APPENDICES

Science Culture: Where Canada Stands

Expert Panel on the State
of Canada's Science Culture

Council of Canadian Academies
Conseil des académies canadiennes

Science Advice in the Public Interest

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Appendix A: Survey Questionnaire

1.1 INTRODUCTION (PHONE)

Hello, my name is ______ and I'm calling on behalf of EKOS Research Associates. May I speak with ______ ? We are conducting a survey and it will only take about 20 minutes. Please rest assured that your answers are completely confidential (this means that no individual will be associated with the survey's results — rather, they will be rolled up into large categories to protect the confidentiality of each respondent) and that this survey is voluntary.

As a token of our appreciation for completing this survey we will enter you into our monthly draw for $1000 and you will earn two charity dollars.

This call may be recorded for quality control or training purposes.

1.2 INTRODUCTION (ONLINE)

We are conducting a survey and it will only take about 20 minutes.

Please rest assured that your answers are completely confidential (this means that no individual will be associated with the survey's results — rather, they will be rolled up into large categories to protect the confidentiality of each respondent) and that this survey is voluntary.

As a token of our appreciation for completing this survey we will enter you into our monthly draw for $1000 and you will earn two charity dollars.

A few reminders before beginning…

On each screen, after selecting your answer, click on the "Continue" button at the bottom of the screen to move forward in the survey.

If you leave the survey before completing it, you can return to the survey URL later, and you will be returned to the page where you left off. Your answers up to that point in the survey will be saved.

If you have any questions about how to complete the survey, please call EKOS at 800-388-2873 or send an email to **online@ekos.com**.

Thank you in advance for your participation.

1.3 QUESTIONNAIRE

1. In what year were you born? __________

2. In everyday life, we have to deal with many different problems and issues, where we feel more or less interested and confident. I am going to read you a list of issue areas. For each of them, please tell me whether you are very interested, moderately interested, or not at all interested in that issue area.

	Very Interested	Moderately Interested	Not Interested
Environmental problems	❐	❐	❐
New medical discoveries	❐	❐	❐
New scientific discoveries and technological developments	❐	❐	❐
Sports news	❐	❐	❐
Culture and the arts	❐	❐	❐
Politics	❐	❐	❐

3. I would like you to tell me for each of the following issue areas in the news if you feel well informed, moderately well informed or poorly informed about it.

	Well Informed	Moderately Informed	Poorly Informed
Environmental problems	❐	❐	❐
New medical discoveries	❐	❐	❐
New scientific discoveries and technological developments	❐	❐	❐
Sports news	❐	❐	❐
Culture and the arts	❐	❐	❐
Politics	❐	❐	❐

4. During a typical week, on how many *days* of the week do you:

Read a daily newspaper (in print)	
Read about news or current events on the internet	
Watch the news on television	
Listen to the news on the radio	

5. Now, thinking about where you get information on issues in the news such as health and medicine, biotechnology, climate change or things like that, approximately how many times have you done the following activities in the last 3 months:

[PROMPT: Provide your best guess]

Read a newspaper article about a scientific issue	
Read an article in a science magazine (in print or online)	
Watched a science program on television	
Listened to a science program on the radio	
Read a blog post or listserv related to science or technology	
Read a book about science or technology	
Watched an online video related to science or technology	
Heard about a science or technology news story through social media such as Twitter	
Spoken to a friend, family member, or colleague about a science and technology issue in the news	

6. And in relation to using the internet to look for different kinds of information, approximately how many times have you done each of the following activities in the last 3 months:

Used the internet to look for information on health and medical issues	
Used the internet to look for information on local weather forecasts	
Used the internet to look for information on climate change	
Used the internet to look for information on influenza and other infectious diseases	
Used the internet to look for information on energy issues	

7. Now, we would like to read some statements and ask how much you agree or disagree with each of these statements. For these questions, please tell me how much you agree or disagree on a zero-to-ten scale. A zero means that you totally disagree with the statement and a 10 means that you totally agree with the statement. You may use any number between zero and 10.

	Disagree										Agree
	0	1	2	3	4	5	6	7	8	9	10
Science and technology are making our lives healthier, easier, and more comfortable.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Because of science and technology, there will be more opportunities for the next generation.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
We depend too much on science and not enough on faith.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
One of the bad effects of science is that it breaks down people's ideas of right and wrong.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
It is not important for me to know about science in my daily life.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Science makes our way of life change too fast.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒

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	Disagree 0	1	2	3	4	5	6	7	8	9	Agree 10
Even if it brings no immediate benefits, scientific research which adds to knowledge should be supported by government.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
Scientists do not put enough effort into informing the public about new developments in science and technology.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
The application of science and technology will make people's work more interesting.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒
We can no longer trust scientists to tell the truth about controversial scientific and technological issues because they depend more and more on money from industry.	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒

8. All things considered, would you say that the world is better off, or worse off, because of science and technology? Please tell us which comes closest to your view on a scale of 0 to 10: 0 means that "the world is a lot worse off," and 10 means that "the world is a lot better off."

