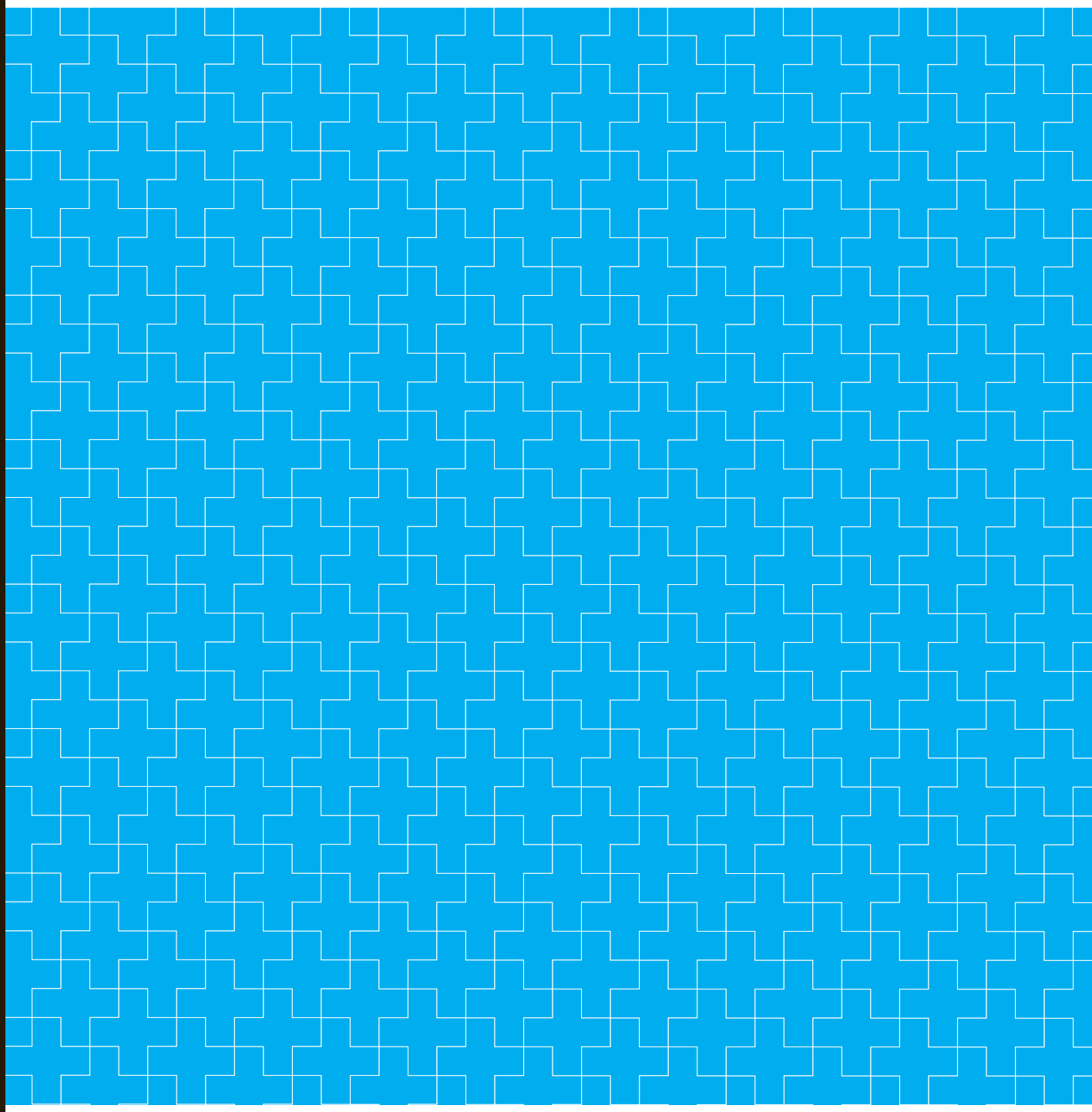
Mathematical Sciences HE Curriculum Innovation Project

Being a Professional Mathematician



Tony Mann and Chris Good

The Higher Education Academy Maths, Stats & OR Network

National HE STEM Programme

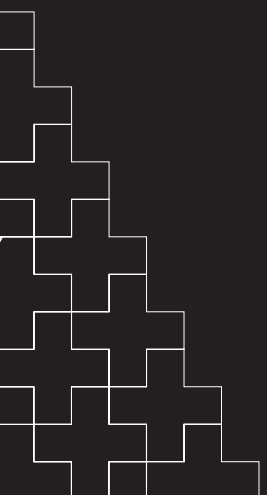
Being a Professional Mathematician

Tony Mann and Chris Good

University of Greenwich and University of Birmingham

June 2012

A project supported by the MSOR Network, the Institute of Mathematics and its Applications and the Universities of Greenwich and Birmingham as part of the National HE STEM Programme.



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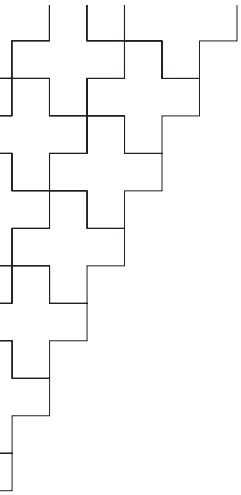
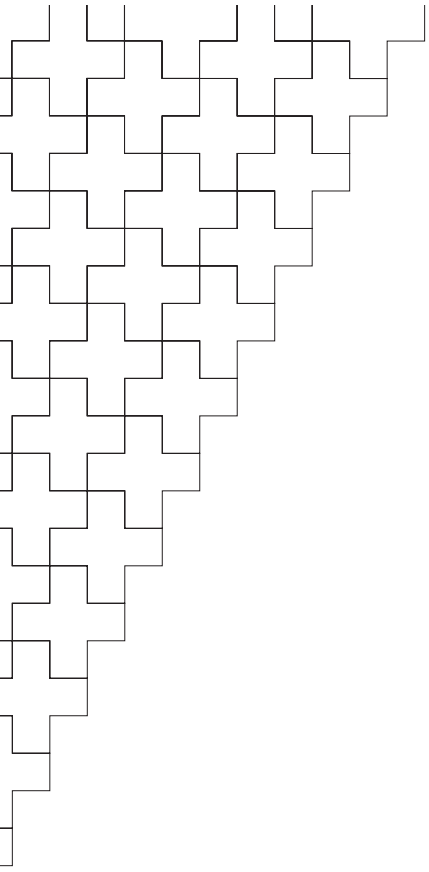


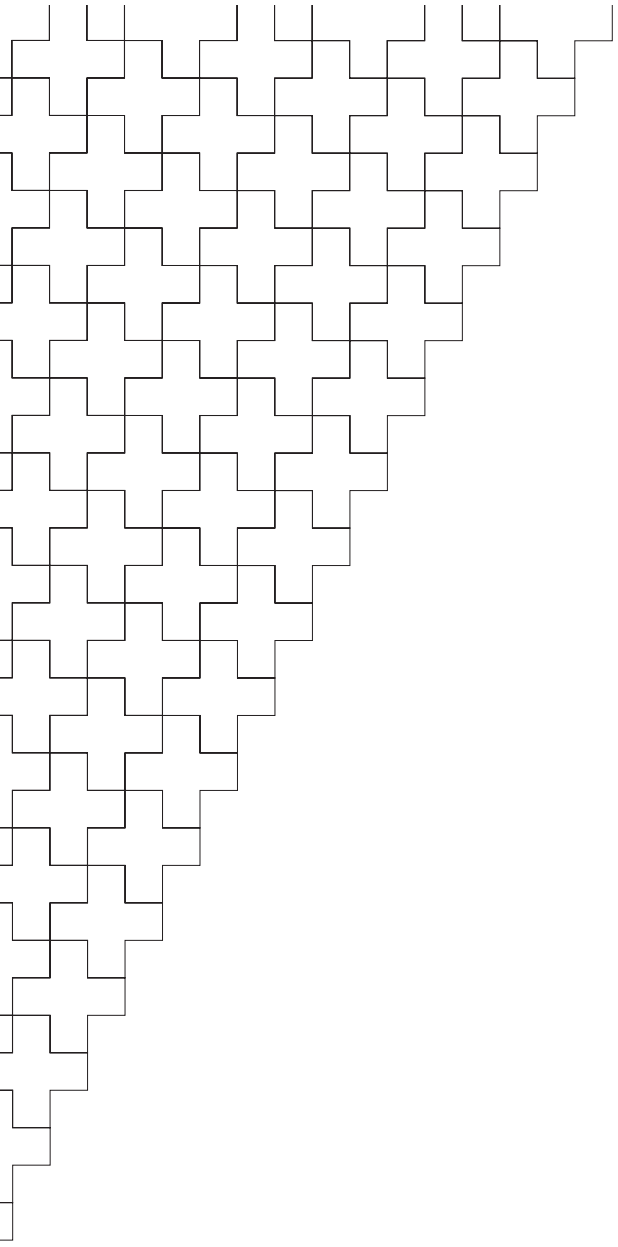
Acknowledgements

We would like to thank all the mathematicians and historians who generously gave up their time to record case studies, and Noel-Ann Bradshaw and Kevin Parrott who recorded supplementary material for this project. We are also grateful to the participants at the HE STEM workshop ‘Being a Professional Mathematician’ at the University of Greenwich on 15 May 2012, and students on the University of Greenwich module ‘Mathematics in Society’ who trialled some of the teaching materials.

The London Mathematical Society provided a venue for some of the interviews. The Universities of Greenwich and Birmingham provided support and we are particularly grateful to Peter Rowlett of the MSOR Network for his advice and guidance throughout the project.



Contents



Introduction

This project aimed to create teaching materials on 'Being a Professional Mathematician' along with guidance as to how they could be incorporated into the undergraduate curriculum. This followed a recommendation at the 2011 HE Mathematics Curriculum Summit [1] that teaching materials be produced to help "develop students' awareness of the culture of mathematics" (p. 29).

The project set out to present information about mathematical practitioners, mainly from the present day but with some historical examples included. It was decided that the main output would be audio recordings of interviews with contemporary mathematicians, and with historians talking about mathematicians of the past. Audio was felt to be convenient for today's students, for material supplementary to their lectures. Students might listen to the material, for example, while travelling to or from University, and thus optimise the use of their available time. While video interviews might have been valuable, the substantial extra costs and added expertise required made this impractical. However it has been possible to add some images and text headings in mp4 versions of the interviews and these are available alongside the audio-only mp3 files. Other outputs include worksheets for classroom discussion, suggested titles for essays or personal development planning reflective assignments, and suggested final year projects based around these resources.

