various points in the questionnaire.

The positioning of science in society and trust in science
Questions relating to trust in various aspects of science and scientists, as well as trust more broadly in society, were generally well understood, once the key terms ('science', 'scientist', etc.) were explained. A few of the questions on science and society did not resonate with some respondents. For example, a question asking people if they thought science was moving too fast was often understood to be asking if science was moving fast – not *too* fast. Hence, this question was removed from the survey and this section of the questionnaire was reduced to items that worked well across all countries and demographic groups.

The first draft of the questionnaire contained several questions on the intersection of science and religion. However, those were reduced to two key questions in the final draft, as some of the original questions seemed to cause offence or discomfort – or did not resonate – for many respondents.

Understanding of drug-resistant infections
Some questions on drug-resistant infections were asked in the testing process, but this notion – including the word 'antibiotic' – was not understood by low education respondents. This topic – important though it is to global health – was therefore not included in the 2018 wave of the global survey, and more research and testing is necessary. Other questions which were tested in the first round of the questionnaire but were not included in the final section include questions on knowledge of specific scientific topics (such as physics, chemistry, biology, etc.) and questions on sources of scientific information to which people referred.

Vaccines
Vaccines was chosen as a focus topic given its universal importance to global health. A selection of questions that asked about vaccinations proved effective in testing, although some terms had to be clearly defined to be understood by low education and underprivileged groups across all countries

Second phase - Fieldwork
The section above describes the first phase of this unique and innovative project which will shed light on global attitudes to science. The results should help researchers, policymakers and interested stakeholders understand the main challenges associated with the development of a globally effective questionnaire on the subject.

The second phase of this project in 2018 will take the questionnaire (which will be the equivalent of ten minutes in length in the English language) to over 140 countries, delivered in face-to-face or telephone interviews to all respondents. This should reveal important insights and considerations for all who are interested in the application of science and the public's receptivity to it. Understanding what people think of science and scientists is hugely important to all of us, and especially to the scientific community, health professionals and policymakers, to enable a more effective delivery of the benefits of science to society.

For further updates please visit wellcome.ac.uk/monitor

Introduction

In principle, scientific research aims to improve humanity's wellbeing. People's attitudes to science and scientific discoveries are a critical constituent part which affects levels of uptake of scientific findings and discoveries. It is therefore important to understand the state of public attitudes to and engagement with science globally, especially at a time when health and disease cross borders at ever-increasing speeds. Many people in the scientific community and related policymakers are concerned that the general public's attitudes to science, including their trust in scientists and their work, might be weakening. Yet trust does not exist in isolation. The 'ecosystem' and social context in which science and scientists operate has a significant impact on people's attitudes to and engagement with science and scientists. While a certain level of scepticism is healthy and should drive a more rigorous approach to scientific research, an increasing and more widespread reduction of trust could affect the critical role that science plays in advancing human development, and in the extreme, could lead to outbreaks of diseases and grave health outcomes to humanity.

This report describes work commissioned by Wellcome in 2017 to measure attitudes to and engagement with science and scientists globally. The research study consists of two phases: Phase I involved the careful development and design of a robust and reliable 'Wellcome Global Monitor' questionnaire module that could be implemented in a multi-country study. The questionnaire is designed to be ten minutes in length, for implementation globally by phone and in person (face-to-face interviews). Phase II of the project will consist of fielding this questionnaire in nationally representative surveys in over 140 countries, interviewing more than 140,000 people worldwide, using the Gallup World Poll[1]. While this topic has been well researched in some countries, a study using comparable metrics and methodology has never been undertaken on a global scale.

The findings from the Wellcome Global Monitor survey will be of immense value to researchers, practitioners, policymakers and stakeholders interested in understanding the public's attitudes to science and scientists. This study will seek to obtain information about people's engagement with, understanding of and trust in science and scientists, and explore those dimensions in the local cultural contexts and personal religious beliefs across the world. In addition, the questionnaire contains a short series of questions on a critically important practical application of scientific research: vaccines. This will help understand the public's attitudes towards vaccines and will enable people to think more concretely about practical and tangible applications of science.

The structure of this report follows the qualitative research process that was applied to develop the questionnaire. Section I starts with the research stage and a review of some of the main ideas in existing literature and other survey instruments which explored this topic in various countries. It contains a summary of the stakeholder interviews which were conducted with various experts and knowledgeable individuals on different aspects of the subject under study. Both of these stages of research were used to develop the first draft of the Wellcome Global Monitor questionnaire.

[1] For additional information please visit **http://www.gallup.com/analytics/213704/world-poll.aspx**

Section II describes the various testing processes and resulting questionnaire refinements which were implemented to arrive at the final questionnaire module, including multi-country cognitive interviews and pilot testing. Section III outlines some of the underlying criteria behind the development of the final questionnaire, and Section IV concludes with some final thoughts on the project, including summarising the main challenges faced during the survey design process, and how these challenges were resolved.

The final questionnaire will be published in full in 2019, along with a report on the main findings from the study and the aggregated data for each country.

Section I: Survey Research and Design

I.A Review of the Questionnaire-Related Literature

The questionnaire development and design process started with a review of existing literature on attitudes to science, public engagement with science, trust in science, and existing studies and questionnaires on the subjects under study. This research, along with the stakeholder interviews which were conducted at the same time (described in "I.B Stakeholder Interviews"), formed the underpinnings of the first draft of the Wellcome Global Monitor questionnaire.

The goal of this literature review is to identify the main approaches to the topic of attitudes to science and if and how these have been operationalised in survey research. This phase is crucial to the survey development process because it helps in identifying the main areas that should be covered by the survey. This then informs the specific survey items or groups of items that will address the research questions. Reviewing existing surveys that have focused on the same or similar topics also helps to identify best practices and pitfalls that other researchers have uncovered in their research. The overall goal of this section is not to examine the results of each study conducted on this topic but to understand how this survey can incorporate existing research into a global survey.

Why Study Attitudes to Science?

Understanding the public's attitude to science is a fundamental topic for researchers and policymakers. The field of research that focuses on the interaction of the public with the scientific community is known as public engagement (PE) with science. This field has undergone a radical shift over the last 50 years.[2] While early research considered the public fundamentally lacking in some way and therefore not able to understand and engage with science, current research focuses instead on the broader cultural, historical and societal factors that can lead individuals to reject science.[3]

When individuals and communities are disengaged from and distrust scientific findings this can have serious and far-reaching consequences for society at large. Research on food and nutrition, medical innovations, technological discoveries and environmental science can greatly improve lives, but in many cases, large-scale societal advances rely on some form of public support for policies in order for this to impact individual and community behaviours and support.[4] But if the public comes to believe that a certain type of research, such as climate change, or a medical innovation, like a vaccine, is actually driven by nefarious intentions or is harmful, this can lead to widespread distrust and resistance to acting on this scientific information.[5] In addition, public

[2] Marta Entradas, "Science and the Public: The Public Understanding of Science and Its Measurements," *Portuguese Journal of Social Science* 14, no. 1 (March 1, 2015): 71–85; Martin W. Bauer, Nick Allum, and Steve Miller, "What Can We Learn from 25 Years of PUS Survey Research? Liberating and Expanding the Agenda," *Public Understanding of Science* 16, no. 1 (January 2007): 79–95; Rainer Bromme and Susan R. Goldman, "The Public's Bounded Understanding of Science," *Educational Psychologist* 49, no. 2 (April 3, 2014): 59–69.

[3] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"

[4] Entradas, "Science and the Public."

[5] Eve Dubé, Maryline Vivion, and Noni E. MacDonald, "Vaccine Hesitancy, Vaccine Refusal and the Anti-Vaccine Movement: Influence, Impact and Implications," *Expert Review of Vaccines* 14, no. 1 (2015): 99–117; Paul A. Offit, *Deadly Choices: How the Anti-Vaccine Movement Threatens Us All* (Basic Books, 2015); Anthony A. Leiserowitz et al., "Climategate, Public Opinion, and the Loss of Trust," *American Behavioral Scientist* 57, no. 6 (June 1, 2013): 818–837; Stephan Lewandowsky and Klaus Oberauer, "Motivated Rejection of Science," *Current Directions in Psychological Science* 25, no. 4 (August 1, 2016): 217–22.

support is necessary to ensure continued funding for and involvement in scientific research.[6] For these reasons, amongst others, it is very important for scientists and decision-makers to understand the factors that shape the public's engagement with science.