Worse Off										Better Off
0	1	2	3	4	5	6	7	8	9	10
❒	❒	❒	❒	❒	❒	❒	❒	❒	❒	❒

9. To what extent would you recommend a career in science to your own child or young relative? Please use a 7-point scale where 1 means to no extent whatsoever, 7 means to a great extent, and the mid-point 4 means to some extent.

No Extent			Some Extent			Great Extent
1	2	3	4	5	6	7
❒	❒	❒	❒	❒	❒	❒

10. I would like to read out some statements that people have made about young people's interest in science. For each statement, please tell me how much you agree or disagree (totally agree, tend to agree, neither agree nor disagree, tend to disagree, totally disagree).

	Totally Agree	Tend to Agree	Neither Agree nor Disagree	Tend to Disagree	Totally Disagree
Most science studied in school isn't helpful later in life.	❐	❐	❐	❐	❐
By being interested in science, young people also improve their culture.	❐	❐	❐	❐	❐
It is natural for young people to be bored by science and math.	❐	❐	❐	❐	❐
Science prepares the younger generation to act as well-informed citizens.	❐	❐	❐	❐	❐
Young people interested in science have better chances of getting a job.	❐	❐	❐	❐	❐

11. How important is the role that science and research play in each of the following areas? Please use a 7-point scale where 1 means not at all important, 7 means extremely important, and the mid-point 4 means somewhat important.

	Not Important			Somewhat Important			Extremely Important
	1	2	3	4	5	6	7
Providing Canadians with a good quality of life	❐	❐	❐	❐	❐	❐	❐
Improving Canada's economic prospects	❐	❐	❐	❐	❐	❐	❐
Protecting Canada's environment	❐	❐	❐	❐	❐	❐	❐
Developing more informed and engaged citizens	❐	❐	❐	❐	❐	❐	❐
Developing a highly qualified and adaptable workforce	❐	❐	❐	❐	❐	❐	❐
Helping Canadian businesses become more competitive and innovative	❐	❐	❐	❐	❐	❐	❐
Making our communities and cities more sustainable and vibrant	❐	❐	❐	❐	❐	❐	❐
Contributing to an improved and sustainable health care system	❐	❐	❐	❐	❐	❐	❐

12. The following questions are short, quiz-type questions. For each statement that I read, please tell me if it is: definitely true, probably true, probably false, or definitely false. If you don't know or aren't sure, just tell me so, and we will skip to the next question.

	Definitely True	Probably True	Probably False	Definitely False
The continents on which we live have been moving their location for millions of years and will continue to move in the future.	❐	❐	❐	❐
All radioactivity is man-made.	❐	❐	❐	❐
Electrons are smaller than atoms.	❐	❐	❐	❐
Lasers work by focusing sound waves.	❐	❐	❐	❐
The universe began with a huge explosion.	❐	❐	❐	❐
The cloning of living things produces genetically identical copies.	❐	❐	❐	❐
Ordinary tomatoes do not contain genes, while genetically modified tomatoes do.	❐	❐	❐	❐
Antibiotics kill viruses as well as bacteria.	❐	❐	❐	❐
Human beings, as we know them today, developed from earlier species of animals.	❐	❐	❐	❐
The centre of the earth is very hot.	❐	❐	❐	❐
The primary human activity that causes global warming is the burning of fossil fuels such as oil and gas.	❐	❐	❐	❐
More than half of human genes are identical to those of mice.	❐	❐	❐	❐
All plants and animals have DNA.	❐	❐	❐	❐

13. Now, does the Earth go around the Sun, or does the Sun go around the Earth?

[HALF OF RESPONDENTS WERE ASKED A SECOND QUESTION]

Now, does the Sun go around the Earth, or does the Earth go around the Sun?

❒ Earth go around the Sun	❒ Sun go around the Earth

[IF PREVIOUS RESPONSE WAS CORRECT]
How long does it take for the Earth to go around the Sun: one day, one month, or one year?

❒ One Day	❒ One Month	❒ One Year

14. When you read news stories, you see certain sets of words and terms. We are interested in how many people recognize certain kinds of terms and would like to ask you a few brief questions in that regard. First, some articles refer to the results of a *scientific study*. When you read or hear the term *scientific study* do you have a clear understanding of what it means, a general sense of what it means, or little understanding of what it means?

❒ Clear understanding of what it means	❒ General sense of what it means	❒ Little understanding of what it means

[IF CLEAR UNDERSTANDING OR GENERAL SENSE]
Please indicate what you think it means to study something scientifically?

15. Next, when you read or hear the term *molecule*, do you have a clear understanding of what it means, a general sense of what it means, or little understanding of what it means?

❒ Clear understanding of what it means	❒ General sense of what it means	❒ Little understanding of what it means

[IF CLEAR UNDERSTANDING OR GENERAL SENSE]
Please indicate what you understand the word *molecule* to mean?

16. Next, when you read or hear the term *DNA*, do you have a clear understanding of what it means, a general sense of what it means, or little understanding of what it means?