Eight mathematicians were selected for the case studies from a call for participants placed in various professional body newsletters and websites in the autumn of 2011, and from personal contacts. These exemplified a wide range of mathematical occupations and levels of experience. They were[1]:

- Danny Brown, mathematics teacher
- Nira Chamberlain, mathematical modelling consultant
- Rosemary Dyson, academic applied mathematician, University of Birmingham
- Peter Furness, mathematics consultant
- Jay Jobanputra, risk analyst
- Sue Merchant, operational research consultant
- Mason Porter, academic applied mathematician, Oxford University
- Gwyneth Stallard, academic pure mathematician, Open University

In addition, five historians were interviewed about historical mathematicians. Jackie Stedall (Oxford University) talked about Thomas Harriot, a mathematical practitioner when career paths in mathematics were very different from today. Patricia Fara (Cambridge University) talked about Emilie du Chatelet, whom she describes as "a normal woman and a good scientist". Karen Sylvester (University of Virginia) described James Joseph Sylvester, a great mathematician whose religion was an obstacle to his career. Noel-Ann Bradshaw (University of Greenwich) talked about Florence Nightingale, as a pioneer of statistics. Finally, Tony Mann (University of Greenwich) gave an account of Hugh Everett III, whose career in operational research in the second half of the twentieth century, working both for the military establishment and for consultancy companies he set up, shows the range of options becoming available to mathematicians.

In view of the importance of professional bodies and learned societies for mathematics professionals, representatives of the Institute of Mathematics and its Applications (David

[1]Unfortunately an interview with an academic statistician became impossible at a late stage. If she, or another academic statistician, is able to record an interview in the future, it will be posted on the project website

Youdan), the London Mathematical Society (Fiona Nixon), the Operational Research Society (Louise Orpin) and the Royal Statistical Society (Roeland Beerten) were also interviewed.

It was expected that certain common themes would emerge from the case studies, and indeed the interview plans were designed with this in mind, but it was gratifying that the results cast light on some questions from different angles, while showing that other concerns are common across the field. Many of the points arising from the interviews feature in the worksheets, but it is perhaps worth identifying here some general themes.

The mathematicians working in industry and commerce talked about the skills mathematicians need in their sectors. The message which seems to emerge is that employability skills really do matter to graduating mathematicians. Invariably communication and networking skills were seen as crucial: this is brought out in particular by Furness and Jobanputra. They and Merchant mentioned the connotations in their area of employment of describing oneself as a 'mathematician'.

The nature of mathematical work – solitary or collaborative – is discussed by Stallard and Merchant, and also arises in the case study of Harriot. Most of the interviews include discussion about the dissemination of mathematical work, which may be by journal paper or conference (Stallard, Porter and others), or may be limited for reasons of commercial confidence or national security (Furness, Merchant, Everett).

Interviewees including Brown, Chamberlain, Furness, Jobanputra and Porter discussed the value, to themselves and to others, of professional bodies and learned societies in supporting working mathematicians. The importance of credentials, such as Chartered Mathematician status, was discussed by Chamberlain, Furness, Merchant and Porter.

The mathematicians had faced different challenges in their careers. Furness and Stallard talked about the problem of finding an academic post after completing a PhD – an issue that also arose for Everett. Merchant and Stallard had both experienced the challenges of returning to work after maternity leave. Chamberlain mentioned the absence of black mathematicians as role models and Merchant commented on the lack of female role models for her. While Brown and Porter had not felt they personally needed role models, they also discussed the desirability of role models for potential mathematicians, and Dyson mentioned how important role models have been to her.

The historical case studies of du Chatelet and Nightingale, and the interviews with Stallard, Dyson, Merchant and Porter, raise issues around equal opportunities for women in mathematics and the "leaky pipeline" whereby women are lost to mathematics at each career stage. These might be explored by students, but care must be taken not to discourage young mathematicians by over-stressing the difficulties that may exist. The interview with Dyson is perhaps particularly useful in this context as she talks about how she took encouragement from successful role models.

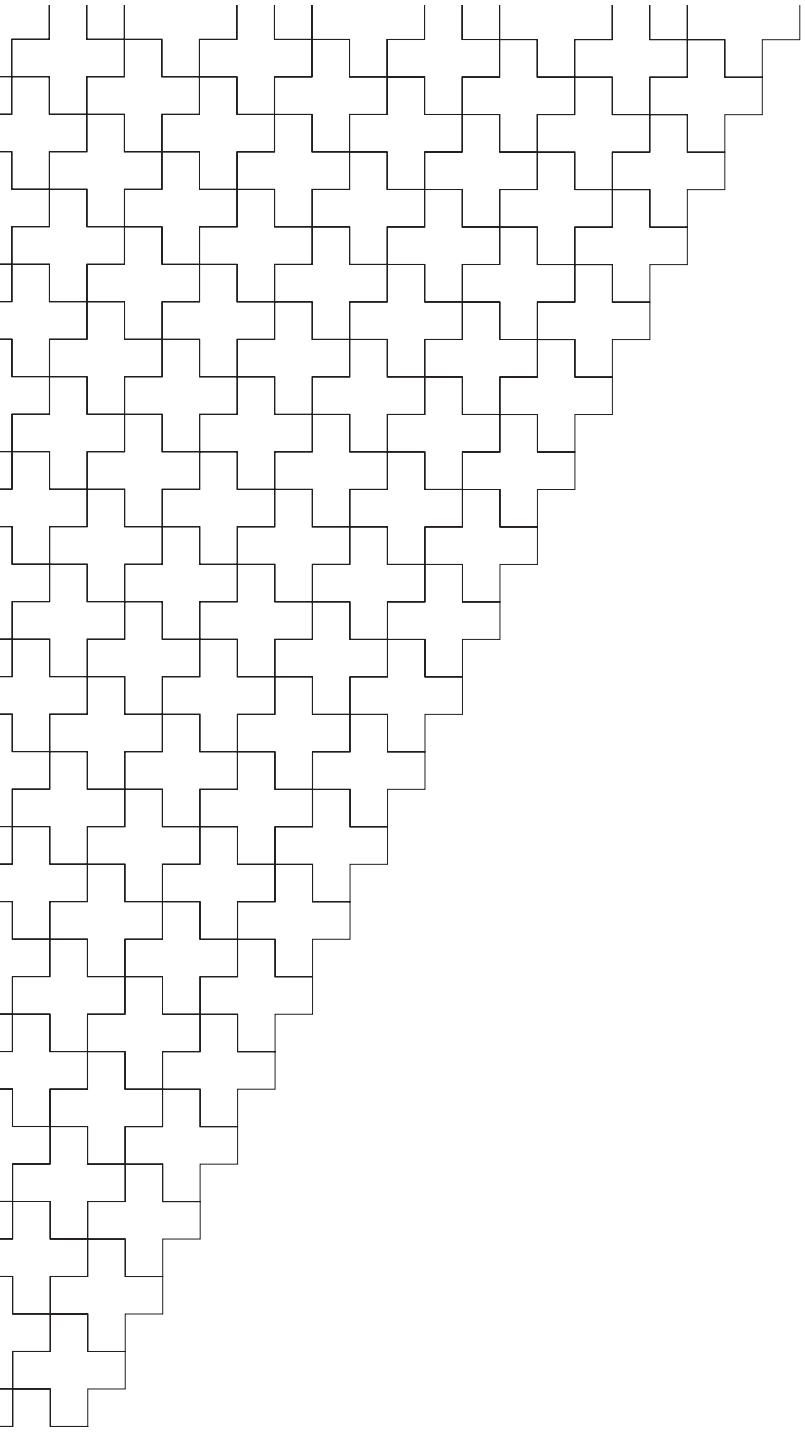
To support the case studies, worksheets and other teaching materials have been prepared. These draw on the interviews and on other available sources. Since the jokes people tell about their profession can be very revealing about the culture of that profession, Kevin Parrott (University of Greenwich) recorded a few well-known jokes about mathematicians, which are used in one of the worksheets.

This project is not about teaching the details of mathematics (though as discussed below, the case studies could be used to motivate and illustrate lectures on some topics in mathematics). Nor does it address the teaching of mathematical thinking, on which there are excellent books by Mason, Burton and Stacey [2] and by Houston [3].

An annotated list of recent biographies and books about how professional mathematicians work is also provided. While it would be unreasonable to ask students to read all of these books, they provide valuable, and often provocative, insights into the culture of mathematicians. They are probably already to be found in most university libraries but would be a useful addition if they are not already held.

Some of the material was trialled in a final year University of Greenwich module ('Mathematics in Society') in December 2011 and student feedback was very positive. Preliminary versions of some of the outputs were demonstrated at a workshop 'Being a Professional Mathematician' at the University of Greenwich on 15 May 2012. Feedback from the participants was encouraging, and some suggestions made at that workshop have been incorporated. It is hoped that further feedback will be forthcoming from future users of the resources.

The outputs are available on the website www.BeingAMathematician.org which the project team will maintain. The project outputs are intended to be used by lecturers in any way they wish and are released under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License. The audio mp3 and mp4 files are also available as a podcast feed.



How to use the resources

The report of the 2011 HE Mathematics Curriculum Summit noted the desirability of teaching resources which aimed "to counter a view of mathematics as a static, completed body of knowledge and instead encourage awareness of the process of doing mathematics. They should develop students' awareness of the culture of mathematics." ([1], p. 29)

The case studies produced for this project involve mathematical practitioners in a range of industrial, commercial and academic fields, and set out to show that mathematics graduates have the opportunity to develop new mathematics in many different contexts in the twenty-first century workplace. Since in many of the interviews the participants talked about the skills required by mathematicians in their field, the need for continuing professional development and the importance of professional practice such as networking, the resources also contain material relevant for those developing undergraduates' understanding of their employability and employers' expectations.

Here we first suggest how the resources relate to the undergraduate mathematics curriculum, and then offer specific ideas as to how tutors could use the resources with students.

'Being a Professional Mathematician' in the undergraduate mathematics curriculum

Mathematics degree programmes vary widely between universities, for the reasons discussed in the relevant Quality Assurance Agency Benchmark subject statements ([4], [5]) but there are likely to be four areas in which undergraduates may naturally explore 'being a professional mathematician':

- The PDP (Personal Development Planning) of any degree programme is likely to include investigation of employability and career possibilities. This part of a mathematics programme may provide opportunities for workshops, seminars, and/or directed private study on careers in mathematics, planning for career development, and the professional practice of mathematicians.
- Modules on the culture of mathematics, 'mathematics in society' or the history of mathematics may provide opportunities for students to explore, in class or in independent study, the role of professional mathematicians today and in the past. Such modules are offered by at least eighteen UK mathematics departments, according to a recent survey by the British Society for the History of Mathematics [6].
- Individual projects may allow students to explore topics regarding the role or mathematicians and aspects of the culture of being a professional mathematician.
- Many mathematics modules cover mathematics used in the work of the participants in the case studies and material from these could be used to motivate this mathematics when it is presented to undergraduates, to demonstrate how the mathematics students are learning is relevant to the workplace.