This concern for the public's engagement with science and the long-term effects of this issue is evident in the discourse of influential members of the scientific community. At the British Science Association's inaugural 2016 Huxley Summit, the focus was on "Trust in the 21st Century".[7] The common thread of the talks was how the scientific community can gain social acceptance for innovation and overcome stereotypes about science. Similarly, Rush Holt, CEO of the American Association for the Advancement of Science, echoed these concerns at the plenary session of the American Physical Society in 2017, titled "Science Policy in the 21st Century". A physicist and former member of U.S. Congress, Holt noted that he had "never seen the scientific community so uncertain, concerned, or so anxious ... We [scientists] have a reverence for evidence, but now [people] see evidence as wilfully denounced and banished in principle."[8] Carlos Moedas, EU Commissioner for Research, Science and Innovation, raised similar concerns at the 2017 Annual Conference of the Joint Research Center in a session called "Why Should We Trust Science?" He noted that the increase in the use of the terms "Post-fact", "Post-truth", "Science scepticism" and "Crisis of faith" are clear indications of the integrity of science being questioned.[9]

Research on Attitudes to Science

Research on PE with science has focused on identifying the obstacles to a fully engaged public by leveraging the scholarship of sociology, psychology, history, political science, communication studies, and science policy analysis.[10] In a first approach, based on a review of 25 years of research on this topic, Bauer et al. (2007) identified three paradigms that have shaped the way scholars, and consequently, policymakers, have tried to understand and address the breakdown that can occur between the public and the scientific community.

The key element of this first approach to PE with science is the attribution of a deficit. Namely, researchers identify a key lacking element that therefore should be the starting point for the framing of the problem and the development of a solution.[11] The early research on PE with science attributed the deficit to the public in the form of either a deficit of knowledge or the correct attitude to fully grasp scientific concepts and internalise them.

More recent research has instead adopted a different approach focused on contextual factors and identified a deficit of trust in science and the advocates of science, i.e. scientists and representatives of scientific and technological institutions.[12]

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[6] Cynthia Selin et al., "Experiments in Engagement: Designing Public Engagement with Science and Technology for Capacity Building," *Public Understanding of Science* 26, no. 6 (2017): 634–649.
[7] British Science Association, "**Huxley Summit 2016**," 2016.
[8] American Physical Society, "**Science Is Not Just For Scientists**," APS, 2017.
[9] European Commission, "**EU4Facts: Evidence for Policy in a Post-Fact World. Session Titled: 'Why Should We Trust Science?**,'" Text, European Commission, September 26, 2017.
[10] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"
[11] Bauer, Allum, and Miller; Nick Allum et al., "Science Knowledge and Attitudes across Cultures: A Meta-Analysis," *Public Understanding of Science* 17, no. 1 (January 2008): 35–54; Entradas, "Science and the Public."
[12] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"; Entradas, "Science and the Public."

Approach 1: Deficit of Knowledge and Positive Attitudes

Starting in the 1960s, relying on data from the first large-scale surveys of public knowledge and attitudes to science, scholars began to formulate a theory as to why the public had little understanding of science: either they didn't know enough about it or they had the wrong attitude.[13]

Durant et al. (1989) first hypothesised the relationship between knowledge and attitude, arguing that: "there are important relationships between public understanding and public attitudes, with a tendency for better-informed respondents to have a more positive general attitude towards science and scientists."[14] The deficit of knowledge approach attributes unfavourable attitudes towards science, including distrust, to a general lack of familiarity and knowledge.[15]

This deficit of knowledge in the public required the creation of the concept of "scientific literacy", to allow individuals to be able to engage in the public sphere on scientific topics.[16] Jon Miller (1983), operationalised this concept based on the 1979 National Science Foundation Science Indicators Survey, relying on three areas of knowledge: (1) Understanding of scientific approach – whether or not respondents could define with reasonable accuracy the nature of a "scientific study"; (2) Understanding basic scientific constructs – comprehension of scientific terms, such as atom, molecule and gravity; (3) Understanding of science policy issues – for which the respondent was asked to think of two benefits and two potential harms associated with controversial science policies.[17]

This focus on knowledge led to the creation of an additional concept of attentiveness to science in order to understand the different roles the public could play in science policy.[18] Visualised as a pyramidal structure, Miller (1983) categorised the respondents of the survey starting from the top as:

1. The 'attentive public' – individuals who declare themselves very interested in and very well-informed about science and technology policy issues;
2. The 'interested public' – individuals who declare themselves very interested in science and technology policy issues but who do not classify themselves as being very well-informed about them;
3. The 'residual public' – individuals who report that they are neither informed nor very interested in science and technology policy issues.

Based on these categories, researchers used the 1979 and subsequent 1981 Science Indicators survey to show that respondents in the first category were also most likely to be supportive of science and more active in discussing the controversies surrounding it.

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[13] Allum et al., "Science Knowledge and Attitudes across Cultures"; Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"
[14] J. R. Durant, G. A. Evans, and G. P. Thomas, "The Public Understanding of Science," *Nature* 340, no. 6228 (July 6, 1989): 11–14.
[15] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"; Entradas, "Science and the Public."
[16] Jon D. Miller, "Scientific Literacy: A Conceptual and Empirical Review," *Daedalus*, 1983, 29–48.
[17] Not surprisingly, only 12% of the respondents in the 1979 National Science Foundation Survey could define what the scientific approach was, half could define at least one of the scientific constructs and only 7% could be considered proficient in science policy issues.
[18] Entradas, "Science and the Public"; Miller, "Scientific Literacy."

The Science Indicators survey was replicated in the UK in 1988 and Miller and a British scholar, John Durant, created the "Oxford scale", a series of quiz-like questions to measure knowledge about science. This effort led to comparisons between the British and American publics and the formalisation of the deficit of knowledge approach to PE with science research. Further surveys were also conducted in Europe starting in the late 1980s, where the European Commission included measures of scientific literacy on the Eurobarometer, still administered today.

Surveys including a component of scientific literacy have been fielded in a wide variety of countries and this has allowed for meta-analysis of the relationship between knowledge and attitudes. Allum et al. (2008) found 193 samples in 40 separate countries spanning the years 1989 to 2004 that allowed for meta-analysis. They found that higher levels of scientific knowledge have a modest but positive impact on attitudes towards science in low- and middle-income countries but this relationship disappears in developed countries. Furthermore, the relationship not only breaks down when examining specific controversial scientific issues but appears to have the opposite relationship. For some issues, such as vaccinations or genetically-modified foods, higher levels of knowledge are associated with less favourable attitudes towards the underlying scientific issue.

Furthermore, recent research has shown how individuals with greater scientific literacy and education can have negative attitudes and polarised opinions on scientific issues, contrary to well-established scientific results. In the U.S., research based on the General Social Survey revealed that beliefs were correlated with both political and religious identity for stem cell research, the Big Bang theory, and human evolution. Meanwhile, political identity was relevant to attitudes to climate change. Finally, individuals with greater education, science education, and science literacy displayed more polarised beliefs on these issues.[19] Similarly, another study found that general education and scientific literacy do not mitigate rejection of scientific findings, such as the fact that emission of greenhouse gases produces global warming.[20]

Starting in the mid-1980s up until the mid-1990s, researchers shifted focus to account for the need to understand how the public could develop negative attitudes towards science.[21] In 1985, the Royal Society of London published a report entitled 'The Public Understanding of Science' which aimed to "investigate ways in which the public understanding of science might be enhanced" because it was deemed inadequate.[22] This report reframed the deficit as being the negative public attitudes themselves and was the first of many to set out to measure this phenomenon with attitudes-to-science scales.[23] PE with science research, however, continued to assert that greater knowledge of science was associated with the greater appreciation of science.[24]

Contemporary surveys on PE with science include a greater focus on attitudes to science in general, types of scientists, sources of science and various fields or scientific discoveries (a selection of the main examples of these types of surveys is listed in the paragraph "

[19] Caitlin Drummond and Baruch Fischhoff, "Individuals with Greater Science Literacy and Education Have More Polarized Beliefs on Controversial Science Topics," *Proceedings of the National Academy of Sciences* 114, no. 36 (September 5, 2017): 9587–9592.
[20] Lewandowsky and Oberauer, "Motivated Rejection of Science."
[21] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"; Allum et al., "Science Knowledge and Attitudes across Cultures."
[22] Royal Society, "**The Public Understanding of Science**," 1985, 15.
[23] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"
[24] Bauer, Allum, and Miller; Entradas, "Science and the Public."