❐ Clear understanding of what it means	❐ General sense of what it means	❐ Little understanding of what it means

[IF CLEAR UNDERSTANDING OR GENERAL SENSE]
Please indicate what you understand the term *DNA* to mean?

17. Now, let me ask you about your use of museums, zoos, and similar institutions. I am going to read you a short list of places and ask you to tell me how many times you visited each type of place during the last year, that is, the last 12 months. If you did not visit any given place, just say none.

An art museum	
A natural history museum	
A zoo or aquarium	
A science or technology museum	
A public library	
A public lecture/talk on a science-related subject	
Sporting event even as spectator	
Science activity at a school/college/university	
Planetarium	
Literature festival	
Science festival	
Nature park	

18. And now, there will be a few questions on how you engage with science and technology. Do you...? (regularly, occasionally, hardly ever, or never)

	Regularly	Occasionally	Hardly Ever	Never
Donate money to fundraising campaigns for medical research such as research into cancer?	❒	❒	❒	❒
Sign petitions or join street demonstrations on matters of nuclear power, biotechnology, or the environment?	❒	❒	❒	❒
Attend public meetings or debates about science and technology?	❒	❒	❒	❒
Participate in the activities of a non-governmental organization dealing with science and technology related issues?	❒	❒	❒	❒
Participate in a hobby or interest related to science and technology?	❒	❒	❒	❒

19. Now we have a few more questions to be used for statistical purposes only.

What is the language that you first learned at home in childhood and still understand?		
What is the highest level of education you completed?		
[IF RESPONDED UNIVERSITY] What is the highest level of university you obtained?		
Did you take any science courses in college or university?		
[IF YES] How many college or university science courses have you taken?		
Is your current occupation in an area of science or engineering?		
Do you have any children under the age of 18 living in your home?		
Other than Canadian, to which ethnic or cultural group(s) do your ancestors belong?		
Record gender of respondent?	Male ❒	Female ❒
What is your postal code?		
What is your annual HOUSEHOLD income from all sources before taxes?		

Appendix B: Coding Protocol for Open-Ended Knowledge Questions

Appendix B: Coding Protocol for Open-Ended Knowledge Questions

This appendix contains the protocols used in the coding of the three open-ended survey questions included in the Panel's survey. These protocols, developed by Jon Miller and his colleagues at the International Center for the Advancement of Scientific Literacy, have been used in the coding of these same questions for surveys undertaken in other jurisdictions. For the Panel's survey, all open-ended responses were coded independently by three bilingual coders, following a training teleconference on the use of this protocol. Where the coders disagreed on the correct code, a fourth coder reviewed all three submissions and made a judgment as to the final code that would be assigned.

The detailed coding categories provided below can be further collapsed into a division of correct versus incorrect responses, as reported in Chapter 4 of the report. For the question on the meaning of *molecule*, answers in Categories 1 and 2 are regarded as correct. For the question on the meaning of *DNA*, 1 and 2 are regarded as correct, 4 and 5 are regarded as incorrect, and 3 is regarded as ambiguous and recoded if possible based on the same respondent's answers to other survey questions on DNA, genes, and inheritance. For the question on *scientific study*, codes 1, 2, and 3 are all regarded as correct responses, while codes 4, 5, and 6 are regarded as incorrect responses.

MEANING OF MOLECULE

Question: What is a molecule?

	Coding Categories	Examples
0	*Incorrect:* This category includes all incorrect responses, vague responses, and "I don't know" responses. Responses that indicate that a molecule is smaller than an atom should be placed here. Responses that indicate that a molecule is the "smallest part of matter" should be placed here as the respondent is confusing molecules with atoms. Responses that reference molecules as only making up life (e.g., "building block of life") should also be coded as incorrect.	• It is hard to explain, I'd rather pass that question • A gathering of cells • Smallest part of an atom • Part of heat, can't identify • Something in outer space • Chemical compound found within organic body • The makeup of an object • The smallest particle of matter *(unless it specifies that it still maintains the identity of the larger material)* • Basic component of matter containing a nucleus, protons, and electrons *(this is describing an atom, not a molecule)* • Round thing in science class • Little thing
1	*Recognizes that molecules comprise matter, but not structure:* Responses indicating that molecules make up matter should be coded as a "1." However, if the respondent says that the molecule is the "smallest particle of matter" it should be coded as a "0" for they are confusing molecules with atoms. If the respondent says that molecules make up atoms then the response should be coded as incorrect "0." However, if the respondent makes a general comment like "atoms" it should be coded as a "1." If someone only gives an example, such as "how about a molecule of water" they should be assigned a code of "1."	• Basic building block • It is a small particle of a substance of molecule of water of blood, whatever • What we are all made up of, everything • The real small particle of matter (if the respondent had said the "smallest particle of matter" the response would have been coded as a "0") • Substance that makes up larger things • The thing that is pretty much the basis of what everything is made up of • Has to do with atoms (this is coded as a "1" because we do not know if the respondent thinks that an atom is smaller than a molecule or larger than a molecule) • Molecule of water
2	*Correct; understands molecules as combinations of atoms:*	• Made up of atoms everything that we are made of what the universe consists of • Group of atoms held together by nuclear forces • The composition of one or more atoms in combination • The next size bigger than an atom • A form made out of atoms • A chemical entity that's a group of elements joined together by bonds, that is water is bigger than atoms • A portion of matter. An assembly of various components of atoms • Particles of atoms • A combination of elements, like H_20, which is the elements of water

MEANING OF DNA

Question: Please tell me — in your own words — what is DNA?