It is envisaged that the resources produced for this project can support all four of these areas. The next section suggests ways in which lecturers can use these resources.

Using the case studies and worksheets in teaching undergraduates

The materials produced for this project are (with the consent of the participants in the case studies) released under a licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License [7]. This means that users are free to adapt them for their own (non-commercial) purposes. This section indicates ways in which the case study interviews

might be used. The following sections go on to describe worksheets which could be used without modification or from which tutors could extract sections to incorporate into their own teaching materials, and possible essay and discussion titles. We have also provided further guidance for tutors with the worksheets. All this material is available in the form of editable Word files on the project website www.BeingAMathematician.org.

Examples of contexts in which the materials might be used are:

- in seminars or discussion classes
- as preparatory material for student essays, logbooks or other assessed or unassessed elements of the Personal Development Planning (PDP) component of the degree programme
- as source material for final year projects
- as examples to motivate mathematical content in traditional lecture courses

Seminar-type discussion might be tutor-led or student-led. In the former case, the tutor might lead discussion around some of the issues covered in the project's worksheets, using examples from the case studies such as those suggested in the worksheets. Students might be asked to prepare in advance by listening to some of the case study interviews, or the tutor might plan the class as an introduction to the issues without requiring student preparation.

Universities cover PDP in different ways, but reflection on learning, personal development and career planning is usually central to the implementation. The case studies, and the material in which representatives of professional bodies and learned societies explain the role of their organisations, are likely to be useful in the delivery of PDP. The careers of the participants in the case studies, and the challenges they have faced in forging their careers, provide a context for students to think about their own futures. The comments about the skills required in careers in the different area of mathematics will support students in reflecting on their own preparation for careers after they graduate.

The case studies could provide a starting point for a variety of final year projects. These might focus on applications of mathematics, the culture of doing mathematics, or the history of mathematics. Suggestions for possible project titles, and notes on issues that might be explored, are provided below.

Tutors wishing to provide context for standard mathematical material might play extracts from the case study interviews in class, to motivate students, break up "chalk and talk" sessions, and show mathematics as a living subject.

Participants at the HE STEM workshop "Being a Professional Mathematician", at the University of Greenwich on 15 May 2012, commented on how they might incorporate these materials in their teaching.

> *At the University of Hertfordshire, the School of Physics, Astronomy and Mathematics runs a second-year module called Professional Skills that seeks to expose students to what it means to be a working mathematician and what skills they need to develop besides the ability to solve mathematical problems. Some of the worksheets developed by the project are likely to be adopted or at least adapted for use in this module, as they provide some interesting case studies and challenges to the mindset of early-undergraduate mathematicians.*
>
> Sean Ryan, University of Hertfordshire

> *I like the idea of using snippets or sound bites of the audio to motivate what is about to come in a lecture, relate what has been taught to something 'real' and, more generally, to provide a context and remind students that what they are doing is not just austere elegance but also real and applicable. I would see the contributors as being credited as guest stars on the lecture slides etc, and would try to get continuity by having the same people coming up all through the lecture course. I wouldn't be afraid of repetition of key and powerful messages - and would like to post the audio files on out intranet/VLE site so the students could download and listen in their own time.*

I doubt I would use a whole unbroken segment though - even 5 mins is probably too long to passively listen.

I am likely to use the worksheets, or an edited version, during induction sessions for Level 1 - to orient them towards the "becoming a mathematician" direction. And I may well use them for level 3 - to motivate and frame their job applications. Come to that, they may well be useful for placement students too...

Some of the fun stuff on the worksheets would I think work well for outreach & recruitment activities with school kids.

Simon Shaw, Brunel University

Worksheets for discussion

Eight worksheets have been created to suggest ways in which the case studies can be used. They have been designed to be complete in themselves and could be issued to students for tutorial work exactly as they stand. However, lecturers are free to adapt them to their needs, to extract material from the worksheets to incorporate into their own teaching material, or to create their own exercises around the material. The worksheets are provided in both Microsoft Word format (to allow lecturers to extract material as they wish) and as PDFs.

These worksheets could be used to structure seminars or classroom discussion, or they could be issued to students as self-study material. Where they are used for classroom discussion, it is for the lecturer to decide whether they wish students to think about the issues in advance or whether in some cases a more useful discussion might arise if students have to 'think on the spot'. 'Tutors' versions' have also been provided which add brief notes to tutors to suggest points that might be brought out in discussion or directions in which discussion might be steered. The website www.BeingAMathematician.org contains both 'students" and 'tutors" versions of the worksheets. The material for tutors rarely contains 'answers' – the worksheet questions rarely have simple answers – but tutors should be aware of the possibility that since this material is freely available on the web, students might find this supplementary material for themselves.

The worksheet topics are as follows. The full worksheets (tutors' versions) are given in Appendix 1 of this document, and tutors' and students' versions are available at www.BeingAMathematician.org.

- Is mathematics a static body of knowledge or a developing subject?
- The public image of a professional mathematician.
- What makes a professional mathematician?
- The importance of professional bodies.
- What skills do you need to become a professional mathematician?
- Are there equal opportunities in mathematics?
- Role models in mathematics.
- Visual representations of mathematicians.

There is some overlap between the worksheets on 'What makes a professional mathematician?' and 'The importance of professional bodies': the latter goes into more detail on issues which arise in connection with the former. The worksheet 'Role Models in Mathematics' follows on from 'Are there equal opportunities in mathematics?' and these two might well be used together.

Essay / PDP reflection topics

A list of possible essay titles is provided. Depending on the design of a degree programme, these might be appropriate in PDP work or in history of mathematics or 'mathematics in society' modules. The titles could be set as essay questions or for small group discussion.

Once again, these are intended as suggestions which lecturers can adapt in any way they wish. The list of topics is in Appendix 2 and can be found at www.BeingAMathematician.org.

Final year project suggestions

Many mathematics students undertake a final year project where the student works independently with guidance from a tutor. It can be difficult to find suitable projects in mathematics, since few undergraduates are in a position to produce original work, but a successful individual project develops, and is evidence of, skills in time management, independent learning, and communication which are highly valued by employers. The topics with which 'Being a Professional Mathematician' is concerned provide a rich area for final year projects, involving research, critical thinking, and understanding of the mathematical community.

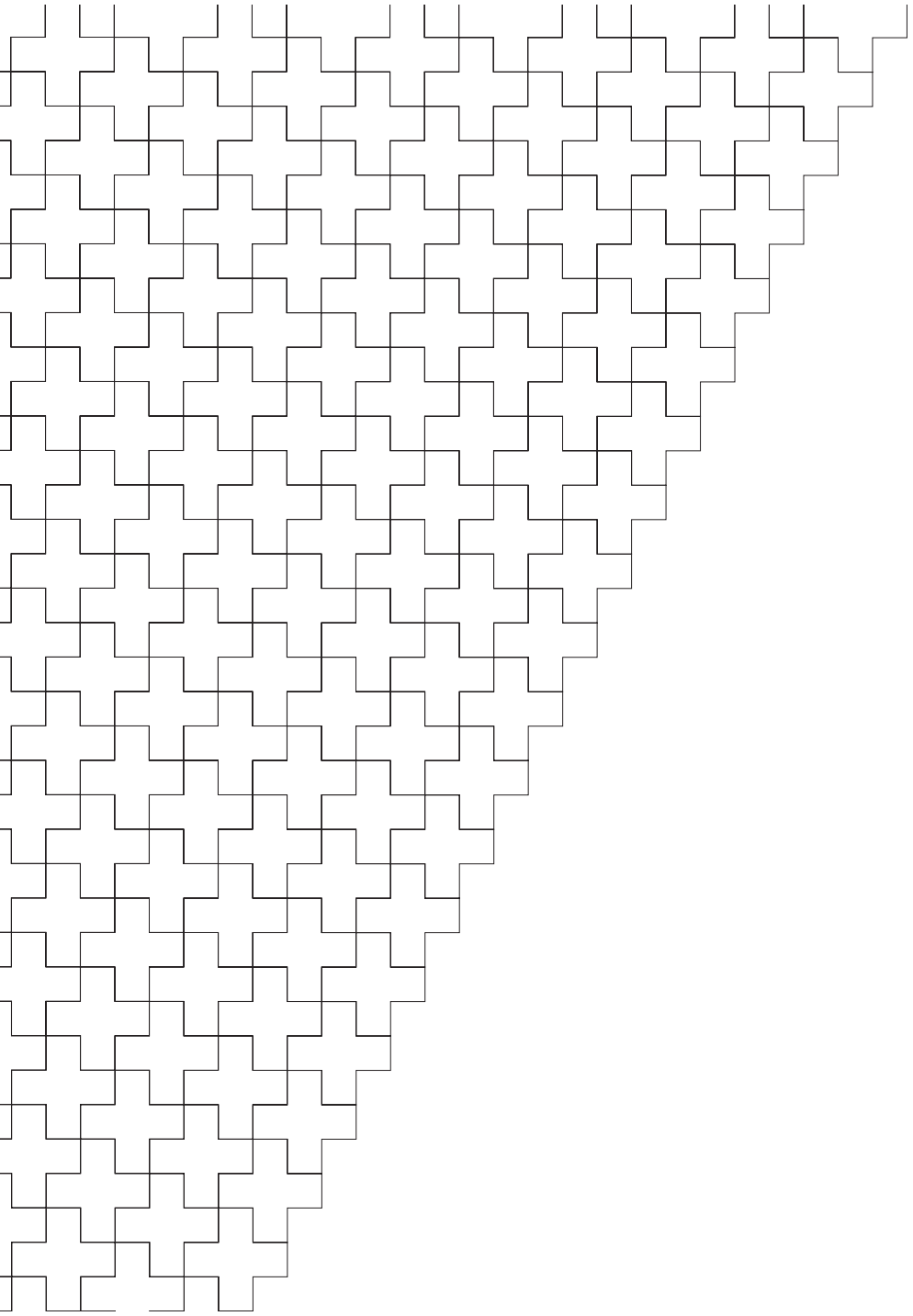
This list provides a variety of possible project ideas with, in many cases, suggested starting points. The list of possible project titles is in Appendix 3 and can be found at www.BeingAMathematician.org.