Existing Surveys on Attitudes to Science").[25] These surveys aim to comprehensively measure the public's attitudes to every aspect of science.

The first aspects generally found in these surveys on attitudes are the interest, information sources, and involvement the public has with science.[26] The focus is also on where the public is getting their information, whether they feel well-informed and if they would like to be more involved with science.[27] Involvement in science constitutes informal interactions with science institutions, such as zoos, museums and aquariums.[28] Involvement can also mean how the government and institutions that produce scientific findings communicate information to the public and whether or not the public feels this is appropriate and sufficient.[29] These three components are believed to influence each other and have a positive relationship.[30]

Secondly, surveys on attitudes to science generally probe for the public's opinion of various aspects of science and trust and confidence in scientists and scientific findings. Science can impact the lives of citizens in many ways. For example, the Eurobarometer survey includes questions about the public's opinion of science's impact on the complexity of daily life, the harmful consequences of discoveries, religion's role in decisions vs. science, protecting the environment, improving health, economic development thanks to innovation and science's impact on job security and fulfilment.[31] Finally, an important component of public attitude to science surveys is the issue of trust (further developed in the paragraph "What is the Role of Trust?"). Surveys generally include questions regarding the public's trust in science and scientists to be accurate, transparent and unbiased by external influences, such as funding sources.[32]

The paradox of the PE with science research agenda was that on the path to measuring and understanding the public's distrust or lack of interest in science, the scientists themselves revealed a deep distrust in the public and focused their research efforts on developing the appropriate scales and constructs to understand the phenomenon. At its core, the PE with science framework places the deficiencies of the interactions between the public and the scientific community on the shoulders of the citizens who lack either enough or the right kind of knowledge and fail to display sufficiently positive attitudes.[33] Fundamentally, the PE with science approach focuses narrowly on two dimensions of the interaction: the public and science. It fails to take into account a third dimension, now considered critical to understanding this topic, which is the context of scientific knowledge.

[25] NSF, "**S&E Indicators 2016**," 2016; European Commission, *Public Perceptions of Science, Research and Innovation: Report.*, Special Eurobarometer 419 (Luxembourg: Directorate-General for Research & Innovation, 2014); Tom Huskinson et al., "**Wellcome Trust Monitor Report. Wave 3. Tracking Public Views on Science and Biomedical Research**." (Wellcome Trust, 2016).
[26] NSF, "S&E Indicators 2016."
[27] Sarah Castell et al., "Public Attitudes to Science 2014," *London, Ipsos MORI Social Research Institute* 194 (2014).
[28] NSF, "S&E Indicators 2016."
[29] Castell et al., "Public Attitudes to Science 2014."
[30] NSF, "S&E Indicators 2016"; Allum et al., "Science Knowledge and Attitudes across Cultures."
[31] Rafael Pardo and Félix Calvo, "Attitudes toward Science among the European Public: A Methodological Analysis," *Public Understanding of Science*, 2016
[32] Castell et al., "Public Attitudes to Science 2014."
[33] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"; Entradas, "Science and the Public."

Approach 2: The Context of Science in Society

In response to the "deficit model" of PE with science, some researchers have used a contextual approach to understand the third dimension beyond just science and the public. Advocates of this model argue that the deficit model neglects the cultural, social, political, economic, religious and ethical contexts in which individuals come into contact with science.[34] The contextual approach contends that "acceptance of science is not fully dependent on one's knowledge of science, but rather is based on people's lived experiences, morality, worldviews, beliefs, concepts of risks, and trust in various social institutions."[35]

From a policy standpoint, this approach requires taking into consideration "local knowledge" and "lay knowledge".[36] Understanding the context in which science is presented is crucial in order for the public to accept and internalise science. The scientific community and those who wish to communicate science must not only understand the audience but leverage their pre-existing knowledge in order for interventions to succeed. A contextual approach relies on an in-depth understanding of the social realities of the target population in order to appropriately communicate findings.[37]

This approach presents methodological challenges for survey design as attempts to measure "contextual knowledge" on a survey must be customised to each local context.[38] This approach to PE with science does not have the advantage of measuring universal concepts, such as the correct answers to a scientific literacy quiz, where regardless of the context the answers to the survey do not change. However, certain concepts can be translated into universally understood contextual elements. Cross-cultural research on public trust in biotechnology has shown that one's acceptance of a biotechnology may have more to do with trust in various institutions, such as industry, environmental groups, consumer organisations, media, and government than in the science itself.[39]

Similarly, studies on public support for stem cell research have shown more trust in the research of publicly funded researchers as opposed to privately funded scientists.[40] In addition, trust in stem cell research was also mediated by trust in religious leaders.[41] Finally, a national survey conducted in the UK on public perspectives on human cloning found that negative opinions were tied to a lack of trust in scientists and those who manage or control the research.[42]

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[34] John Ziman, "Public Understanding of Science," *Science, Technology, & Human Values* 16, no. 1 (1991): 99–105; Entradas, "Science and the Public."
[35] Zubin Master and David B. Resnik, "Hype and Public Trust in Science," *Science and Engineering Ethics* 19, no. 2 (June 1, 2013): 323.
[36] Brian Wynne, "Public Engagement as a Means of Restoring Public Trust in Science – Hitting the Notes, but Missing the Music?," *Public Health Genomics* 9, no. 3 (2006): 211–220; Brian Wynne, "A Reflexive View of the Expert-Lay Knowledge Divide," *Risk, Environment and Modernity: Towards a New Ecology* 40 (1996): 44.
[37] Entradas, "Science and the Public."
[38] Entradas.
[39] Susanna Hornig Priest, Heinz Bonfadelli, and Maria Rusanen, "The 'Trust Gap' Hypothesis: Predicting Support for Biotechnology across National Cultures as a Function of Trust in Actors," *Risk Analysis* 23, no. 4 (2003): 751–766.
[40] Christine R. Critchley, "Public Opinion and Trust in Scientists: The Role of the Research Context, and the Perceived Motivation of Stem Cell Researchers," *Public Understanding of Science* 17, no. 3 (2008): 309–327; Hui Liu and Susanna Priest, "Understanding Public Support for Stem Cell Research: Media Communication, Interpersonal Communication and Trust in Key Actors," *Public Understanding of Science* 18, no. 6 (2009): 704–718.
[41] Liu and Priest, "Understanding Public Support for Stem Cell Research."
[42] Wellcome Trust, "Public Perspectives on Human Cloning," 1998.

What is the Role of Trust?

In order to understand the public's distrust of science in general, or of specific scientific findings, it is first important to understand the components of trust. Understanding trust in institutions more broadly has been the subject of considerable research in recent decades. As early as 1975, the "dissatisfaction with, and lack of confidence in, the functioning of the institutions of democratic government" in North America, Europe and Japan has been the subject of much research and speculation.[43] This concern about the overall levels of trust in institutions has continued over time and across many countries. For example, in many countries in Africa, Afrobarometer data reveals a greater trust in traditional leaders than in government.[44]

Contextualising trust specifically in science and scientists within this wider societal shift is useful because the concept of trust does not exist in a vacuum but is instead complex and multi-faceted.[45]

Resnik (2011) summarises the literature on trust, identifying five key insights:

1. Trust is the relationship between or among people. Trust can be explicit or implicit, concrete or abstract, but fundamentally trust applies to the relationships between individuals; individuals and a group; or between groups of people.

2. The main purpose of trust in society is to facilitate cooperative interactions where a certain behaviour is expected.

3. Trust involves risk-taking. Deciding to put ones' trust in someone does not involve certainty that the counterpart will act as expected or, indeed, not cause deliberate or negligent harm. This means that trust can be easily damaged.

4. People chose to put their trust in others because they deem them trustworthy, based on a subjective judgement of competence, experience, sound judgement, reliability, goodwill, or professional or social standing.[46]

5. Finally, trust implies the ethical and/or legal duty of the entrusted person to uphold expectations.

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[43] Ken Newton and Pippa Norris, "Confidence in Public Institutions," in *Disaffected Democracies. What's Troubling the Trilateral Countries*, Political Science (Princeton University Press, 2000); Susan J. Pharr and Robert D. Putnam, *Disaffected Democracies: What's Troubling the Trilateral Countries?* (Princeton University Press, 2000); M. Rainer Lepsius, "Trust in Institutions," in *Max Weber and Institutional Theory* (Springer, Cham, 2017), 79–87.