This question has traditionally been coded to indicate the respondent's level of knowledge about DNA. The coding categories used for the knowledge measure are presented below.

Coding Categories		Examples
1	*Understands inheritance:* Description given which indicates that the respondent knows DNA to be the genetic code or blueprint which determines the characteristics of living matter (i.e., it is the mechanism by which inheritance occurs and thus our form and shape are determined). Responses should also be coded as "1" if the respondent simply says "Deoxyribonucleic acid."	• Ladder composed of genes, with all chromosomes • Hereditary make-up • Is the informational data on chromosomes they carry • Backbone for genetic information • Genetic construction of a human • Genetic material • Genetic makeup of person • Determines characteristics of future offspring
2	*In humans/no inheritance:* Level below "1"— respondent knows words like genes, chromosomes, but does not indicate that he/she knows that DNA is the basis of inheritance — include in this category responses which simply name "chromosomes" or "genes" without any further explanation (but an answer which says "genetic material" or "what genes are made of" should be given a "1").	• Stuff about genes • Genes • Chromosomes • Chromosomal makeup • Genetics
3	*Blueprint of Life/Building Blocks of Life:* Respondents in this category either indicate simply that DNA is the "blueprint for life" or that DNA is the "building blocks of life." These responses will be examined separately after all coding is completed in conjunction with the respondent's other answers to attempt to determine if the respondent really understands DNA or does not understand DNA.	• Building blocks of life • Blueprint of life

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	Coding Categories	Examples
4	*Living thing:* Incorrect answers that describe some aspects of a living being; many of these answers will mention "blood" or "body" in some fashion but will not include information that would allow them to be categorized as a "1," "2," or "3." If the respondent simply says "blood" the answer should be coded as a "4." However, if the respondent says "blood testing" or "testing of blood" the response should be coded as a "5."	• Chemical makeup of blood • Chemical makeup of the body • Biological makeup • Cells • Blood • It is the blood particles, so you can determine what type of blood it is and whose blood it is • Is an identifying part of the blood, can identify someone • A formation of cells • Something that's found in human body
5	*Wrong or vague:* This category includes incorrect answers which do not fit into any of the above categories. Answers referring simply to the "testing of blood" or "used in crimes" are placed here.	• Something to do with murder trials • Effect it has on the environment • Dead on arrival • Drugs and alcohol • Blood test • Testing of blood • Something nucleus • Testing looking for fibers or something on crime scenes • Department of natural resource • Drugs and agricultural • When they test your blood to match it • It's where they can tell from the blood if people are guilty of a crime • Certain kind of test results like the OJ thing that DNA stuff • Something to do with genetic testing of blood • OJ thing

MEANING OF SCIENTIFIC STUDY

Question: In your own words, could you tell me what it means to study something scientifically?

In analyses the first three categories are considered to be correct, and are generally collapsed into a code of "1" or "scientifically correct." The last three categories are considered to be incorrect, and are collapsed into a code of "0" or "incorrect" in analyses.

	Coding Categories	Examples
1	*Formulation of theories, test hypotheses:* The top category includes some notion of theory or hypothesis. However, if the response is simply "theory" or "hypothesis" with no elaboration then code the response as a "5."	• A theory or hypothesis that you prove or back with data • Start with a hypothesis, come to a conclusion either supporting or not • To generate a hypothesis then test it by performing controlled experiments • Use scientific method, form hypothesis, test it and draw conclusions
2	*Do experiments, control group:* This does not include theory, but mentions experiment or control group. Key words to be placed in this category are "control group," "experiment," or "controlled group."	• Control group, then the experimental group, and try to make a random sample • To look, experiment with it • Experimentation having experts do it • With controlled conditions/specific number/two groups different environment (*this is explaining an experiment*) • Controlled environment, control group • Controlled group • Has an experimental side and a placebo side (control side) • Set up a controlled study group, set something else not controlled, watch