Connections with mathematics in the curriculum

The participants in the case studies were not in general asked to talk in detail about the mathematics they do. However in order that lecturers can use clips from the interviews as illustration during mathematics lectures, we have indicated in Appendix 4 some of the subject areas to which each interview might be relevant. This can be used, along with the timings given in the description of each case study in the next section and on the project website, to find short extracts from the interviews which are suitable as illustrative material in lectures.

List of books about mathematicians

There have been many recent books for the general reader about mathematicians and doing mathematics. Some are by mathematicians, and some are by writers outside the subject. In either case they can be the source of insights into the practise of mathematics, although of course there are issues concerning how representative of the profession a particular example might be. This list is included as Appendix 5 and is also available at www.BeingAMathematician.org.



Case Studies

This section contains summaries of each of the case studies – essentially what is on each web page.

Danny Brown:
"How about physically making something?"

Danny Brown is a mathematics teacher at Thomas Tallis School in Greenwich.

He talks about:

- is he a 'mathematician'? (at time 0:21)
- support and professional networks (1:32)
- the value of social media (2:38)
- Twitter (3:09)
- his mathematics website (4:01)
- obstacles to his career (5:24)
- role models (5:37)

Danny's website at www.makemaths.com contains ideas about mathematics teaching, and he tweets as @dannytybrown

Nira Chamberlain:
"You don't need anybody's permission to be a great mathematician"

Nira Chamberlain is a mathematical modelling consultant.

He talks about:

- his career (at time 0:10)
- the skills mathematical consultants need (1:37)
- professional bodies and Chartered status (2:22)
- doing a part-time PhD and working the "Nairobi shift" (3:53)
- the obstacles he has faced (5:03)
- the joys of being a professional mathematician (6:42)

Rosemary Dyson:
"A very very very applied mathematician"

Rosemary Dyson is a Lecturer in Applied Mathematics at the University of Birmingham and part of the Systems Science for Health initiative.

She talks about

- her career so far (at time 0:10)
- the kind of mathematics she does and how she describes herself (0:51)
- what is an applied mathematician? (1:31)
- the mathematics of how plants grow (2:46)

- how mathematicians differ from other professionals (3:48)
- how social networking facilitates collaboration (4:39)
- dissemination of her work (7:07)
- encouraging people to stay in mathematics - the LMS Women in Mathematics Day and the IMA Younger Mathematicians Conference (8:10)
- outreach (8:40)
- study groups (9:09)
- women in mathematics and the importance of role models (10:34)
- teaching and its connection with research (12:39)
- teaching mathematical modelling: the skills required, and how some potential mathematicians are turned off the subject (14:05)

Peter Furness:
"I have 'Mathematician' on my business card"

Peter Furness, consultant in decision analytics, modelling and data mining, talks about his career.

He discusses:

- how he describes himself (at time 0:08)
- the image of mathematics in his field of commercial consultancy (1:23)
- the skills required by a mathematician in that field (4:21)
- the support available (6:26)
- the value of Chartered Mathematician status (9:29)
- how he disseminates his work (11:59)
- the obstacles he has faced in his career (13:43)
- the opportunities for mathematicians setting out on careers now (15:39)

Peter Furness's website is at www.peterfurness.co.uk

Jay Jobanputra:
"A mathematician will always stand out"

Jay Jobanputra talks about his career as a mathematician in the investment banking sector in the UK and abroad. He now works part-time in order to have time to develop an educational product to motivate children at a critical time in their mathematical education.

He talks about:

- his career (at time 0:09)
- mathematics in the financial sector (0:30)
- the value of qualifications and credentials (1:34)
- what 'mathematician' means in the City (1:51)
- the value of mathematics (2:20)
- the culture of financial organisations (2:54)
- support for one's career (3:59)
- the importance of networking and upskilling (4:25)
- professional bodies (5:06)

- obstacles facing mathematicians in the financial sector (5:36)
- his outside interest in mathematics education (6:48)
- what a mathematician offers to employers in the financial sector (8:16)

Jay Jobanputra's educational website is at www.jdbooster.com

Sue Merchant:
"An ability to empathise with the client"

Sue Merchant is an independent management consultant. She is a past President of the Operational Research Society and Vice-President elect of the International Federation of OR Societies (IFORS). "Factors essential to survival as a working mum include a hugely supportive family, painstaking organisation and helpful bosses."

She talks about:

- her career in operational research (at time 0:10)
- how she describes herself professionally (1:17)
- the skills needed by mathematicians in her field (1:45)
- the characteristics of a mathematician (3:08)
- the credentials needed by a practitioner (3:35)
- the support available to operational research professionals (4:36)
- how she disseminates her work (5:40)
- working on her own and with others (7:06)
- obstacles she has faced in her career (8:07)
- the challenges faced in returning to work after maternity leave (9:02)
- role models (11:30)

Mason Porter:
"I don't usually prove theorems"

Mason Porter is an applied mathematician who is a University Lecturer and Tutor at the University of Oxford.

He talks about:

- his work (at time 0:09)
- being a mathematician (1:04)
- how mathematics compares with other disciplines (1:35)
- applied mathematics and pure mathematics (2:04)
- academic mathematics and industry mathematics (2:48)
- support in his professional life (3:56)
- professional credentials (5:32)
- dissemination of his results (6:15)
- promoting the subject (8:39)
- the public image of mathematics (10:12)
- the "leaky pipeline" where women are lost to mathematics careers (11:44)
- the value of role models for potential mathematicians (14:28)

Gwyneth Stallard: "That moment when suddenly things fit together"

Gwyneth Stallard is Professor of Pure Mathematics at the Open University.

She talks about:

- defining her profession (at time 0:29)
- teaching at the Open University (0:44)
- research in pure mathematics (1:40)
- the characteristics of a mathematician (5:42)
- the value of collaboration (7:28)
- the support a research mathematician needs (9:26)
- how work is disseminated (11:41)
- the difficulties she has overcome, in finding a job after completing her PhD (13:17)
- and in returning to research after maternity leave (15:14)
- women in mathematics (16:54)

Jackie Stedall on Thomas Harriot (1560-1621)

Jackie Stedall talks about Thomas Harriot, a notable mathematician who lived in the late sixteenth and early seventeenth centuries.

She talks about:

- Harriot's mathematics (at time 0:16)
- was Harriot a ‘professional mathematician’? (0:42)
- Harriot's patrons (0:51)
- mathematical career patterns in Harriot's time (1:32)
- Harriot's interest in navigation (2:22)
- the problem of stacking cannon balls (3:14)
- mathematics without immediate practical applications (4:11)
- did Harriot work collaboratively with others? (4:59)
- Harriot's communications with other mathematicians (5:51)
- how Harrriot disseminated his work (6:45)
- Harriot's reputation as a mathematician (7:45)
- would Harriot have described himself as a mathematician? (9:50)
- were Harriot's patrons interested in his mathematics? (10:48)

Jackie Stedall researches and teaches history of mathematics at the University of Oxford. She has written a number of books on Early Modern European mathematics. She is a longstanding member of the British Society for the History of Mathematics and Editor of its *Bulletin*.

Further reading:

Jacqueline Stedall, *A Discourse Concerning Algebra: English Algebra to 1685* (Oxford: Oxford University Press, 2003)

Jacqueline Stedall, *The Greate Invention of Algebra: Thomas Harriot’s Treatise on equations* (Oxford: Oxford University Press, 2003)

Wikipedia: Thomas Harriot

Jackie Stedall’s other works include:

Jacqueline Stedall, *The History of Mathematics: A Very Short Introduction* (Oxford: Oxford University Press, 2012)

Eleanor Robson and Jacqueline Stedall, *The Oxford Handbook of the History of Mathematics* (Oxford: Oxford University Press, 2011)

Jacqueline Stedall: *Mathematics Emerging: A Sourcebook 1540 - 1900* (Oxford: Oxford University Press, 2008)

Patricia Fara on Emilie du Chatelet (1706-1749), "A normal woman and a good scientist"

Patricia Fara, historian of science at the University of Cambridge, talks about Emilie du Chatelet (1706-1749), mathematician, translator and populariser of Newton's work in France.

We learn about:

- du Chatelet's background and education (time 0:28)
- her interest in Newtonian ideas (0:52)
- her relationship with Voltaire (1:32)
- her attitude to life and science (2:11)
- the book Elements of the Philosophy of Newton (2:49)
- her translation of Newton's Principia (4:19)
- what was behind du Chatelet's achievement (6:11)
- her context: differences between French and English society in her time (6:51)
- a parallel with Mary Somerville (8:15)
- du Chatelet as a woman in science (9:42)

Patricia Fara has a degree in physics from Oxford University and a PhD in History of Science from London University. She now lectures in the History and Philosophy of Science department at Cambridge, where she is the Senior Tutor of Clare College. Her major research specialities are science in eighteenth-century England and scientific imagery. A regular contributor to popular journals as well as radio and TV, she has published a range of academic and popular books on the history of science, including *Newton: The Making of Genius* (2002), *Sex, Botany and Empire* (2003) and *Pandora's Breeches: Women, Science and Power in the Enlightenment* (2004). Her latest book is *Science: A Four Thousand Year History* (2009), which has recently been awarded the biennial Dingle Prize by the British Society for the History of Science. Her next book, *Erasmus Darwin: Sex, Science & Serendipity*, will be published by Oxford University Press in the autumn of 2012.

Further reading:

Patricia Fara, *Pandora's Breeches: Women, Science and Power in the Enlightenment* (London: Pimlico, 2004)

"Scientists without Beards": Patricia Fara on Emilie du Chatelet (OUP blog) http://blog.oup.com/2009/05/scientists-without-beards/ [accessed June 2012].

Wikipedia, Emilie du Chatelet

Patricia Fara's other books include:

Science: A Four Thousand Year History (Oxford: Oxford University Press, 2009)

Newton: the Making of Genius (London: MacMillan, 2002)

Karen Parshall on James Joseph Sylvester (1814-1897): "An outsider breaking into the established societal norms"

Karen Parshall talks about the nineteenth-century mathematician James Joseph Sylvester.

We learn about:

- Sylvester's family background and Jewish heritage (at time 0:27)
- being a Jew in Victorian Britain (1:21)
- his mathematical education (1:57)
- further impact of his Jewishness (2:37)
- a Jew at Cambridge (3:13)
- his first publications (4:24)
- progressing his career, and facing obstacles (5:25)
- end of his first stay in the USA (6:51)
- back in London: a job as actuary, and research progress (7:21)
- "creating his own mathematical community" (8:41)
- his friendship with Cayley (8:58)
- Invariant Theory (9:41)
- taking a degree in law (10:19)
- back to Academia as Professor of Mathematics at the Royal Military Academy, Woolwich (10:41)
- defining the "professional mathematician" (11:11)
- Sylvester at Woolwich (11:42)
- enforced retirement, establishing an international reputation (12:30)
- flourishing back in America as a research professor (13:37)
- return to England and the Savilian Chair at Oxford (15:46)

Karen Parshall is a historian of mathematics at the University of Virginia. She has a particular research interest in the life, times, and mathematical work of James Joseph Sylvester. She is the author of many books and articles on the history of mathematics, including those listed below.