[44] Michael Bratton and E. Gyimah-Boadi, "Do Trustworthy Institutions Matter for Development? Corruption, Trust and Government Performance in Africa," 2016; Davide Morselli, Dario Spini, and Thierry Devos, "Trust in Institutions and Human Values in the European Context: A Comparison between the World Value Survey and the European Social Survey," *Psicologia Sociale* 10, no. 3 (2015): 209–222; Jean M. Twenge, W. Keith Campbell, and Nathan T. Carter, "Declines in Trust in Others and Confidence in Institutions among American Adults and Late Adolescents, 1972–2012," *Psychological Science* 25, no. 10 (2014): 1914–1923.

[45] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"; David B. Resnik, "Scientific Research and the Public Trust," *Science and Engineering Ethics* 17, no. 3 (September 2011): 399–409; Lewandowsky and Oberauer, "Motivated Rejection of Science"; Gale M. Sinatra, Dorothe Kienhues, and Barbara K. Hofer, "Addressing Challenges to Public Understanding of Science: Epistemic Cognition, Motivated Reasoning, and Conceptual Change," *Educational Psychologist* 49, no. 2 (April 3, 2014): 123–138.

[46] According to Resnik (2011) trust is based on some evidence of trustworthiness, whereas faith involves belief without evidence.

These characteristics reveal how in the sphere of scientific research, the work that scientists do and the results presented by the scientific community, the public is very much in a position of 'having to trust' given that the information is so vast and complex.[47] In the context of PE with science, individuals are constrained by a "bounded understanding of science" – i.e. the individual must sort through available information to: (1) decide the relevance of the input, (2) interpret the tentativeness with which findings are presented, (3) evaluate whether arguments are based on scientifically accurate claims and evidence or are based on non-scientific dimensions of problems, and (4) ultimately determine who and what to believe.[48] The amount of scientific information available to the general public and the number and complexity of the scientific knowledge necessary for every-day decisions have never been greater.[49] This forces the members of the non-scientific community in the general public to rely on a variety of resources available to them in order to contend with new and often seemingly conflicting scientific information.[50]

There are several ways in which the public is asked to put its trust in science. Scientific researchers are often responsible for public resources, either through the use of facilities, funding or information that belongs to the government and therefore to the public.[51] The scientific community is also tasked with producing information that could impact public policy on a host of issues which may be a crucial factor in legislative and legal proceedings.[52] Finally, science fuels the fields of research that improve life and wellbeing, such as medicine, agriculture, technology and industry. When it comes to new technologies and innovations, gaining public acceptance is essential because individuals rely on scientists to accurately and transparently portray the risks and benefits associated with using them.[53] Over time, the Public Attitudes to Science survey in the UK has shown a steady increase in the percentage of respondents who feel that they have no choice but to trust those who govern science.[54]

The public's trust in science is further mediated by the source that shares the information. Huskinson et al. (2016) found that expertise was the main reason cited for trusting doctors, nurses and other medical practitioners, scientists working in universities and medical research charities to provide accurate and reliable information about medical research. Meanwhile, the same study found that the main reason cited for not trusting journalists was that they might exaggerate information relating to medical research. Similarly, a commonly cited reason to distrust scientists working in the private sector or pharmaceutical companies was that they would try to present themselves in the most positive light.[55]

[47] Resnik, "Scientific Research and the Public Trust."
[48] Bromme and Goldman, "The Public's Bounded Understanding of Science."
[49] Sinatra, Kienhues, and Hofer, "Addressing Challenges to Public Understanding of Science"; Bromme and Goldman, "The Public's Bounded Understanding of Science."
[50] Sinatra, Kienhues, and Hofer, "Addressing Challenges to Public Understanding of Science"; Lewandowsky and Oberauer, "Motivated Rejection of Science."
[51] Resnik, "Scientific Research and the Public Trust."
[52] Entradas, "Science and the Public"; Resnik, "Scientific Research and the Public Trust."
[53] Resnik, "Scientific Research and the Public Trust"; Sinatra, Kienhues, and Hofer, "Addressing Challenges to Public Understanding of Science."
[54] Castell et al., "Public Attitudes to Science 2014."
[55] Huskinson et al., "Wellcome Trust Monitor Report. Wave 3. Tracking Public Views on Science and Biomedical Research."

Existing Surveys on Attitudes to Science

What follows is a non-exhaustive list of some of the existing surveys on public attitudes to science, some of which have already been mentioned in the preceding paragraphs.[56] These surveys have generally included either a narrow range of questions or a limited number of countries. Overall, the reviewed surveys reveal the lack of a cross-national survey on a comprehensive list of relevant topics which also includes a diverse group of countries on a global scale.

- National surveys in the United States as follows:
  - The General Social Survey of the National Opinion Research Center at the University of Chicago has been collecting data on confidence in the scientific community since 1972 and has progressively added related items over time.
  - The National Science Foundation (NSF) Science and Engineering Indicators (formerly known as Science indicators) began in 1978. It covers five key indicators: interest in new scientific discoveries, basic scientific knowledge, the belief that science creates opportunity, confidence in the scientific community, and support for science funding. The 2016 report "indicates that Americans' overall attitudes about science are either stable or becoming more positive and that knowledge may be slowly increasing. […] Looking at these indicators together provides a sense of how Americans' overall attitudes and knowledge about S&T have changed over more than 30 years."[57]

- The Eurobarometer Special Survey on Science and Technology, produced by the European Commission, began in 1979 with eight countries and now covers 32 countries. The most recent 2014 report concludes by saying: "The main findings of this Special Eurobarometer survey suggest that a large proportion of Europeans believe that science and technological innovation will have a positive impact in addressing most of the issues facing society in the next 15 years."[58]

- National surveys in the UK as follows:
  - The Economic and Social Research Council (ESRC) in 1988 first surveyed on the topic of the public understanding of science in the UK, using the concepts previously used in the U.S. by the NSF.
  - The British Social Attitudes Survey by the NatCen Social Research focuses on a variety of social topics, included a wave with some indicators of trust in science (1966).
  - The Wellcome Trust has collected three waves of data on public views of science (2009, 2012, 2015). The Wellcome Trust Monitor is designed to measure the public's awareness, interests, knowledge and attitudes in relation to science, and in particular, biomedical science. [59]
  - The Office of Science and Technology, a non-ministerial government department of the British government between 1992 and 2007, conducted surveys of both

[56] Massimiano Bucchi and Brian Trench, *Handbook of Public Communication of Science and Technology* (Routledge, 2008).
[57] NSF, "S&E Indicators 2016."
[58] European Commission, *Public Perceptions of Science, Research and Innovation*.
[59] Huskinson et al., "Wellcome Trust Monitor Report. Wave 3. Tracking Public Views on Science and Biomedical Research."

stakeholders and the general public in 1996, 2000 and 2004 to develop a new UK vision and strategy for science and society.
  - The government's Public Attitude to Science Survey has been conducted in 2000, 2005, 2008, 2011 and 2014 on a variety of topics related to attitudes to science in the UK, including comparisons to the 1988 ESRC Survey and the 1996 British Social Attitudes Survey. The 2014 survey found that "People today are generally more interested in science, more likely to think the benefits of science outweigh any harms, less likely to see a conflict between science and faith and more comfortable with the pace of change than they were in 1988."[60]

- Across Latin American countries, Mexico, Paraguay, Chile, Argentina, Brazil, Panamá and El Salvador, the Latin American Network for Science Indicators have measured scientific knowledge and consumption of scientific information yearly since 2003.

Additional national surveys that have collected indicators of public understanding of science and scientific literacy include the following:

- In Brazil, studies conducted by the Ministry of Science and Technology of Brazil (2006) and the Brazilian National Research Foundation (1987, 2003)
- In Canada, studies conducted by the Ministry of Science and Technology of Canada (1989)
- In China, studies conducted by the Ministry of Science and Technology of China (1992) and China Academy of Sciences and Technology (1995, 1997, 2001, 2003)
- In France, studies conducted by the Centre for the Study of Political Life, SciencePo (1972, 1982, 1988)
- In India, studies conducted by the National Centre for Applied Economic Research, Delhi, (2004)
- In Japan, studies conducted by the National Institute of Science and Technology Policy (1991, 2001)
- In Malaysia, studies conducted by the Strategic Thrust Implementation Committee, (2000)
- In New Zealand, studies conducted by the Ministry of Science and Technology of New Zealand (1997)
- In South Africa, through the South African Social Attitudes Survey (2010).[61]

Conclusion

The literature review has explored the major research approaches in the field of public attitudes towards science. This research and the associated studies and surveys formed an important foundation upon which to build in the development of the questionnaire for this global study. While existing studies have explored the relationship among different dimensions related to attitudes, awareness and trust in science in the countries listed in the previous paragraph, the analysis of this topic is severely limited by the lack of comparable studies across countries. Indeed, cross-country studies have either included a limited number of countries, in terms of geographic and socioeconomic variability, or a limited amount of cross-culturally relevant measures, such as literacy and knowledge of concepts.

