APPENDIX 2:
REPORT FROM THE PRELIMINARY SURVEY

GATSBY

PURPOSES OF PRACTICAL SCIENCE

If you want to know what 'good' practical science looks like, you need to know the reason for doing it – so we needed to find out why people do practical science in the first place. We realised that the *intended* purposes of practical (as conveyed by official curriculum documents) might not be the same as the *actual* purposes in teachers' minds. We also appreciated that assessment will have a powerful effect on what actually happens in practical science.

WHAT WE DID

We identified 11 countries where science education was known to be effective, as judged, for example, by the Programme for International Student Assessment (PISA). Rather than simply going for the top 11 PISA countries, we chose countries where we knew by repute that there were interesting things to see in practical science. The countries are:

– Australia (Victoria)
– Canada (Ontario)
– Finland
– France
– Germany
– Japan
– Netherlands
– New Zealand
– Singapore
– Switzerland
– USA (Massachusetts)

We used the questionnaire in the Annex. In addition to asking about the purposes of practical science, we used this opportunity to find out about strengths and weaknesses in each country and how each country assesses practical science, if at all. This supplementary information helped us to choose the countries for our later visits.

Our approach was to identify a single expert witness in each country. Ideally, these expert witnesses were both knowledgeable about science education in their country, and independent enough to give an objective view. Typically, they were university academics specialising in science education. We recognise the limitations of this essentially subjective approach, but the alternatives, for example to carry out a structured survey of teachers, would have been prohibitively time-consuming and expensive.

The names and roles of the expert witnesses in the table below.

Expert witnesses	
Australia (Victoria)	Graeme Oliver, LaTrobe University, Melbourne
Canada (Ontario)	Nandanee Sawh, Program Coordinator for STEM, Science and Technology, Toronto District School Board
Finland	Jari Lavonen, Professor of Physics and Chemistry Education, University of Helsinki
France	Elena Pasquinelli, La Main à la Pâte
Germany	Knut Neumann, Professor and Director of the Department of Physics Education, Leibniz-Institute for Science and Mathematics Education (IPN) Kiel
Japan	Yasushi Ogura, Associate Professor (science teacher training), Saitama University
Netherlands	Harrie Eijkelhof, Emeritus Professor of Physics Education Utrecht University
New Zealand	Azra Moeed, Senior Lecturer & Curriculum Leader Science Education, Victoria University of Wellington
Singapore	Ramanathan Subramanian, Associate Professor, National Institute of Education, Nanyang Technological University
Switzerland	Peter Labudde, Professor and Head, Centre for Science and Technology Education, University of Applied Sciences and Arts Northwestern Switzerland
USA (Massachusetts)	Hannah Sevian, Associate Professor of Chemistry, University of Massachusetts, Boston

Each expert witness was asked to complete the questionnaire, consulting as appropriate to supplement their own expertise. Most commonly, the witnesses consulted official curriculum documents, research literature, colleagues and teachers.

THE DEFINITION OF PRACTICAL SCIENCE

For the purposes of this questionnaire, we gave the working definition of 'practical science' in Box 1.

Box 1.

Our definition of practical science

'Practical science' describes a wide variety of activities in which students manipulate and observe real objects and materials to increase their knowledge and understanding of the natural world. It includes student experiments in laboratories and field studies, but it excludes practical demonstrations by teachers, and it excludes visits to places of scientific interest where no fieldwork or hands-on activity takes place. 'Science' includes physics, chemistry, biology, earth science and astronomy, but excludes engineering, design and technology, computer science and geography.

This definition was accepted by most witnesses, though it was suggested that it should include technology and engineering (USA), manipulation of secondary data (Canada), demonstrations (Singapore) and virtual experiences (Australia). We decided for the purposes of this preliminary survey to leave the definition unchanged, though we modified it slightly for the final report.

The purposes of practical science

From experience, and from a study of the literature, we developed the initial list of purposes of practical science given below.

A. To teach the principles of scientific inquiry.

B. To improve understanding of theory through practical experience.

C. To teach specific practical skills, such as measurement and observation, that may be useful in future study or employment.

D. To motivate and engage students.

We asked witnesses to rate the importance of each purpose in their country. They did this twice: first for the *intended* purposes of practical science (as defined by curriculum documents) and second for the *actual* purposes as interpreted by real teachers in real schools. Our experience from the UK suggested the two might not be the same.

Here is a summary of what the witnesses told us.