Further Reading

Karen Hunger Parshall, *James Joseph Sylvester: Jewish Mathematician in a Victorian World* (Baltimore: Johns Hopkins University Press, 2006).

Karen Hunger Parshall, *James Joseph Sylvester: Life and Work in Letters* (Oxford: Clarendon Press, 1998).

Wikipedia, James Joseph Sylvester

Karen Parshall's other books include:

Karen Hunger Parshall and David E. Rowe, The Emergence of the American Mathematical Research Community (1876-1900): J. J. Sylvester, Felix Klein, and E. H. Moore, AMS/LMS Series in the History of Mathematics, vol. 8 (Providence: American Mathematical Society and London: London Mathematical Society, 1994; paperback edition, 1997).

Jeremy J. Gray and Karen Hunger Parshall, editors, Episodes in the History of Modern Algebra, AMS/LMS Series in the History of Mathematics, vol. 32 (Providence: American Mathematical Society and London: London Mathematical Society, 2007).

Noel-Ann Bradshaw on Florence Nightingale: "What use were mathematics to a married woman?"

Noel-Ann Bradshaw talks about Florence Nightingale (1820-1910), the first woman to be elected a Fellow of the Royal Statistical Society.

We learn about:

- what you may not know about Florence Nightingale (time 0:21)
- her early interest in mathematics and her parents' disapproval (0:49)
- her early career and views on education (1:38)
- the Crimean War (2:36)
- her Polar Area Diagrams (3:34)
- Nightingale's impact (4:06)
- her work back in England (4:52)
- Nightingale as statistician (5:32)

Noel-Ann Bradshaw is principal lecturer in mathematics and operational research at the University of Greenwich, and is currently Treasurer of the British Society for the History of Mathematics. She tweets as @NoelAnn.

Further Reading:

- Eileen Magnello, 'Florence Nightingale: the Compassionate Statistician" (Plus Magazine) http://plus.maths.org/content/florence-nightingale-compassionate-statistician [accessed 8 June 2012].
- Hans Rosling, Eileen Magnello and David Spiegelhalter, The Joy Of Stats: The Lady With A Data Visualisation (Open University video)
- Wikipedia: Florence Nightingale
- Florence Nightingale biography (MacTutor) http://www-history.mcs.st-andrews.ac.uk/Biographies/Nightingale.html [accessed June 2012].

Tony Mann on Hugh Everett III: Many Worlds of Mathematics

Tony Mann talks about the career of Hugh Everett III (1930-1982), famous for his 'Many Worlds' interpretation of quantum theory.

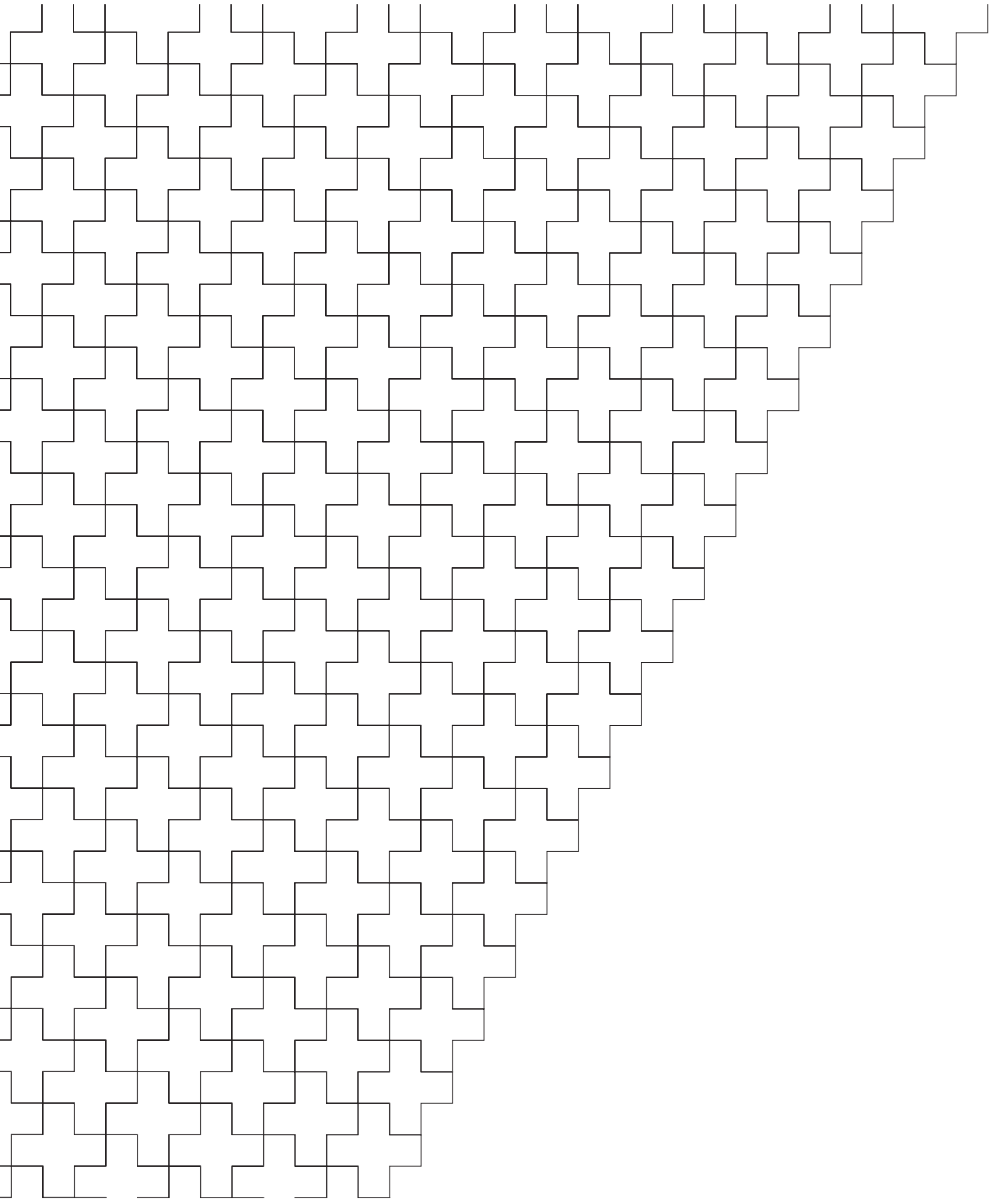
He talks about:

- introduction to Everett's career (time 0:10)
- Everett's work in Quantum Theory (0:43)
- Game Theory and Operations Research (2:13)
- consultancy (3:12)
- belated interest in Everett's ideas on Quantum Theory (3:30)
- Everett's death (4:01)
- summary of his career (4:25)

Tony Mann teaches mathematics at the University of Greenwich, and was President of the British Society for the History of Mathematics 2009-2011. He is Visiting Professor of Computing Mathematics at Gresham College for 2012-2013, and runs the maths blog 'Tony's Maths'. He tweets as @Tony_Mann.

Further Reading:

- Peter Byrne, The Many Worlds of Hugh Everett III: Multiple Universes, mutual assured destruction, and the meltdown of a nuclear family (Oxford University Press, 2010)
- Wikipedia: Hugh Everett III



Providing feedback

We hope that the resources created by this project will prove useful. We would welcome all feedback.

In particular, we would like to know:

- How the resources are being used;
- Tutors' views of the resources;
- Students' views of the resources.

Feedback can be sent to the project team by email: contact details as of May 2012 are as below. Up-to-date contact information will be maintained on the project website www.BeingAMathematician.org

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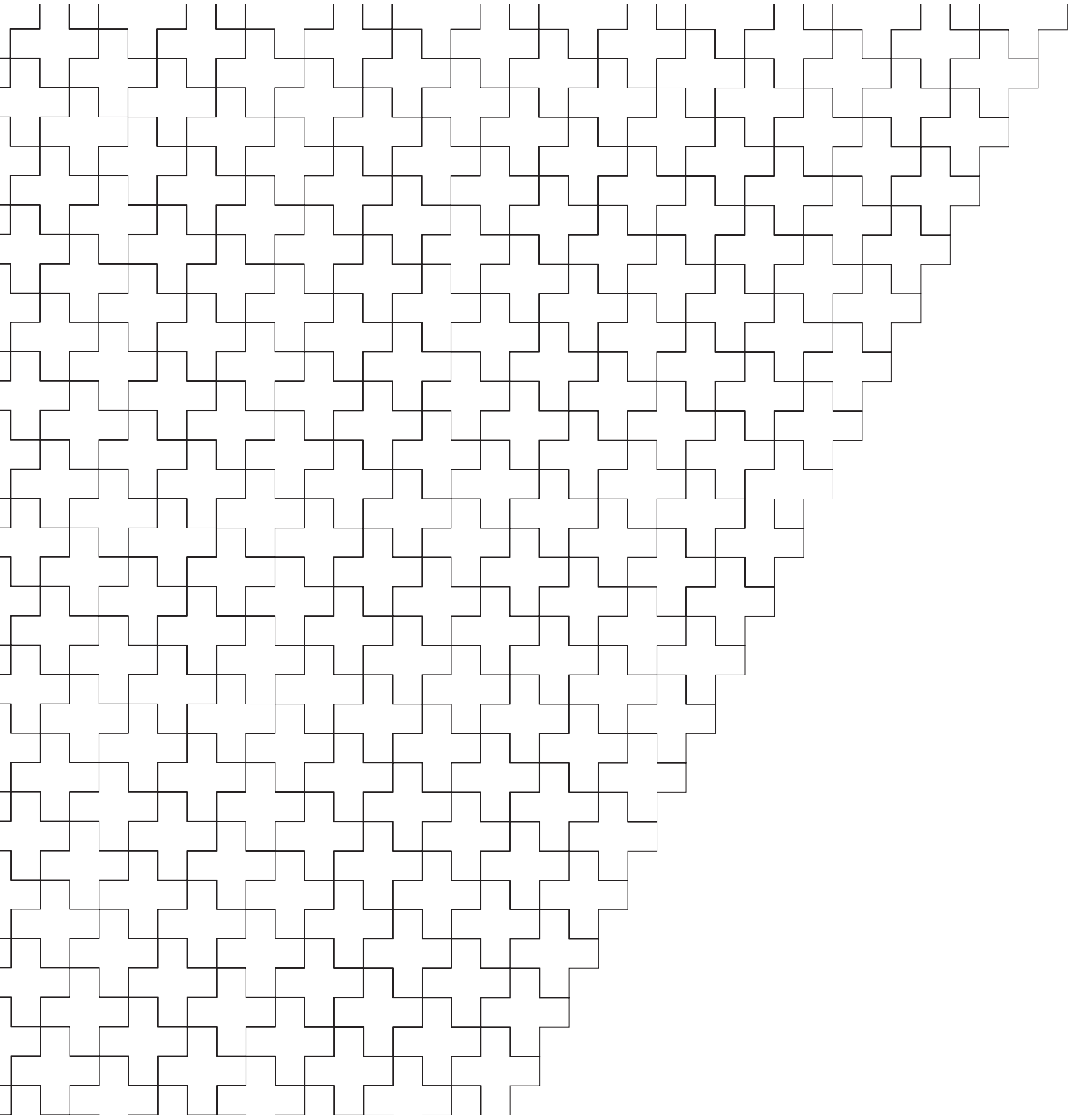


References

[1] P. Rowlett (editor) (2011). *HE Mathematics Curriculum Summit: A report on the summit held at the University of Birmingham on 12 January 2011*. MSOR Network. Available via: http://mathstore.ac.uk/node/1730 [accessed May 2012].