[60] Castell et al., "Public Attitudes to Science 2014."
[61] Vijay Reddy et al., "Public Attitudes to Science in South Africa," *South African Journal of Science* 109, no. 1–2 (2013): 1–8.

Taking into account the existing research and what this has contributed to the understanding of PE with science, the Wellcome Global Monitor will fill a gap in this field by supplying a survey that can be fielded globally. While studies on attitudes to science in developed countries, for example in Western Europe and the U.S., have shown parallels, research that has included the limited available data from low- and middle-income countries shows very different patterns.[62] In fact, a 2013 study in South Africa raised interesting questions about generational and period effects in science attitudes in South Africa, and whether the post-apartheid generation, with increased educational levels, is characteristically different.[63] Considering the range of variations in attitudes to science that could be uncovered by a global survey, the research possibilities and policy implications that a global study on this topic will offer will be truly unprecedented.

I.B Stakeholder Interviews

Two groups of stakeholders were interviewed in developing the questionnaire: internal stakeholders from across Wellcome and external stakeholders – both as suggested by Wellcome and through independent research into the topics under study, and recommendations. Wellcome's stakeholders helped clarify the research objectives of the survey and of the project more broadly, by expanding on the purpose and vision for the project, as well as how the data are envisioned to be useful and utilised. External stakeholders shared their expertise and knowledge of the subject or related topics, and highlighted helpful relevant research to examine and avenues to explore. Stakeholder interviews can provide very insightful ideas and analyses to take into account in the survey design and development process. They can help clarify some of the main topics to explore, and highlight some of the challenges that might arise.

External Stakeholder Interviews

The broad aim of the interviews was to gain a more in-depth understanding of what questions and issues would be important to take into consideration when designing the questionnaire, exploring the constituent parts of trust in science as understood by each expert, and asking the experts about the type of questions they would consider useful to incorporate, both from research and practitioner perspectives.

Gallup researchers interviewed ten experts: Professor Martin Bauer (London School of Economics); Dr Bankole Falade (Stellenbosch University – London School of Economics); Professor John Helliwell (Vancouver School of Economics - University of British Columbia); Dr Somnath Chatterji (World Health Organization); Arnaud Bernaert (World Economic Forum); Marco Mira d'Ercole (Organisation for Economic Co-operation and Development); Dr Elizabeth Tayler (World Health Organization); Kerry Albright (UNICEF Office of Research - Innocenti); Emily Hayter (INASP); and Professor Sir Angus Deaton (Princeton University).

All of the external stakeholders were enthusiastic about the scope of the study in exploring the attitudes and perceptions of people on the subject of science – especially given that it was an initiative that has not been attempted before on a global scale. Stakeholders highlighted that there is already substantial research on the topic in developed countries and that it would be advantageous and constructive to understand various aspects of trust in science around the world, noting differences across regions and countries. The gathering of baseline data on this

[62] Bauer, Allum, and Miller, "What Can We Learn from 25 Years of PUS Survey Research?"; Reddy et al., "Public Attitudes to Science in South Africa"; European Commission, *Public Perceptions of Science, Research and Innovation*.
[63] Reddy et al., "Public Attitudes to Science in South Africa."

topic on such a large scale was of particular interest to the stakeholders interviewed, especially given the broader global socio-political developments, and issues of trust in experts more broadly.

The following is a summary of the main findings from those external stakeholder interviews:

1. Given the unique opportunity to investigate this research topic across different cultures and geographic regions, a suggestion was made that the study starts off by asking an open-ended question along the lines of "What comes to mind when you think of science?" This recommendation was implemented for the cognitive testing phase of the project (see section "Section II: Survey Instrument Development – Cognitive Interview Testing"), but given the difficulties of coding and translating such an open-ended question for over 140 countries, it is not a question that will be asked in the final questionnaire.

2. External stakeholders highlighted the potential link between attitudes to science and exposure to scientific sources and information, with a focus on the lack of simplified effective communication narratives by the scientific community. It was, therefore, suggested that the scientific community needs to improve and simplify its communication and engagement with the general public, to explain better the benefits and risks of scientific discoveries.

3. Many of the stakeholders interviewed suggested formulating questions that explored the subject of public perceptions of science as a tool that improves health and wellbeing, rather than one that could cause harm. They highlighted how often the public's perception of scientific innovation is presented in connection with potentially negative consequences which make science and scientists appear unconcerned with the greater good.

4. Stakeholders recommended paying attention to local contexts and social norms that influence people's interaction with and trust in science. Experts listed examples of religious beliefs in a range of countries where science appears to undermine the beliefs and the way of life of the community.

5. Some stakeholders highlighted the 'disconnect' between the scientific community and the general public when it comes to the public understanding of nuances and the complexities of the scientific process. The public often hears conflicting scientific narratives and 'evidence', such as those on climate change or genetically modified foods, which could create greater misunderstandings and therefore reduce trust. This is often complicated by 'corporate counter-narratives' on the topics being discussed, all of which increases confusion and may affect trust levels in science and scientists.

6. Also of interest was the exploration of sources and channels through which people access scientific, health and medicine-related information, and the degree to which people obtain such information via new and traditional media, social circles such as family and friends, as well as specialists such as doctors and nurses.

7. Another aspect that was of interest to investigate relates to who people trust most to give them scientific or medical advice (e.g., close family, doctor, nurse, religious leader, traditional healer), and whether that preference would change if medical advice was easily accessible and affordable in their local area and context (e.g. would people prefer

obtaining medical advice from a doctor or from a traditional healer, if both were equally affordable and easily 'reachable').

8 Asking about the educational level at which people learned about science was a matter of interest to stakeholders. As has also been explored in the literature review, the matter of education levels and overall knowledge of scientific concepts and methods is believed to mediate the relationship the public has with scientific information.

9 Asking whether people believe that science benefits or causes harm to society overall, as well as whether people feel that science and scientific discoveries benefit them personally was another area of interest to external stakeholders.

10 Stakeholders were also keen to explore the public's perceptions of the intersection between science and religion, and whether science is perceived as a threat to personal or religious beliefs.

11 It was recommended that trust in science should be viewed in relation to trust in other institutions in society, such as the government, religious authorities, judicial system, etc. This should provide a more holistic picture of the trust in society ecosystem given the recent "crisis of trust in experts". The role of regulations governing scientific activities was also mentioned as a potential source of trust or the lack of it, and stakeholders expressed interest in learning more about the reasons that cause people to mistrust science, including levels of transparency surrounding funding of scientific research.

12 Concerning dissemination and engagement efforts, it was suggested that relevant medical and research bodies from low- and middle-income countries are not being actively involved or engaged in the wider global scientific discussions. Greater engagement with such groups could enhance the public discourse on the topics under consideration.

13 Finally, when asked about various sub-topics within the subject of health and medicine which could be of interest, stakeholders highlighted issues such as drug-resistant infections, or anti-microbial resistance (AMR), vaccines, and climate change.

Overall, the stakeholder interviews provided critical insight that fed into the questionnaire development and testing process, and many of those topics were included in the final questionnaire.

Section II: Survey Instrument Development – Cognitive Interview Testing

II.A Key Objectives of Cognitive Interview Testing

Cognitive interviewing is used to evaluate questionnaire items to ensure they are clear, easy to understand and interpret and focused on eliciting the desired information from respondents. In a cognitive interview participants are asked to:

1. Discuss their interpretation of survey instructions, questions, and response choices
2. Discuss the process in which they would go about answering the questions
3. Provide any recommendations to clarify question-wording for unclear or difficult-to-answer items.

Researchers frequently use cognitive testing to assess respondents' comprehension, item relevance to the sampled population, the extent to which it is feasible for respondents to answer a survey question and the steps required to select a response. The testing process ensures individual survey items and the final questionnaire elicit the desired information while minimising respondent burden. The process is designed so that it reveals information usually unseen in the survey administration process.