1. This is a universal list of purposes but it needs extending. Although there were variations, witnesses agreed that all the purposes were important. Other purposes were proposed, in particular the development of attributes that are not directly related to science (USA, Finland, France, Switzerland, Australia). This includes 'higher level' skills and attributes such as communication, teamwork and perseverance. This purpose was also confirmed by the Rapid Evidence Assessment in Appendix 1, which can be found at www.gatsby.org.uk/GoodPracticalScience

As a result, we extended the list of purposes to the agreed list in Box 2.

Box 2.

The purposes of practical science

A. To teach the principles of scientific inquiry.

B. To improve understanding of theory through practical experience.

C. To teach specific practical skills, such as measurement and observation, that may be useful in future study or employment.

D. To motivate and engage students.

E. To develop higher level skills and attributes such as communication, teamwork and perseverance.

2. *Teachers do not interpret the purposes of practical science in exactly the same way as official documents.* In particular:
   - Teachers tend to rate the motivational purpose of practical science more highly (D).
   - They tend to rate less highly the use of practical science to teach the principles of scientific inquiry (A) and specific practical skills (C).
   - In reality, what is intended to be scientific inquiry may end up as following recipe-like instructions.
3. *Within each country, there are some variations* between subjects, type of school and age groups. In Finland, for example, there is less emphasis on inquiry in the biological sciences than in the physical sciences. In general, older students do less practical science – in Japan, we were told there is *no* practical science in senior secondary schools.
4. *The differences between intended and interpreted purposes are attributed to:*
   - Shortage of time.
   - The experience and training of teachers.
   - The availability of facilities for practical science.

The assessment of practical science

Knowing the powerful influence that assessment has on teaching in the UK, we were interested to know how different countries approach the assessment of practical science. We are talking about *summative* assessment here, particularly where it leads to public qualifications. We recognise that assessment has a greater influence on teachers' behaviour where there is high-stakes accountability for schools, as in the UK.

For the 11 countries in our survey, the majority do not assess practical science separately from theory.[1] In these countries, assessment of practical science would be through written questions, if at all.

Some countries (New Zealand, Canada, France and the Netherlands) use some form of teacher assessment of practical science. In the case of the Netherlands, this is the assessment of the final year project, the *profielwerkstuk*. In Singapore, the higher ability groups undergo a teacher assessment and the lower ability combined science groups have a practical exam.

For countries that use an assessment of practical science, our witnesses felt that the assessment method did not match the intended purposes particularly well.

[1] In the USA, our expert witness responded with reference to Massachusetts. We were told that the neighbouring state of Connecticut has a set of suggested laboratory experiences that are used as the context for state-wide assessments of science, and some skills are also assessed.

ANNEX TO APPENDIX 2: QUESTIONNAIRE ON PURPOSES OF PRACTICAL SCIENCE

PURPOSES OF PRACTICAL SCIENCE

About this questionnaire: defining the purposes of practical science

We believe that practical work is fundamental to science. Scientific discoveries are made as the result of practical observations, and scientists in academia and industry depend on experimentation.

However, when it comes to science education in schools, there are many views, both in the UK and internationally, on what practical science is for, and it is difficult to find a consensus on the purposes of practical science in education.

Possible purposes of practical science are:

A. To teach the principles of scientific inquiry.

B. To improve understanding of theory through practical experience.

C. To teach specific practical skills, such as measurement and observation, that may be useful in future study or employment.

D. To motivate and engage students.

We are asking science education experts in 11 countries to complete a structured questionnaire designed to identify what consensus exists in each country as to the purposes of practical science in schools. We are interested in both the intended purposes of practical science (as set out for example, in national curriculum documents, national standards for science and national examination syllabuses) and the purposes of practical science as actually interpreted by teachers and experienced by students.

The results will be analysed and a summary will be made of the purposes of practical science across the countries surveyed.

We are asking an acknowledged science education expert in each country to complete the questionnaire on the basis of their expert knowledge, drawing on specialist advice where necessary.

Notes on answering the questionnaire:

1. We realise that one person, however expert, may find it hard to answer the questionnaire unaided. We encourage you to consult colleagues for advice.
2. For these purposes, **'practical science' describes a wide variety of activities in which students manipulate and observe real objects and materials to increase their knowledge and understanding of the natural world.** It includes student experiments in laboratories and field studies, but it excludes practical demonstrations by teachers, and it excludes visits to places of scientific interest where no fieldwork or hands-on activity takes place. 'Science' includes physics, chemistry, biology, earth science and astronomy, but excludes engineering, design and technology, computer science and geography.
3. Our main interest is in government or state-funded schools. Where privately funded schools are a significant exception to the general rule, we would be interested to know about them.
4. In this study, we are concerned only with secondary education (age 11–18).
5. We are interested in science as part of general education, as opposed to science education in vocational programmes.
6. This questionnaire is available online and as a Word document. Please complete in either format.
7. All questionnaire responses will be treated confidentially, and if we quote from the responses in our report, we will do so anonymously.