[2] J. Mason, L. Burton and K. Stacey (2010). *Thinking Mathematically*. Prentice-Hall.

[3] K. Houston (2009). *How to think like a mathematician*. Cambridge University Press.

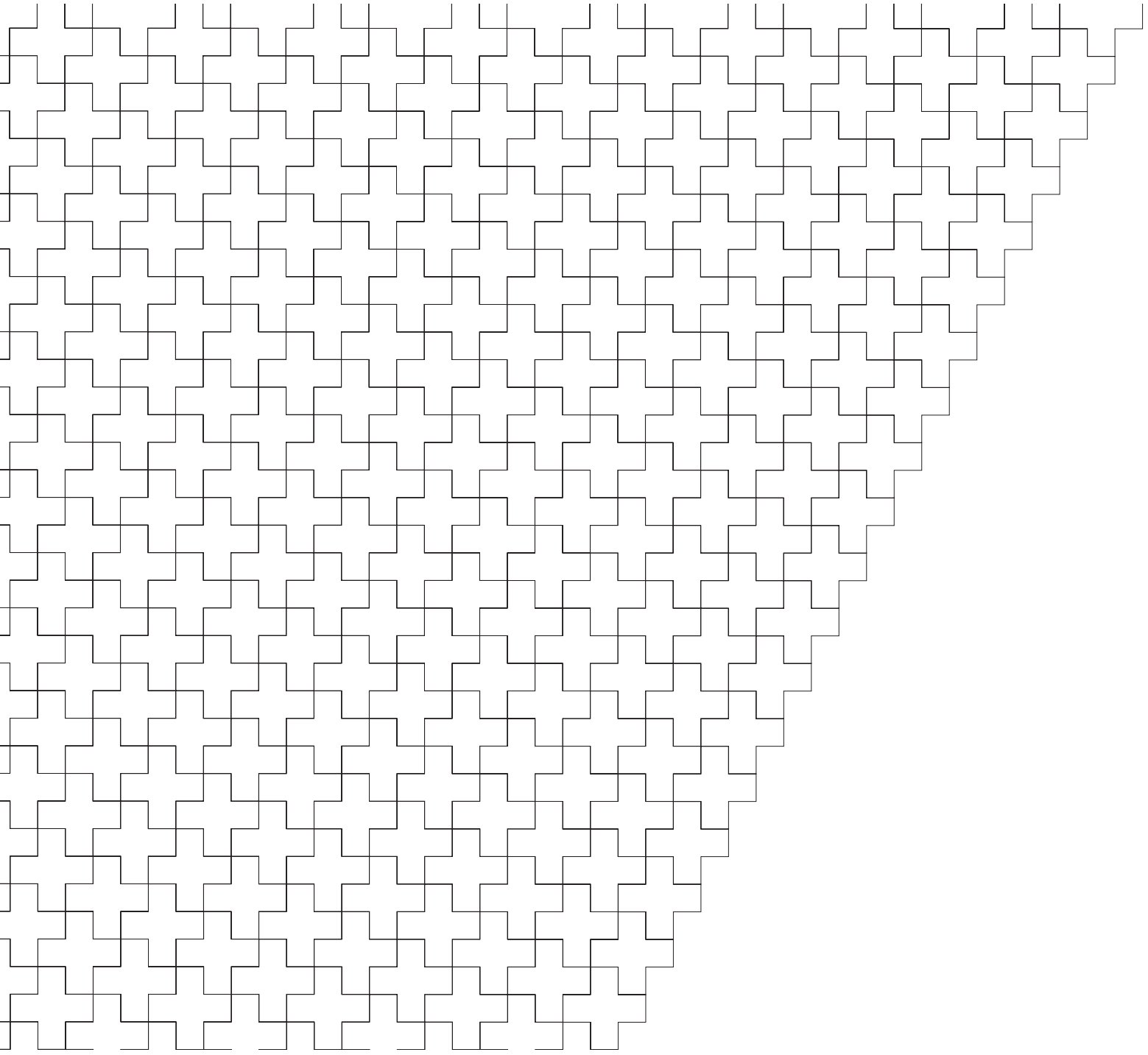
[4] QAA (2007). *Subject benchmark statement: Mathematics, statistics and operational research*. Available via: http://www.qaa.ac.uk/Publications/InformationAndGuidance/Pages/Subject-benchmark-statement-Mathematics-statistics-and-operational-research.aspx [accessed May 2012].

[5] QAA (2009). *Annex to subject benchmark statement: Mathematics, statistics and operational research*. Available via: http://www.qaa.ac.uk/Publications/InformationAndGuidance/Pages/Annex-to-Subject-benchmark-statement-Mathematics-statistics-and-operational-research.aspx [accessed May 2012].

[6] McCartney, M., ed., 2012. *History of Mathematics in the Higher Education Curriculum*. MSOR Network.

[7] Creative Commons. *Human-readable Summary of Licence Terms*. Available via: http://creativecommons.org/licenses/by-nc-sa/3.0/ [accessed May 2012].

References which appear in the worksheets and other resources reproduced from www.BeingAMathematician.org are not duplicated here.



Appendix 1 – Worksheets

The following pages reproduce the ‘Tutor versions’ of the eight worksheets on the following themes discussed in the report on page 13.

The topics covered are

- Is mathematics a static body of knowledge or a developing subject?
- The public image of a professional mathematician.
- What makes a professional mathematician?
- The importance of professional bodies.
- What skills do you need to become a professional mathematician?
- Are there equal opportunities in mathematics?
- Role models in mathematics.
- Visual representations of mathematicians.

Mathematics: a static body of knowledge? – worksheet

	Exercise	Tutor's comments
1)	Do you regard mathematics as an essentially static, already worked out, body of knowledge or as a developing subject in which new discoveries are being made? Has your view changed during your degree studies?	
2)	Identify mathematical topics from your degree which were developed to their present level: • Before 1600 • In the seventeenth century • In the eighteenth century • In the nineteenth century • In the first half of the twentieth century • In the second half of the twentieth century • In the 21st century Can you identify mathematical ideas you have come across during your studies that were not known ten years ago? If not, is this because there are no mathematicians working today or because it takes time for new ideas to reach the university curriculum?	Possible answers (not necessarily definitive, or even right! Most of these are ongoing) Before 1600: Euclidean geometry C17: logarithms, calculus C18: Euler's work C19: analysis, electrodynamics Early C20: relativity, classical number theory, probability and statistics. Even Galois theory! Late C20: group theory, combinatorics, operational research, statistics, numerical mathematics, cryptography (RSA), Black-Scholes C21: ??

3)	Where are mathematicians creating new mathematics? Of the mathematicians interviewed in the case studies at www.BeingAMathematician.org which ones say they are creating new mathematics? Do you think the others, who are generally being paid to solve problems that no-one has solved before, are not creating new mathematics, then what are they doing? How do mathematicians disseminate their work? (Many of the interviews talk about this.) Why does it take new ideas so long to reach the University curriculum? Find recent news stories about mathematics. How do they present the mathematics? Do the reporters get it right? Would a non-mathematician appreciate, from their school education, from news coverage, or from other sources, that mathematics is a living subject in which new discoveries are being made? Why do we not often read about new mathematical ideas in the newspapers? (Mason Porter talks about this in the interview at www.BeingAMathematician.org, at 8:39). How is mathematics presented at the annual British Science Festival (http://www.britishscienceassociation.org/web/britishsciencefestival/)? Why do you think there are relatively few presentations about new discoveries in pure mathematics at this Festival?	In academia? In industry? In the financial sector? Sitting at computers? At blackboards? Stallard and Porter (the academics) are explicit that they are creating new mathematics. Dyson's account of doing mathematics is worth discussion. Most of the others don't say it explicitly but they discuss disseminating their work, which implies new ideas! Danny Brown, as a teacher, might not be thought to be creating new mathematics, though he may be making new mathematicians. It is very hard to convey pure mathematical ideas to the lay public in a short talk in the Festival format. The organisers would be delighted if more such maths were presented in an accessible way!

The public image of professional mathematicians – worksheet

	Exercise	Notes for tutors
1)	Draw a sketch of a mathematician. What do the sketches say about your idea of a mathematician? Search Microsoft clipart or Google Images for “mathematician”. What kind of images come up?	Consider age, gender, race of sketched figures. Consider accessories (Spectacles? Beards?) Are these positive or negative images? Do students draw people like themselves? Do clipart images reflect similar assumptions?
2)	What do mathematical jokes tell us about being a mathematician? Consider (some of) the following jokes at www.BeingAMathematician.org/Jokes: • Three logicians go into a bar… (Spiked Math) • The Null Hypothesis (xkcd) And four jokes that are part of mathematicians’ folklore: • The mathematician, the doctor and the lawyer • The mathematician, the engineer and the computer scientist • The racehorse study • Putting out a fire In each case: i) Explain the point of the joke ii) Do you think it is funny? iii) Would a non-mathematician think it is funny? iv) Does it present a positive image of a mathematician? v) Does it make assumptions about the age, gender and other characteristics of the mathematician? Analyse other jokes about mathematicians in the same way. Why do professional communities tell jokes about their profession?	Discuss the assumptions behind the jokes. Eg mathematician, doctor, and lawyer: is there a hidden assumption that any professional is male? Search Microsoft clipart for images of “doctor” and “lawyer”. Do the results reflect on the assumptions in this joke? How old is this joke? Are the attitudes it embodies still current? Are jokes used to define a profession, to distinguish it from others, to create a sense of community (you belong to the community if you find these jokes funny)?