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Coding Categories		Examples
3	*Rigorous, systematic comparison:* This category understands scientific study as such things as being rigorous (repeated testing, over a long time), systematic (or orderly), unbiased, and repeatable. Responses mentioning the need for a "controlled study" or "controlled environment" will be classified here if they do not include additional information that would allow them to be categorized as a "1" or a "2."	• To have it tested over and over with different specimens (*rigorous, repeated testing*) • Run tests and you collate data and draw conclusions from your data • Repeat tests over and over again • Taking data on a consistent basis (*notion of being systematic*) • To test as unbiased as possible, as thoroughly as possible (*systematic and unbiased*) • Testing done in a controlled environment • "Scientists" take a problem and try to follow what would happen if it was treated this way. And some handle the same problem another way and then they compare results. • That some particular something is under study seeking empirical proof or that it cannot be proven • Access data, analyze it, and draw conclusions from the results of the study • Conduct a controlled series of tests and analyze the results • In my opinion, it means to gather data in a way that it can be used to support or reject an idea • Objective study using research data and scientific procedures, i.e., double-blind studies • To apply the scientific method, research, revise, review, re-test, and then draw conclusions based on the information you collected • To be able to develop theories from these facts • To collect enough data to arrive at an objective conclusion with enough "proof" to support the conclusion. All the germane facts and possibilities should have been looked at with a high degree of confidence in the sampling process. • To see what makes the item work. To see what happens when you try to change parts of the setup of the item. • To study something scientifically, one studies its genetic makeup and how different parts come together to make something work. There is usually clear evidence why something works the way it does, or why it's made up the way that it is. There's no guessing or theorizing — the scientific proof is actually seen. • To take into account all variables and potential factors which may influence results. To have an accurate baseline of study, as well as an appropriate sample of the studied material or population. Also need to present findings in a logical and correct manner.

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	Coding Categories	Examples
4	*Measurement:* This category includes the notion of something done "in a laboratory" or focuses on quantitative methods such as surveys or polls or gathering facts without additional information to allow them to be categorized in one of the above categories. Responses that simply indicate "testing" are coded here.	• I would say going into a laboratory looking through microscope • Survey of how a product would work and how the public would react to it • In a lab • With actual facts • Find out how it works • Data collection • Analyze data • Do tests (this is not coded as a "3" because there is no description of the tests as repeated, rigorous, replicated, or some similar descriptors) • Take samples • Do a survey or poll • Gather data
5	*Classification:* These responses focus on more vague forms of research such as "investigate" or "go to a library" or "go in depth" or "do research."	• To read and follow up on it • Over and above the average information we receive • Literature on the subject; go to library • Research it • Study it • Learn more about it • To investigate it • Break it down • Get a hypothesis and present ideas (this is a "5" because there is no information about testing hypotheses)
6	*Redundancies/incorrect:* This category includes all incorrect responses as well as redundant responses that mention "what scientists do" or "the scientific method."	• To study something scientifically • Scientists try to study something • To use science methods and technologies • Reading a bible — meditate on your beliefs and see what it's all about • Somebody trying to impress somebody • Nuclear energy • A mystery • Use scientific method • Knowledge • New discoveries

Appendix C:

Science Culture Surveys

Appendix C: Science Culture Surveys

The assessment includes results from many international surveys as well as two earlier Canadian surveys. Table C.1 provides additional information on the surveys cited throughout the report including the year each survey was conducted, sample size, interview mode, and types of survey results cited in the assessment.

Table C.1

International Science Culture Surveys

Survey Name	Sample Size	Survey Type	Usage
Brazil: Ministry of Science and Technology of Brazil, Public Perceptions of Science and Technology (2010)	n=~ 2,000 Margin of error of general population estimates: ±2.2%	Face-to-face	• Visits to science and technology museums
Canada: EKOS Rethinking Science and Society (2004)	n=2,001 Margin of error of general population estimates: ±2.2% 19 times out of 20		• Importance of science and research for achieving socio-economic objectives
Canada: Scientific Literacy: A Survey of Adult Canadians, E. Einsiedel (1989)	N=2,000 Margin of error of general population estimates: ±2.2% 19 times out of 20	Telephone	• Science attitudes • Science interest and information • Visits to cultural institutions • Science knowledge
China: Chinese Association for Science and Technology/China Research Institute for Science Popularization, Chinese National Survey of Public Scientific Literacy (2007)	n=10,059 Margin of error of general population estimates: ±3.0%	Face-to-face	• Support for government funding of scientific research • Visits to science and technology museums • Science knowledge

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Survey Name	Sample Size	Survey Type	Usage
European Union: Eurobarometer 224 / Wave 63.1 and Eurobarometer 340 / Wave 73.1	2005: Finland: 1,007 France: 1,021 Germany: 1,507 Italy: 1,006 Netherlands: 1,005 Spain: 1,036 Sweden: 1,023 UK: 1,307 2010: Finland:1,001 France: 1,018 Germany: 1,531 Italy: 1,018 Netherlands: 1,018 Spain: 1,004 Sweden: 1,007 UK: 1,311	Face-to-face	2005: • Visits to science and technology museums • Science knowledge • Percentage of population that is scientifically literate 2010: • Support for government funding of scientific research • Scientific interest and information • Engagement with science and technology-related issues
India: National Council of Applied Economic Research, National Science Survey (2004)	n=30,255	Face-to-face	• Visits to science and technology museums • Science knowledge
Japan: National Institute of Science and Technology Policy/Ministry of Education, Culture, Sports, Science and Technology, Survey of Public Attitudes Toward and Understanding of Science and Technology in Japan (2001)	n=2,146	Face-to-face	• Visits to science and technology museums • Science knowledge • Percentage of population that is scientifically literate
Multiple countries: World Values Survey	Minimum 1,000 per country	Face-to-face	• Attitudes towards the promise of science • Reservations towards science