Cognitive interviews are useful for refining questions by identifying issues such as comprehension, ordering effects and respondent burden. Interviewers ask probing questions for every questionnaire item, to assess the following.

- Are respondents stumbling over certain words or phrases?
- Are respondents interpreting the items differently? Are there any differences between subgroups in how they interpret items? This is a very important point for a global study, as different interpretation by different respondents renders cross-respondent and cross-country comparisons unreliable.
- Do respondents have any difficulty answering certain questions? If so, why?
- Is the ordering of items or sections creating interactive effects that impact how respondents are interpreting and answering questions?
- Are instructions clear and easy to understand?
- Are there any issues with survey length?

II.B Wellcome Global Monitor Cognitive Interview Findings

The first draft of the 10-minute questionnaire was developed using insights and findings from the literature review and stakeholder interview processes, as well as other surveys previously conducted on the topic. In addition, Gallup reviewed its extensive database of survey questions asked on previous surveys for items that may be useful for this survey. The first draft was then reviewed by the Wellcome team and modified in an iterative feedback process.

The survey was cognitively tested in a number of low- or middle-income countries in Asia, Africa and Latin America. Those countries were chosen because several studies were conducted on

this topic in many high-income countries, and given the shortage of research on this topic in most lower-income countries, it was important to test the reliability of questions in those settings. Seven countries were selected for testing: Colombia, India, Kenya, Nigeria, South Africa, Thailand and Vietnam.

1. Colombia (Spanish)
2. India (Bengali and Hindi)
3. Kenya (Swahili)
4. Nigeria (English and Hausa)
5. South Africa (English and Zulu)
6. Thailand (Thai)
7. Vietnam (Vietnamese)

Twelve cognitive interviews were completed in each country[64], with respondents selected across different demographics such as age, income groups, education levels, and gender.

Main Topics Covered by the Cognitive Questionnaire

The content of the questionnaire was developed in order to measure various aspects relating to the central research questions of attitudes to, trust in and engagement with science. A critical integral part was to ensure that the questions also have analytical value and insights on the topic. The questions included in the study could be grouped into the following main categories:

Scientific Knowledge: In the first draft of the questionnaire, the survey included questions that asked about a person's factual understanding of different types of sciences, such as physics, chemistry, biology, etc. It also included questions that asked respondents to assess their own grasp of science, and at what stage in their education they learned about any type of science.

Interest in and Engagement with Science: Some of the literature suggests that a person's general interest in science could, in some instances, help explain their attitude to and trust in science and scientists. The survey contains several questions to assess interest.

Direct Measures of Trust in Science and Scientists: Several questions in the survey ask if respondents have confidence or trust in science and science-related individuals or institutions, including scientists, hospitals and health clinics, doctors and nurses.

Science and Society: Several survey items ask respondents to assess how they think science will affect important aspects of their lives and more broadly, of society, such as job availability and the lives of the next generation.

'Cultural Authority' of Science: As mentioned in the literature review, some people may not have much trust in science because there are other cultural forces and social norms in a society which have greater authority and influence on their lives. Most notably, this would be the influence of religion and traditional leaders/healers. The survey asked a few questions that explored this topic.

General Levels of Trust in Other Institutions in Society: Some of the literature has shown that levels of trust in different parts of society more broadly, such as institutions or key groups, can be important in understanding whether a person trusts science and scientists specifically. This survey asks several questions about trust levels in different institutions or professions in society.

[64] With the exception of South Africa, where 15 cognitive interviews were conducted.

Vaccination Questions: The survey contains a number of questions about issues related to vaccinations. It will be of great interest to study how trust in science, in general, relates to attitudes about this critical application of science.

Demographics: A number of key demographic items will be collected as part of the survey, such as gender, household income, education levels and employment.

General Observations

The findings from the cognitive interviews presented in this section show that several questions were understood across all countries and demographics. However, one important high-level insight was that while many respondents were able to provide answers to the questions after probing, it was clear that many from lower-educational backgrounds did not really understand some of the concepts they were being asked about, or they did not have opinions on issues they did not understand.

In addition, sometimes respondents from less privileged backgrounds felt that they were being 'quizzed' or 'tested' during the survey. As a result, they showed signs of discomfort during the interview and many tried to give the 'correct' answer rather than the answer that best represented their own views.

The first recommendation that was made for the survey based on the findings from cognitive testing was to include a simple definition of the words "science" and "scientists" at the beginning of the survey and to allow interviewers to repeat this definition as needed throughout the duration of the survey.

Accordingly, the following definition was included in the next phase of testing:
On this survey, when I say "science", I mean the understanding we have about the world from experiments, observations, and testing ideas. When I say "scientists", I mean those that use science to study nature, people, medicine, and outer space, among other things.

In addition, whenever possible, *it was recommended to include examples of scientific concepts throughout the survey.*

In the survey introduction, *it was also recommended that interviewers inform respondents where necessary that this survey is "not a test or a quiz".* This would set respondents' mind at ease by informing them that there are no right or wrong answers in the survey.

Furthermore, *it was recommended that in some instances, interviewers should be allowed to read out and offer the "don't know" response option during the survey because, in some questions, respondents may genuinely not be able to provide an answer to particular questions.*

Open-Ended Questions in the Cognitive Testing Stage

During the cognitive interview stage, two questions were included asking respondents:

What does the word "science" mean to you?

and:

What does the term "scientific research" mean to you?

These open-ended questions were asked to determine what respondents understood "science" to be in a testing environment, and were not planned for inclusion in the final survey given the huge challenges that would be faced in translating and coding answers from over 140,000 respondents globally. However, the findings from those questions fed into the questionnaire design.

Some respondents found it difficult to define science and scientific research, due to what seemed like a limited vocabulary and difficulty in finding other words to express these concepts. Many respondents felt the question was too general as science can be many things, while others related it to specific topics they learned at school, such as physics and chemistry.

The words 'scientific research' and what that entails were not fully understood by many lower (or no) education respondents. In addition, many lower-education respondents said that science is not a subject they thought about or gave any consideration to, as it was 'not for them'. In India, for example, "science" and "scientific research" is considered a luxury only studied and known to the wealthier sections of society. As a result, those from less privileged backgrounds struggled to answer several questions in the survey. It was also found that in some languages and contexts, the word 'scientist' was understood to mean religious scholar (for example in some of the Muslim countries). Hence it was concluded that the words 'science' and 'scientists' needed to be clearly defined.

Some examples of how people defined science were:

> "*For example, when the villagers believe that a person is possessed by a spirit or a ghost, science doesn't believe so. Science says that it's mass hysteria." (*Thailand)
>
> "*Love, order, responsibility, respect."* (Colombia)
>
> "*Running a business.*" (Vietnam)
>
> *"It is a systematic operations. The study of living and non-living things. It means an investigation of solving problems. Going to laboratory to investigate the blood test for solving their blood problem.*" (Nigeria)
>
> *"I am seeing it as a research, or something to do, and bring out the truth."* (Nigeria)
>
> *"Truly, I do not understand." (*Nigeria)

Recommendation: insert a definition of 'science' and 'scientist' where needed, and give examples to help explain concepts where relevant.

Knowledge, Interest in and Engagement with Science Questions

The questionnaire includes a few items exploring people's knowledge of science, and whether they had studied science at various levels of education, or not.

The cognitive interviews found that, for some respondents, science is a large concept and respondents are not exactly sure what they should think about when they hear the word. Moreover, questions relating to self-evaluations may not be accurate reflections of knowledge

levels. Some people may over- or under-state their knowledge level when asked about how much they know about a subject.

The first draft of the questionnaire included questions asking respondents about their level of agreement with various statements about the study of science and what that involved (e.g., understanding the world we live in, making conclusions only based on solid evidence, etc.). However, those questions were removed from the final version of the questionnaire due to the comprehension difficulties which lower-education respondents seemed to experience.

Respondents were also asked whether they tried to get any information on topics related to science, and if so, which information sources they used to obtain such information. A list of options was read out, such as radio, television, the Web/Internet, social media, etc. These questions were also removed from the final questionnaire because 'science-related' information was interpreted differently across respondents. For example, in Vietnam, one respondent said it could be customer satisfaction or consumer information. Another thought it was information related to problems in her life. In India and Thailand, the term "social media" was not understood without examples. There was also some evidence of a "social desirability" effect with some respondents stating that they used all information sources to sound knowledgeable, but further probing revealed that it was because they had heard of those sources of information, not that they had ever used them.