3)	What images of mathematicians are available to the general public? • What (contemporary and historical) mathematicians are known to the public? • Think of TV programmes, films, novels etc involving (real or fictitious) mathematicians. Do these appeal to mathematicians, non-mathematicians or both? What are typical characteristics of fictional mathematicians? How are they used by their creators? For example, are fictional mathematicians generally • Intelligent • Attractive • Evil • Introverted • Ambitious • Successful How are "scientists" portrayed in fiction and popular culture? Is that different from "mathematicians"? Do the characteristics of these (real or fictional) publicly-known mathematicians match those of real mathematicians you have come across? Do they match the characteristics of mathematicians you have identified in answering the previous questions? What impression of mathematicians is conveyed in recent biographies of mathematicians such as Paul Erdos, Simon Norton and Grigori Perelman?	Expect answers to include: Real mathematicians – probably very few. Marcus du Sautoy? Stephen Hawking? Dara O'Briain? Carol Vorderman? **TV programmes:** Dara O'Briain's *School of Hard Sums* *Numb3rs* Marcus du Sautoy's *The Code* *The Big Bang Theory* **Novels:** Mark Haddon's *The curious incident of the dog in the night-time* Scarlett Thomas's *PopCo* Tefcros Michaelides's *Pythagorean Crimes* Is "mathematician" shorthand for "intelligent"? Are mathematicians portrayed as scheming villains? Is this different from the portrayal of scientists? Does the public image of mathematicians focus on the most eccentric? If you sample random mathematicians in the St Andrews biographical archive, do you get a different perspective?
4)	How do people respond in social situations when you tell them you are studying maths? Which aspects of the responses are positive and which are negative?	Possible answers: Positive: people think you are intelligent Negative: People are intimidated, or write you off as an uncool nerd.

What makes a professional mathematician? – worksheet

	Exercise	Tutor's comments
1)	What is your definition of mathematician? You might consider the following: Someone who does mathematics Someone who uses mathematics Someone who proves theorems Someone who solves problems Someone who has a degree in mathematics Someone who has studied or is studying mathematics Do you consider yourself to be a mathematician? Listen to what the case study interviewees at www.BeingAMathematician.org say about being a mathematician – eg Danny Brown: is a maths teacher a mathematician? What definition do professional bodies (LMS, IMA, RSS) use?	Can you call yourself a mathematician, or do you need credentials? A medical student would call themselves a "medic". A language student would call themselves a "Linguist". Would the community regard a maths undergraduate as a mathematician? The LMS expects a PhD or similar. The RSS accepts anyone who says they want to be a member.
2)	What makes something a "profession"? Think of examples and suggest what distinguishes them from non-professional activities. Which of the characteristics of other professions apply to the world of mathematics?	Prompts: If students don't raise these, suggest the following Professions might include law, accountancy, medicine, etc Characteristics might include: • Existence of professional bodies? • Registration / credentials • Regulation / fitness to practice • Recognition by others • High salaries
3)	What credentials might a mathematician have? In what circumstances would they be useful? (Think about the different views expressed in the case studies at www.BeingAMathematician.org – for example Nira Chamberlain, Peter Furness, Sue Merchant and Mason Porter, and in the historical case study James Joseph Sylvester seeking to build an international reputation.)	Degree Membership of professional body Chartered status Publications Useful in seeking employment, promotion, convincing clients you are qualified? Depends on age – once you are established credentials are less important? Less important for academics? (Porter interview)

4)	What is the role of professional bodies? (You will find at www.BeingAMathematician.org/ProfessionalBodies interviews with representatives of the four main mathematical professional bodies and learned societies, together with links to the websites of other organisations) • What are the professional bodies and learned societies in mathematics? • How many members do they have? How does this compare with, say, the Institute of Physics? • What kind of people are members of each society? Academics? Industry mathematicians? Teachers? Students? Retired people? • Do people join more than one of these societies? Why, or why not? • How do you join? • What grades of membership do they offer? • Do they offer credentials such as letters after your name? • What else do they offer to support professional mathematicians? What are the consequences of the existence of so many professional bodies and learned societies in mathematics? Who puts the views of mathematicians to policy-makers? Is there a single voice for mathematicians, like the Institute of Physics for physicists? Would mathematics benefit from having a single professional body? Why has this not happened?	This question is studied in more detail in the worksheet "The importance of professional bodies". In alpha order, IMA, LMS, ORSoc, RSS plus teaching bodies MA, ATM etc IOP has a lot more members than any single maths body? Difference between professional bodies supporting industry mathematicians and LMS for academics? Compare different criteria Compare different approaches Compare different approaches Conferences, research grants, magazines, journals etc. Compare different magazines!
5)	In a recent book (*Duel at Dawn: Heroes, Martyrs and the Rise of Modern Mathematics*) Amir Alexander has argued that since the nineteenth century mathematicians have seen their role model as the romantic rebel, working alone, and probably dying young and unappreciated by the established mathematics community. Examples would include Abel and Galois, as presented in E.T. Bell's *Men of Mathematics*. Is this your idea of a mathematician? Listen to the interviews with Gwyneth Stallard and Rosemary Dyson at www.BeingAMathematician.org. Do they have similar views about being a mathematician? Do the historical case studies at www.BeingAMathematician.org support Alexander's argument?	Prompts: Is this pure mathematics or applied? Is mathematics still a solitary pursuit? Was it ever? Has the computer changed things? Has email? Has the way pure mathematicians disseminate their results? Do these interviews suggest fundamental differences between the practice of pure and applied mathematics.

The importance of professional bodies – worksheet

Mathematical professional bodies, learned societies and other organisations relevant to the UK include:

- IMA (Institute of Mathematics and its Applications)
- RSS (Royal Statistical Society)
- OR Society
- LMS (London Mathematical Society)
- EMA (European Mathematical Society)
- EMA (Edinburgh Mathematical Society)
- MA (Mathematical Association)
- ATM (Association of Teachers of Mathematics)
- NANAMIC (National Association for Numeracy and Mathematics In Colleges)
- MEI (Mathematics in Education and Industry) (an independent curriculum development body)
- FMSP (Further Mathematics Support Programme)

By contrast, there is one main professional body for physics: the Institute of Physics (IOP), which has 40,000 members.

www.BeingAMathematician.org has interviews with representatives of the IMA, LMS, OR Society and RSS, who talk about the benefits the societies offer to their members. Find these under the **Resources** link.

There are also interviews with professional mathematicians who talk about how they see professional bodies and learned societies. The relevant sections begin at the times indicated.

- Danny Brown (from 1:32)
- Nira Chamberlain (from 2:22)
- Peter Furness (from 6:26)
- Jay Jobanputra (from 5:06)
- Sue Merchant (from 4:36)
- Mason Porter (from 4:24)
- Gwyneth Stallard (from 16:54)

	Exercise	Comments for tutors
1)	How do the mathematical learned societies and professional bodies differ from one another in the way the services they offer to their members? Do these differences result from different needs of different kinds of professional mathematician, or from some other cause? • What do their websites say about the societies (explicitly and implicitly)? • How open are the societies to potential members? • Do the societies have different categories of membership? • Do the societies offer professional accreditation? • What other benefits do the societies offer their members?	This worksheet looks in more detail at questions also raised on the worksheet "What makes a professional mathematician".
2)	One benefit offered by some professional societies is **credentials**. If you are a senior member of some professional bodies you may be a "Fellow" and may be entitled to put initials after your name. There is also "Chartered Mathematician" status. Are these credentials important for professional mathematicians in the fields in which you might make your career? The value of accreditation is discussed by mathematicians in the case study interviews at www.BeingAMathematician.org, at the following points: • Nira Chamberlain (from 2:22) • Peter Furness (from 9:29) • Jay Jobanputra (from 1:34) • Sue Merchant (from 3:35) • Mason Porter (from 5:32) • Gwyneth Stallard (from 16:54)	Note that the professional mathematicians in the www.BeingAMathematician.org case studies offer differing views on this. It depends, for example, on the kind of mathematics you do, and where you do it. Industry often values professional body credentials and academia sometimes doesn't.
3)	Why are there so many professional bodies and learned societies? What does the proliferation do for mathematics? • How do mathematicians decide which societies to join? • How big are the societies? • Who do politicians go to for advice on policy? • Do these societies "speak for mathematics"? Do they have influence? • What are the relationships between the societies - co-operative or competitive? A joke from the Institute of Physics (quoted in *Mathematics Today*, April 2012: "What is a mathematician's favourite operator? Division!" Is this fair? Is it funny?	Students might find on the web various discussion about the proposed merger between the LMS and the IMA,, which the LMS members voted against in 2009.

What skills do you need to become a professional mathematician? – worksheet

	Exercise	Comments for tutors
1)	Here is a list, in alphabetical order, of some skills and attributes that might be useful to a professional mathematician setting out on their career: • Ability to teach oneself about unfamiliar mathematical ideas • Ability to use social networking sites • Ability to work on one's own • Computing skills • Foreign language skills • In-depth knowledge of some areas of mathematics • LinkedIn presence • Networking skills • Oral communication skills • Overview of different branches of mathematics • Problem-solving skills • Teamwork skills • Time management skills • Written communication skills What other skills do you think might be necessary? Which three skills would you regard as most important? Which three skills listed above would you regard as least important? Does it depend on the area in which the mathematician wishes to make their career? It might help to listen to some of the interviews at www.BeingAMathematician.org. Relevant material can be found at the times indicated. • Danny Brown (from 1:32) • Nira Chamberlain (from 1:37) • Peter Furness (from 4:21) • Jay Jobanputra (from 0:30 and from 3:59) • Sue Merchant (from 1:45)	You might wish to withhold this list and have students think about the skills from scratch.
2)	For each of the skills and attributes listed above, rate yourself. Which parts of your degree addressed each of these skills? For the skills which you think are important, how do you demonstrate them in your CV? How would you prove to an interviewer that you had these skills? What can you do to improve these skills?	