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Survey Name	Sample Size	Survey Type	Usage
Russia: Survey of Public Attitudes Toward Science and Technology in Russia, British Council (2003)	n=2,107	Paper questionnaires	• Science knowledge
South Korea: Korea Foundation for the Advancement of Science and Creativity (formerly Korea Science Foundation), Survey of Public Attitudes Toward and Understanding of Science and Technology (2008)	n=1,000 Margin of error of general population estimates: ±3.1%	Face-to-face	2004: • Science knowledge 2008: • Visits to science and technology museums
United States: National Opinion Research Center, General Social Survey	n=1,864-2,021 Margin of error of general population estimates: ±2.5% to 3.3%	Face-to-face	2008: • Visits to science and technology museums 2010: • Support for government funding of scientific research • Science knowledge
United States: American National Election Studies (ANES) 2008	n=1,148	Online	• Percentage of population that is scientifically literate

Appendix D:
Structural Equation Modelling

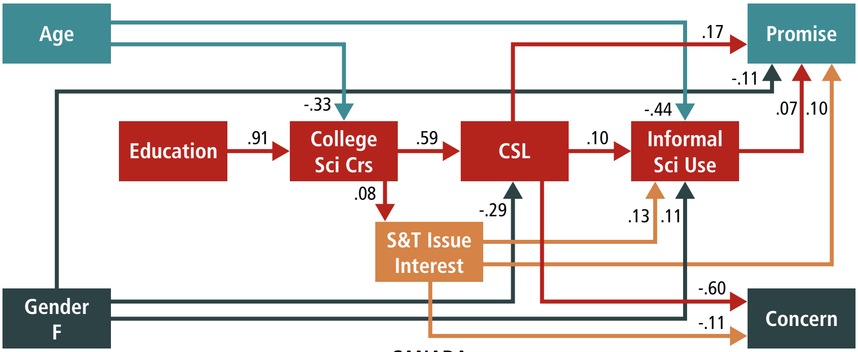
Appendix D: Structural Equation Modelling

The Panel developed a two-group structural equation model (SEM) to assess the relative influence of selected variables on the level of civic scientific literacy (CSL) and attitudes towards science and technology in Canada and the United States using the most recent surveys available in the two countries that include all of the requisite variables.

OVERVIEW

A SEM is a set of standardized regression equations that are designed to allow the examination of the relative influence of a set of variables on one or more outcome variables, taking into account the known logical or chronological order of the predictor variables. SEM analysis is theory-driven because there are hundreds of variables that might be included, and the selection of a smaller set of variables and the specification of the assumed order of those variables is a form of theory specification. Ordinary least squares regression (OLS) models do not take order into account and thus tend to underestimate the contribution of variables that are correlated or related in various ways.

Figure D.1 shows two SEMs for Canada and the United States. The logic of the model is that influence or causation flows from left to right, meaning that age or gender may influence the level of education attained, but that the level of education cannot influence either the age or gender of an individual. Mathematically, the set of assumptions of logical or chronological order reduces the number of equations needed to fit a model and produces a more parsimonious and accurate picture of the structure of a data set. Using a SEM, it is possible to calculate the total net influence (positive and negative) of each variable on each outcome variable, capturing both direct and indirect effects.



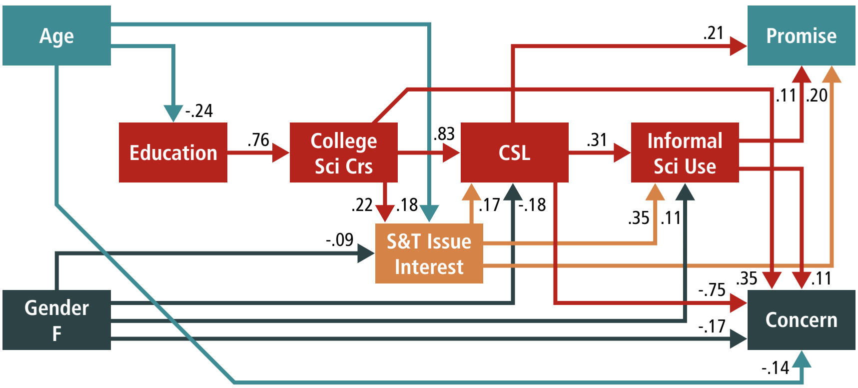


Figure D.1

Two SEMs to Predict Attitudes Towards Science and Technology in Canada and the United States

MODEL DESIGN

In this model, respondent **age** and **gender** are the left-most, or exogenous, variables. Exogenous variables are variables that are not predicted by any other variable in the model and are often characteristics that an individual acquires at birth.

Education is a fundamental variable that is important to understanding many social, economic, and attitudinal differences. In this case, the variable is a five-level ordinal variable that ranges from less than high school graduation to the attainment of a graduate or professional degree. It is computed identically for Canada and the United States.