If you wish to discuss any of the questions, John Holman would be happy to do so by email: john.holman@york.ac.uk.

QUESTIONS

Question 1. Information about you.

Name

Institution and job title

Country/ State

Email Address

Phone Number

Question 2. The formally intended purposes of practical science.

Our definition of practical science is: **'practical science' describes a wide variety of activities in which students manipulate and observe real objects and materials to increase their knowledge and understanding of the natural world.** It includes student experiments in laboratories and field studies, but it excludes practical demonstrations by teachers, and it excludes visits to places of scientific interest where no fieldwork or hands-on activity takes place. 'Science' includes physics, chemistry, biology, earth science and astronomy, but excludes engineering, design and technology, computer science and geography.

2. A. Is this definition appropriate for your country or state?

   B. If no, please describe any changes you would make to this definition to make it more appropriate for your country or state.

Questions 3 to 8.

In these questions, we are interested in the intended purposes of practical science, as set out for example, in national curriculum documents, national standards for science and national examination syllabuses. (Later in this questionnaire we will ask about the purposes of practical science as interpreted by teachers.)

Please look at the following purposes of practical science:

A. To teach the principles of scientific inquiry.

B. To improve understanding of theory through practical experience.

C. To teach specific practical skills, such as measurement and observation, that may be useful in future study or employment.

D. To motivate and engage students.

3. What is your understanding of the intended purposes of practical science in schools in your country or state?

Please tick the appropriate box in the table overleaf.

How important is this as an intended purpose of practical science?

	1 = Not important	2	3	4 = Very important
A. To teach the principles of scientific inquiry.				
B. To improve understanding of theory through practical experience.				
C. To teach specific practical skills, such as measurement and observation.				
D. To motivate and engage students.				

4. Are there any other intended purposes of practical science, not covered by A to D in question 3?
5. How easy or difficult was it to provide the answers to question 3? If it was difficult, please explain why.
6. What sources of evidence did you use for your answer to question 3?
7. Is there any variation in your answers to question 3 depending on different science subjects, school type, or other factors?
8. Do you have any other comments on the answers you have given to question 3?

Questions 9 to 17. The purposes of practical science as interpreted by teachers.
In these questions, we are interested in what teachers consider to be the purposes of practical science based on their own professional experience.

9. Look again at the possible purposes. What is your understanding of what teachers consider to be the purposes of practical science in schools in your country or state? Please tick the appropriate box in the table below.

How important is this as an intended purpose of practical science?

	1 = Not important	2	3	4 = Very important
A. To teach the principles of scientific inquiry.				
B. To improve understanding of theory through practical experience.				
C. To teach specific practical skills, such as measurement and observation.				
D. To motivate and engage students.				

10. Do teachers have any other intended purposes of practical science, not covered by A to D in question 9?
11. How easy or difficult was it to provide the answers to question 9? If it was difficult, please explain why.
12. What sources of evidence did you use for your answer to question 9?
13. Is there any variation in your answers to question 9 depending on school type, age and experience of teachers, different science subjects etc?
14. Do you have any other comments on the answers you have given to question 9?
15. In your opinion, do teachers generally have a clear understanding of why they use practical science in their teaching? Please explain your answer.
16. In your opinion, how well do the intended purposes of practical science match the way it is carried out in practice?
17. If you think there are differences between the intended purposes of practical science and the way it is carried out in practice by teachers, please suggest reasons.

Questions 18 and 19. Assessment of practical science.

18. Is performance in practical science formally assessed as part of national or state assessments? If so, please describe briefly how this is done.
19. In your opinion, how well does the formal assessment match the intended purposes of practical science?

Questions 20 to 24. Strengths and weaknesses.

We are interested in knowing more about the key features of practical science in your country or state, and the factors which influence these features.

20. What do you consider to be the strongest features of practical science in your country or state?
21. What do you consider to be the weakest features of practical science in your country or state?
22. Over the last 10 years, would you say that the quantity and quality of practical science in your country or state has increased, decreased or stayed about the same?
23. What are the influences that are driving any changes to the quantity and quality of practical science in your country or state?
24. Please give one or more examples of what you consider to be excellent practical science in your country or state.

Questions 25 and 26. Your expertise.

25. Please describe the process that you followed in preparing your responses to this questionnaire. For example, what sources did you draw on, and what people did you consult?
26. Finally, please give a biographical paragraph to describe your professional expertise.

End of survey.