Upon probing, some respondents who had used particular sources of information – such as the Web and social media – for non-science related purposes, also answered "yes" when asked if they used those sources to seek health or other scientific information. They had interpreted the question as asking them if they used those sources for information about anything at all.

Finally, on this topic, the questionnaire originally included a question on knowledge of specific fields of science:

"*Overall, people have different opinions about what science is. In your own opinion, are the following subjects a type of science or not a type of science*?"

The response options included subjects such as physics, chemistry, biology, literature, history and geography, each with a very brief explanation of what that subject entailed. The purpose of this question was to explore people's understanding of science across different demographics. However, most respondents seemed to think this question series was a 'quiz' or a test, which made lower-education respondents very uncomfortable. Further probing by the interviewers also showed that the social desirability effect was sometimes a factor explaining why some people answered this question in the affirmative. This question clearly caused serious comprehension and interpretation difficulties to lower-education respondents and was therefore deleted from the final questionnaire.

Science and Society Questions

The cognitive interviews tested a few questions on the benefits of science to society.

Some of those questions addressed the potentially unequal impact of science on various sections of society, and whether some people feel that science does not benefit them directly. For example, the following question was asked:

- *Do you agree or disagree with the following statement: The people who do scientific*

research care how it affects:

- *Poor people in this country*
- *Rich people in this country*
- *All people in this country*
- *People like me*

Many lower-education respondents said they did not know what "scientific research" meant. Respondents in some countries seemed to interpret the term very broadly. Some respondents were uncomfortable with the distinction made between "rich" and "poor" people, while others said they did not know enough about the subject, and did not know any "people who do scientific research", so they could not speculate on what scientific researchers care about.

The survey also originally included a question asking:

"*Please indicate your level of agreement with the following statement: I feel that science is moving too fast. Agree/Disagree*?"

This question presented the most difficulty for respondents in Thailand and South Africa, although respondents in all countries seemed to struggle to understand what it was asking. Some respondents who answered this question seemed to equate "science" in this instance with "technology". Most respondents seemed to be "agreeing" that science is moving fast – not that it is moving *too* fast.

Recommendation: Following several reviews, some of the questions in this section were re-phrased, while other questions (such as the two above) were deleted from the survey.

Direct Questions on Trust

The survey initially asked many questions on trusting various individuals and groups in society, such as scientists, the police, doctors, nurses, school teachers and traditional healers. Some of those questions remained in the final questionnaire, while others were re-phrased or deleted.

Some of the questions asked about 'trust in' people or groups, while others asked whether a person 'had confidence in' people/groups. In many countries/languages, respondents did not make a distinction between 'trust' and 'confidence', as the words meant the same in some languages. Therefore, with one exception, the words 'trust in' were used in the questions.

One of the questions asked about trust in various professions/groups of people. One profession, in particular, was not well understood in all countries: 'traditional healers'. While this worked in many countries in Asia and Africa, it was not well understood in much of North and South America or Europe. Therefore, it was decided to leave this option out in some countries or to use a different but similar framing where relevant.

Many lower-education respondents in low- or middle-income countries did not understand the difference between scientists working in different institutions. For example, a series of questions asking about levels of trust in scientists working at different organisations such as large corporations, universities or government agencies, was not understood by lower-education respondents as they did not understand the difference between, for example, a scientist working for the government and one working at a university. Hence it was decided to use those questions only in higher income countries where the concepts were better understood.

Another finding relating to lower-education and the less privileged respondents was that those respondents often felt far removed from the world of science and scientists, hence they sometimes volunteered a 'don't know' option. This option was accepted where it was clearly the case that this was a genuine 'don't know' response, and was added as a 'read out' response option in a few instances where it was relevant.

After reviewing the full feedback from the interviews, and taking into consideration the length and complexity of the tested questions relating to trust in science, scientists, and scientific institutions, the questions were cut back to those that worked well and reliably across all countries. Two exceptions – the questions relating to traditional healers and the difference in trust levels between scientists working in different sectors – were kept, but would not be included for countries in which they are not relevant (for example, the term 'traditional healer' did not work well in Europe, the Middle East or the U.S.). The items that were kept in the questionnaire provided a strong sense of people's attitudes to and trust in science and scientists, and should provide reliable responses given the fact that they were well understood across respondents with a range of educational levels.

Special Topic: Vaccination

A number of special topics were considered for inclusion in the Wellcome Global Monitor, including a set of questions on knowledge of and exposure to vaccines. These questions were based on the literature and existing questions on the topic, especially the set of questions fielded by H. Larson et al. in *The Vaccine Confidence Project* - "The State of Vaccine Confidence 2016".[65]

In addition to the above, the survey tested the understanding of various statements about vaccinations and their purpose:

For example, the first draft of the questionnaire included this question:

"*Now, keeping in mind that a vaccination is a medical treatment that helps to prevent someone from getting a certain disease. How important do you, personally, think research into each of the following areas is?*

Very important, somewhat important, not important?"

- *Vaccinations that prevent infectious diseases, such as HIV or measles, that affect many people worldwide*
- *Vaccinations that prevent diseases that can spread very quickly through communities, such as Ebola [tailored locally as necessary]*
- *Vaccinations that could prevent Malaria*
- *Vaccinations that could prevent Polio*

Respondents in all countries experienced problems understanding some of the terms in this question. Many respondents could not distinguish between the first four options. While they may have heard of some diseases, they did not necessarily understand the difference between them.

[65] Heidi J. Larson et al., "The State of Vaccine Confidence 2016: Global Insights Through a 67-Country Survey," *EBioMedicine* 12 (September 13, 2016): 295–301.

The words 'research' and the various disease names often did not resonate and were not well understood. The question was therefore deleted from the final version of the questionnaire.

The survey also tested the following questions, based on a series of questions from *The Vaccine Confidence Project*:[66]

"*Based on your own experiences and knowledge of vaccines, would you agree or disagree with the following statements?"*

- *Vaccines are important for children to have*
- *Vaccines are safe*
- *Vaccines are effective*
- *Vaccines are consistent with my religious beliefs*
- *Vaccines are consistent with my core beliefs.*

These statements – particularly the last two – also caused problems for several respondents, especially those with lower educational levels. Some respondents mentioned that their religion does not say anything about vaccines and they were unsure how to answer. The final statement on the list was also confusing for some respondents, who said that vaccines have nothing to do with their core beliefs. The words 'core beliefs' were also not universally understood. The last two statements were therefore left out of the final questionnaire.

The final set of questions which was used in the questionnaire distinguished between (a) exposure to and knowledge of the purpose of vaccinations and (b) the importance of vaccinating children (while controlling for whether the respondents have children of their own).

Special Topic: Drug-Resistant Infections, or Anti-Microbial Resistance

During the cognitive testing process, a set of questions on drug-resistant infections (or anti-microbial resistance) were included.

The first question asked:

"*Antibiotics are a type of medicine. To the best of your knowledge, have you ever taken an antibiotic such as penicillin [or locally used equivalent]?"*

Response options: Yes/No

Testing found that the word "antibiotic" caused confusion for many respondents, and "Penicillin" (or locally used equivalent) was not widely known among lower education or under-privileged respondents.

Subsequent questions asked respondents to agree or disagree with two statements:

- *If too many people take too many antibiotics, antibiotics may stop working to cure some infections.*
- *If antibiotics stop working to cure some infections, human beings will face a very serious threat to their health.*

[66] Larson et al.

These questions were very difficult for many respondents to understand. Respondents interpreted the items differently, depending on their education level. Again, the word “antibiotic” caused confusion for many respondents. Ultimately, it was decided not to include these questions in this iteration of the survey.

Science and Religion

Finally, the survey contained a set of questions asking about the intersection of science and religion. A question was asked about whether there are times when personal religious beliefs conflicted with science, and a follow-up question on whether, in such eventualities, the person followed their personal religious beliefs or science.

Some respondents found it difficult to disentangle their *personal* religious beliefs (what the question is asking about) from the *beliefs of their religion*. Others were uncomfortable speaking openly against the collective belief of their religion. The word “conflict with” was an issue for a few respondents. Most understood it to mean “contradict.” Some respondents said there may be a conflict, but they do not think about it much and it does not affect their life. In addition, not all respondents had religious beliefs.

There were also two questions about religious beliefs in relation to trust in science. The respondents were asked:

- *If a scientific discovery disproves a view widely held in society [the community], I think it is probably wrong*.

  Agree/Disagree?