The **number of college science courses** has been a reliable predictor of CSL and science and technology attitudes in numerous cross-national studies. The 2013 Canadian questionnaire was constructed to allow an analysis of the influence of college and university science courses. The variable is a three-level ordinal variable: no college/university-level science courses, one to three college/university science courses, and four or more college/university science courses. This classification was developed using U.S. data over the last two decades and reflects the difference between taking college science courses as a part of a general education requirement (not universally used in Canada) and taking science courses as a part of an academic major (reflected by the four-or-more classification).

Individuals differ in their **level of interest** in public policy issues involving science and technology. This variable has been widely used in the literature and has been measured in various ways. The 2013 Canadian survey asked about the level of interest in and self-assessed knowledge about (i) new discoveries in science and technology, (ii) new medical discoveries, and (iii) climate change. All three of these items had been asked in the 2007–2008 U.S. Science News Study, and it was possible to construct an identical measure in both countries. The variable is a count of the number of times each individual reported that they were "very interested" or "very well informed" about each of the three issues, producing an index that ranged from 0–6.

CSL is computed as a continuous variable, using the item-response-theory (IRT) methods described in Chapter 4. The raw IRT score (with a mean of zero and a standard deviation of 1.0) was converted into a 0-to-100 scale. In much of the literature, the CSL scale has been dichotomized into those respondents scoring 70 or higher on the scale and those scoring lower on the scale. This dichotomy reflects a judgment that the level of scientific literacy represented by a score of 70 or higher would equip an individual to read high-quality science journalism. The dichotomous measure of CSL provides a stronger prediction of attitudes and a more accurate portrait of the dynamics of public understanding.

For this analysis, the final predictor variable is the level of **use of informal science education resources and materials**. The variable was computed as a continuous variable based on the sum of (i) the number of science television shows viewed per year, (ii) the number of science and health magazines read in the previous year, (iii) the number of visits to science and technology museums in the last year, (iv) the number of science or health books read in the last year, and (v) the number of online searches or reading of information about science or health in the preceding year. The total number was capped at 240 in both countries, which reflected the 95th percentile or higher. In this specific analysis, the interval measure of informal science use was converted into a five-level ordinal variable: 0-4, 5-25, 26-70, 71-100, and 101 or higher.

The **two attitudinal outcome variables** reflect public attitudes towards (i) the promise of scientific research to improve their lives, and (ii) reservations or concerns about possible negative consequences from scientific research and technological development, as described in Chapter 4. The factor scores in each country were used to create a 0-to-10 variable for both (i) promise and (ii) reservation or concern. In this analysis, both 0-to-10 scales were treated as interval variables.

STRUCTURAL DIFFERENCES AND TOTAL EFFECTS

Figure D.1 demonstrates structural differences between Canada and the United States. The data from the 2013 survey indicate that neither age nor gender influenced the level of educational attainment in Canada. In the United States there was a moderate negative relationship (-0.24) between age and educational attainment, holding constant gender. In Canada there was a moderately strong (-0.33) relationship between age and the number of college science courses taken, but there was no similar path in the United States. In Canada there was a strong negative direct path (-0.44) from age to the use of informal science learning resources, but the influence of age was indirect in the United States and substantially lower.

CSL influences attitude towards the promise of science both directly and through the use of informal science resources. The U.S. data show a positive relationship between CSL and the use of science learning resources (0.31), which is in turn positively related to attitude towards the promise of science (0.11). There is also a direct path from CSL to attitude towards the promise of science (0.21). Thus, the product of the two indirect paths (0.31 x 0.11 = 0.034) plus the direct path means that the total effect of CSL on the attitude towards promise is 0.24 (0.21 + 0.034 = 0.24). Substantively, this pattern means that an individual's attitude towards the promise of science is the product of both his/her level of scientific literacy and the influence of increased informal science learning that results from a higher level of CSL.

Similarly, the level of CSL has both a direct and indirect effect on reservations about the possible negative consequences of science. Again, looking at the case of the United States, CSL has a positive relationship with the use of informal science learning resources (0.31) and a strong negative relationship (-0.75) with reservations about science. There is a small positive relationship between informal science use and reservations about science (0.11). This coefficient is positive because it is moderating the direct influence of CSL. The total effect of CSL on reservations about science is 0.72, which reflects a small reduction in the direct effect by the product of the two indirect paths (0.31 x 0.11 = 0.034). Substantively, this means that the use of informal science learning resources reduces or moderates the tendency of individuals with a higher level of CSL to dismiss or discount the possible negative consequences of science or technology.

The computations above would be correct for a one-group model if the data from Canada and the United States were being analyzed separately. But this analysis uses a two-group model, which pools the covariance from the two studies and produces a set of path coefficients and estimates built on a common database. A two-group model provides a more accurate set of comparisons across countries or groups. In this case, the relationship of CSL to attitude towards promise in the United States was 0.24 in the example above, but is actually 0.25 when computed in the common metric. Similarly, the previous example provided an estimate of -0.72 for the relationship between CSL and reservations towards science in the United States, but the common metric indicates that the best estimate is -0.77 (see Table D.0.1).

THE PREDICTORS OF ATTITUDES TOWARDS SCIENCE AND TECHNOLOGY

Attitude towards the promise of science and technology. The overall predictive power of the models is low: 0.08 in Canada and 0.16 in the United States (see Table D.1). This pattern suggests that there is a strong cultural disposition in favour of science and technology in both countries and that many adults hold generally supportive assessments of the likelihood that science and technology will improve the quality of their lives and the health of society.

Table D.1

Total Effects of Selected Variables in a Two-group Model

Total Effects of …	Canada		United States	
	Promise	Reservation	Promise	Reservation
Gender F	-.15	.17	-.05	.00
Age	-.07	.12	.00	-.11
Education	.11	-.33	.20	-.21
College science courses	.13	-.38	.23	-.24
ST issue interest	.12	-.11	.28	-.09
Civic scientific literacy	.18	-.58	.25	-.77
Informal science use	.00	.00	.11	.11
R^2 =	**.08**	**.36**	**.16**	**.32**

Fit:
Chi-squares = 255.5; Degrees of freedom = 33
Root Mean Square Error of Approximation (RMSEA) = .024
90% Confidence Interval$_{(RMSEA)}$ = .015; .033
N = 1,937 (Canada); 1,165 (U.S.)

Within these relatively weak models, education, college science courses, interest in scientific and technological issues, and CSL were all positively related to higher scores on the 0-to-10 promise index (see Table D.1). These effects were slightly stronger in the United States than in Canada, which accounted for a higher proportion of the total covariance in the two models.

In both Canada and the United States women were likely to hold slightly less optimistic views of the promise of science and technology than were men (-0.15 in Canada and -0.05 in the United States). In Canada older adults were slightly more likely (-0.07) to hold a less optimistic view of the promise of science and technology than were younger adults, but this relationship was not significant in the U.S. data (see Table D.1).

Reservations about science and technology. Both models accounted for about one-third of the total covariance associated with the reservation index score. In both Canada and the United States, education, college science courses, interest in scientific and technological issues, and CSL were all negatively related to reservations or concern about science and technology (see Table D.1). College science courses and CSL were the strongest predictors of a lower level of concern or reservation in both countries. These results suggest that one of the major roles of CSL in modern industrial societies is to alleviate some of the concern about negative consequences from science and technology, and it appears that a higher level of scientific understanding serves that purpose.

In the United States gender was unrelated to attitude towards the promise of science and technology and age was negatively related to concern or reservations — meaning that older U.S. adults were less concerned about science and technology than younger adults, controlling for all of the other factors in the model. In Canada women and older adults were slightly more likely to express reservations than were men or younger adults (see Table D.1).

The models point to an interesting reversal of the impact of informal science learning in Canada and the United States. In Canada the use of informal science learning resources was unrelated to either the promise or concern attitude. In the United States adults who reported a higher level of informal science learning activity were likely to hold a more optimistic attitude towards the promise of science and a more concerned attitude towards possible negative consequences of science and technology. This pattern suggests that U.S. adults who engage in more informal science learning become simultaneously more aware of the potential for positive results and the possibility of negative results. This pattern was not significant in the Canadian data.

THE FACTORS RELATED TO THE DEVELOPMENT OF CIVIC SCIENTIFIC LITERACY

The preceding analyses have focused on the factors related to the development of attitudes towards science and technology, but the same models provide some useful insights about the relative importance of various factors in the development of civic scientific literacy itself. In each of the two models, the first set of variables up to CSL documents the relationships of those background variables on the achievement of CSL by the respondent. These models account for 54% of the total covariance in the Canadian model and 61% of the covariance in the U.S. model, which are very good fits for a relatively small SEM.

Recalling that approximately 43% of Canadian adults qualified as CSL in 2013 and that about 28% of U.S. adults qualified as CSL in 2007–2008, these models assess the relative influence of age, gender, formal education attainment, college science courses, and interest in scientific and technological issues on the development of CSL. Educational attainment and college-level science courses are strong predictors of adult CSL (see Table D.2). This is an interesting result because college-level science courses are required of all college and university students in the United States as a part of a formal liberal education requirement, but the emphasis on college and university science courses for non-science majors in Canada appears to vary by university.

Table D.2

Total Effects of Selected Variables in a Two-Group Model

Total Effects of …	Civic Scientific Literacy	
	Canada	United States
Gender F	-.29	-.18
Age	-.20	-.12
Education	.55	.64
College science courses	.64	.74
ST issue interest	.00	.17
R^2 =	**.54**	**.61**

These models point to stronger age and gender effects in Canada than in the United States. Women in both countries were less likely to be CSL than men, holding constant formal education, college science courses, and other factors in the model, but the magnitude of this difference was stronger in Canada. Similarly, older adults were less likely to be CSL than younger adults, holding constant education, college science course, and the other variables in the models, but the magnitude of the difference was also stronger in Canada than in the United States (see Table D.2). The influence of interest in scientific and technological issues on CSL was positive in the United States and unrelated in Canada.