- *I have religious [or core] beliefs that no scientific discovery can disprove.*

  Agree/Disagree?

Respondents in all countries found these questions confusing. “Core beliefs”, “disprove” and “scientific discovery” were not consistently interpreted or well understood across countries or different demographic groups within a country. In some cases, respondents answered the questions, but upon further probing, it seemed they did not really understand them. Both statements were deleted from the final questionnaire.

After careful review of all the feedback from the cognitive testing of those questions, and taking into consideration that the questionnaire needed to be ten minutes in English, many items which were tested in the first draft of the questionnaire were deleted. What remained in the final questionnaire was a set of some 36 robust questions which were carefully developed and designed so as to be globally applicable, in order to produce reliable results for global comparability.

II. C Summary of the Wellcome Global Monitor Pilot Testing

Pilot testing entails a small-scale version of the large-scale study, in preparation for the main field survey. Some of the main aims of pilot testing a survey instrument are to examine if the planned process of administering and collecting responses is feasible, workable, timely, efficient, and – combined with the results of the cognitive interviews – whether the survey more broadly is "fit for purpose". Importantly, it can highlight areas where logistical and practical challenges might arise, and it should inform the interviewers of the "receptivity" of the respondents to the survey and to being approached to participate in it. Therefore, feedback from pilot testing centres more on the operational and logistical aspects of survey implementation, rather than on any cognitive aspects.

The questionnaire was pilot-tested in ten countries by conducting pilot interviews with 50 respondents per country. Those countries are China, Colombia, Egypt, France, India, Kenya, Nigeria, South Africa, Thailand and Vietnam.

1. China (Standard Mandarin Chinese)
2. Colombia (Spanish)
3. Egypt (Arabic)
4. France (French)
5. India (Bengali and Hindi)
6. Kenya (Swahili)
7. Nigeria (English and Hausa)
8. South Africa (English and Zulu)
9. Thailand (Thai)
10. Vietnam (Vietnamese)

Respondents represented a balanced mix of key demographic characteristics including geographic location (urban/rural), gender, age, education and income. The respondents were selected based on pre-established quotas. In order to test the survey on a wide range of respondents, quotas were set based on urban and rural residence, gender, income, education level, language (if surveying in multiple languages per country) and age. Local partners identified respondents through targeted recruiting and suspended recruiting once all the desired quotas had been met. The majority of interviews were conducted at the respondents' residences for the face-to-face mode of implementation. In this case, the surveys were conducted using a Paper And Pencil Interviewing mode (PAPI). In France, respondents were interviewed over the phone, as the mode of implementation in the Gallup World Poll there is Computer Assisted Telephone Interviewing (CATI).

Overall Findings

1. Overall, the questions were generally well understood across all pilot countries and demographics, meaning that based on interviewer observations, respondents did not hesitate or struggle to answer nor did they ask for the question to be repeated often.

2. It is important that the definitions of the words 'science', 'scientist' and 'vaccinations' are provided to give respondents the best opportunity to understand related questions. In addition, it is important to provide examples of certain concepts, such as vaccinations which are well known in each country (for instance, using the examples of Polio, MMR, or Flu vaccines in countries where those are commonly given to people as a protection against those diseases).

3 The instructions preceding each question were clear and were generally understood by respondents.

4 There were no difficulties relating to the skip patterns – that is to say, where a question does not apply to all respondents, the following one would be skipped. For example, if question one (Q1) asks if the respondent has any children, Q2 asks if those children are under the age of 16, and Q3 asks if the respondent owns the house she/he resides in, then Q2 will be skipped if a respondent answers that she/he does not have any children in Q1. In this case, the interviewer will ask Q1 and then Q3, leaving out Q2.

5 While many respondents were able to provide answers to the questions, in some cases, respondents from lower educational backgrounds tended to think that science does not relate to their lives.

6 Average survey length was above the 10-minute marker across all pilot countries, and respondents with lower-education took longer to complete the interviews than those with higher education levels. Similarly, interview length was higher for rural residents than urban residents.

7 In some countries where the political system does not allow for complete political freedoms, some respondents appeared nervous when responding to some questions that asked about aspects related to government. Those issues arise in all surveys in those countries, and while repeated assurances were made to respondents of full confidentiality of their personal information, this aspect cannot be totally mitigated in those countries.

A few questions were refined in the light of the feedback from the pilot testing process. One comment that came through from several countries relating to a few questions is the suggestion that examples should be given in some instances so that respondents could better understand the meaning of some words, such as ‘science’ and ‘scientist’. In addition, in some countries in Asia, the specific meaning of the term ‘religious leader’ needed explaining with reference to local contexts, given the nature of the local dominant religions in countries such as Vietnam and Thailand.

However, overall, it was found that the revised questionnaire worked well across all ten countries at the pilot testing stage.

Section III: Some of the Underlying Criteria Behind the Development of the Final Questionnaire

The cognitive interview and pilot testing processes provided the survey design team with a critical empirical understanding of the first draft module's strengths and weaknesses, in terms of being an effective and reliable instrument on a question by question basis. In the final survey development stage, the survey instrument was refined using the findings from these testing processes. The final questions included also fulfilled at least the following criteria:

Ensuring High Research and Analytical Value: The overarching concern for the survey designers was whether the questionnaire addressed the research objectives, namely understanding people's attitudes to science and scientists, and the extent to which people engage with and trust science and scientists. It was also important to retain those questions for which there were strong theoretical or empirical reasons to believe that they would be of explanatory or analytical value when reviewing the data. For instance, the literature review suggested that providing measures of respondents' trust or confidence in other institutions was important in understanding their general attitudes with respect to science.

Easing Respondent Burden: The cognitive interview testing confirmed the need to shorten the questionnaire, both for practical reasons, but also to ensure that the respondents remain as engaged as possible throughout the module, so as to provide the most reliable responses possible. The module used in the cognitive interview/pilot-testing phase of the survey design process was intentionally longer than the expected length of the final module, as it included a number of experimental items, including several open-ended questions. Additionally, survey designers also examined those questions which took an especially long time to administer (even if only in one or two countries), and those that were difficult for at least some respondents to understand.

Clarifying Definitions and Concepts: Survey designers also eliminated or revised questions which cognitive interview or pilot testing participants found unclear or ambiguous. Some definitions of certain critical terms – such as 'science' or 'scientist' – were also added to the survey in order to ensure increased respondents' understanding of these terms. The definitions were added to help respondents who have a slightly uncertain understanding of the main terms, by providing them with a clarification of what exactly is meant by words such as 'science' or 'scientist'. Moreover, as it was found that in some countries the word for 'science' or 'scientist' has a double meaning, adding a definition of the exact meaning of those words was deemed even more necessary.

Developing a Cross-Cultural Survey: As this module is to be fielded in around 140 countries globally, it was imperative that cultural sensitivity was taken into account, especially considering any language that may cause the respondent to be confused, offended, anxious or uncooperative. Given the scope of countries included in the global study, it is to be expected that slight modifications would be made to certain questions, especially in countries with a track-record of censoring survey items. Gallup researchers were mindful to either remove, edit or at least flag those survey items that might be problematic in certain countries, such as questions which focused on religious or traditional beliefs, or trust in government and the police.

Question Sequencing: After the final set of questions to be included in the module was finalised, the survey design team considered the optimal way to structure the module's question sequence, taking great care to ensure the sequence was, to the extent possible, logical and any possible "order effects" are minimised ("order effects" occur when earlier questions within a survey unduly influence how people answer later questions in the sequence).

Section VI. Concluding Remarks and Next Steps

The process of questionnaire development for this global study on public attitudes to science has proved immensely helpful in understanding how the concepts of 'science', 'scientists' and associated terms (such as 'vaccines') are understood globally. Not only were there differences in comprehension and interpretation of the terms across countries, but differences were found to be perhaps equally pronounced *within* countries across people with different educational or economic backgrounds.

As this survey will be implemented in 2018 in more than 140 countries across people of all demographic groups, the biggest challenge was to use terms that would be well understood globally. This challenge required an extensive review of existing literature and studies on the topic, thorough testing, and close consultation with local partners in every country where the survey will be implemented. The resulting questionnaire proved to be well understood across various cultural and linguistic settings across the world, and local customisations should render it even more reliable as an instrument to gather much-needed global data on public attitudes to science.

The questionnaire and the results of the study should be published in 2019. We hope that they will be of benefit and use to all those interested in science and its critical role in advancing health, economic development and prosperity.

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