Equal opportunities in mathematics? – worksheet

	Exercise	Tutor's comments
1)	Find on the internet group photographs of participants in mathematics conferences. Look at staff lists of university mathematics departments. Consider the classes you take as a mathematics undergraduate. Look at the list of mathematicians at the MacTutor history of mathematics website (http://www-history.mcs.st-and.ac.uk/). Look at the list of Fields Medallists, or other lists of eminent mathematicians. Are these evidence of diversity in mathematics? What is the gender balance? (In the case of conferences, has this changed over time?) Does the mix reflect that of the communities from which they are drawn?	Note: there are dangers that, for example, a focus on the gender balance in mathematics may discourage female students from pursuing a career in, say, research mathematics. The interview with Rosemary Dyson at www.BeingAMathematician.org is a particularly good resource in this respect because she is so positive in what she says. The excellent novel by Sue Woolfe, *Leaning towards infinity*, contains an account of a (hopefully fictitious) conference in which female mathematicians are very badly treated. If you have access to this book, you could discuss with students whether this account is plausible.
2)	Research some of the following mathematicians. What obstacles, if any, did they face as a result of their gender, race or other factors? Were and are there differences in equal opportunities in different parts of the world? Emilie du Chatelet (listen to Patricia Fara's account at www.BeingAMathematician.org)) Florence Nightingale (listen to Noel-Ann Bradshaw's account at www.BeingAMathematician.org) James Joseph Sylvester (listen to Karen Parshall's account at www.BeingAMathematician.org) David Blackwell Emmy Noether S. Ramanujan Mathematicians in the www.BeingAMathematician.org case studies - Danny Brown, Rosemary Dyson, Nira Chamberlain, Sue Merchant, Mason Porter, Gwyneth Stallard (listen to the recorded interviews) Jonathan Farley (see http://www.guardian.co.uk/commentisfree/cifamerica/2012/apr/12/black-mathematicians-john-derbyshire-fields-medal) See also the book *Loving + Hating Mathematics* by Reuben Hersh and Vera John-Steiner for discussion of lack of equal opportunities in the US mathematics world in the second half of the twentieth century.	

3)	Is there concern in the UK mathematics community about equal opportunities?	
	The London Mathematical Society as a "Women in Mathematics" Committee (see Gwyneth Stallard interview at www.BeingAMathematician.org). What does this tell us about the situation?	It tells us that there is a problem!
	Consider the LMS policy on Women in Mathematics at http://www.lms.ac.uk/sites/default/files/Mathematics/wim_statement.pdf	
	What does this tell us about the situation?	
	Do you support this policy?	
	What is the "leaky pipeline" in UK mathematics? (In the www.BeingAMathematician.org case studies, listen to Mason Porter talking about this. Listen to Gwyneth Stallard and Sue Merchant talking about returning to their mathematical careers after maternity leave, and listen to Rosemary Dyson about her experience as a woman in mathematics.)	
	What can be done to reduce the leaks in this pipeline?	
	Are things happening?	
	Is there similar concern about the racial equality in UK mathematics? Why, or why not?	Is there a class dimension to the problem? Is the under-representation of black mathematicians because black children aspire to be doctors or lawyers rather than mathematicians?
	What steps could be taken to make the UK mathematical community more representative of the population as a whole?	Role models may be important. There is a separate worksheet on role models which follows on naturally from this one.

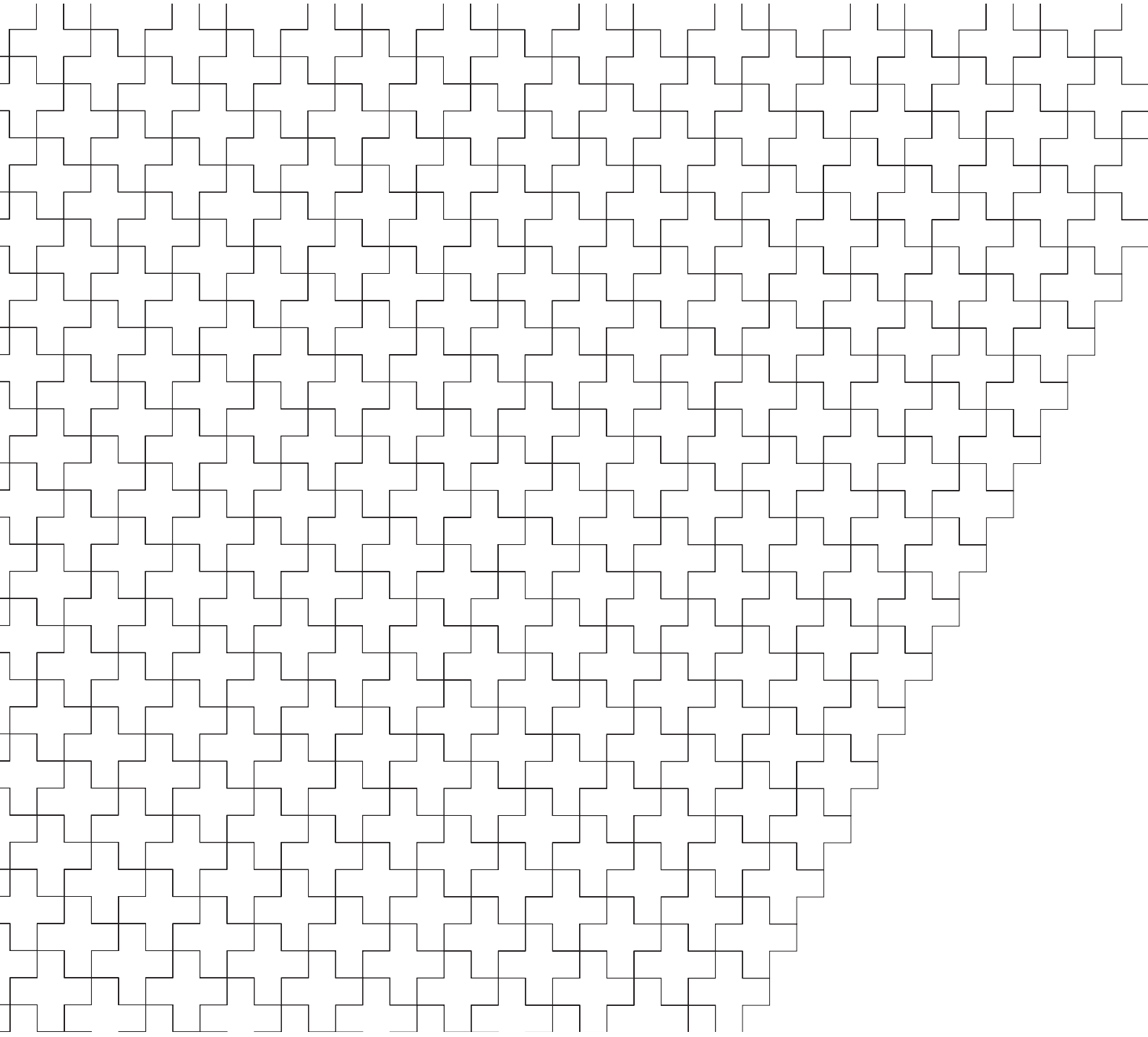
Role models in mathematics – worksheet

	Exercise	Tutor's comments
1)	Did you have a role model in mathematics when you were young? Do you now? Do your friends have role models in mathematics? Did or do you have role models for other important aspects of your life, for example in sport or music? Do people you know who are not mathematicians have role models in their fields? Can you give examples of people who might be role models for young footballers, athletes, musicians, celebrities? Can you suggest people who might be suitable role models for young mathematicians?	This worksheet can be used independently but could follow on from the "Equal opportunities in mathematics?" worksheet
2)	Listen to the case study interviews at www.BeingAMathematician.org where mathematicians Danny Brown, Nira Chamberlain, Rosemary Dyson, Sue Merchant, Mason Porter and Gwyneth Stallard talk about role models. Note that their personal experiences have been very different. Do their comments suggest that role models are less important for white men than for others? What do you conclude about the circumstances in which people benefit from role models? Is the lack of female or black role models in mathematics a factor in the continuing imbalance in the profession? If role models make a difference to members of minorities, why?	Role models give confidence, show that "someone like me" can succeed: they are an "existence proof" that it is possible that you can have a career in your chosen profession. White males have plenty of examples (at least if they are middle-class!) But if you don't see people like yourself in a profession, you may feel you don't belong! Rosemary Dyson's interview at www.BeingAMathematician.org is particularly instructive on this, as are the comments of Danny Brown and Mason Porter.

Visual representations of mathematicians – worksheet

	Exercise	Comments for tutors
1)	Draw a sketch of a mathematician. What do the sketches say about your idea of a mathematician? Search Microsoft clipart or Google Images for "mathematician". What kind of images come up? What attributes define the images as mathematicians?	This exercise also appears on the worksheet "The public image of professional mathematicians". Consider age, gender, race of sketched figures. Consider accessories (Spectacles? Beards?) Are these positive or negative images? Do clipart images reflect similar assumptions?
2)	Look carefully at the portrait of Emilie du Chatelet reproduced at www.BeingAMathematician.org/du_Chatelet. Does she look like a mathematician? Why, or why not? Does she look like a woman who enjoys parties and social life? What features in the painting relate to these questions? Now listen to Patricia Fara's account of du Chatelet.	Her fine, carefully chosen clothes; the dividers and geometrical diagrams; her well-used books; her direct gaze at the viewer
3)	Find some portraits or photographs of mathematicians. For example, you might look up specific mathematicians on Wikipedia, look at pictures in the MacTutor History of Mathematics archive (http://www-history.mcs.st-and.ac.uk/). Think about the images. Bear in mind that some may be posed photographs or paintings intending to document someone for posterity while others might be casual snaps. For these questions, paintings or formal portrait photographs may be more revealing than snapshots. Look also at some of the commissioned photographs "Faces of Mathematics" at http://www.ma.hw.ac.uk/~ndg/fom.html For each image you are considering: Do the images make the viewer think they are looking at a mathematician? If so, how? What (if anything) do the images tell you about being a mathematician?	

4)	In his recent book *Duel at Dawn: Heroes, Martyrs and the Rise of Modern Mathematics* (Harvard, 2010), Amir Alexander argues that portraits of Abel, Galois and János Bolyai (which you can find on the MacTutor website at http://www-history.mcs.st-and.ac.uk/) depict "misunderstood heroes whose inner fire and profound insights set them apart from their uninspired fellow men". Do you read the portraits in this way? Can you find other portraits of nineteenth-century mathematicians which support the view of mathematicians that Alexander describes? Can you find images which don't conform to that view? Do the "Faces of Mathematics" at http://www.ma.hw.ac.uk/~ndg/fom.html present contemporary mathematicians in this way? Do these images tell us anything about how mathematicians see themselves?	
5)	What does Arthur Sasse's famous photograph of Einstein sticking his tongue out tell us about Einstein? And about the public image of mathematicians? (http://en.wikipedia.org/wiki/Albert_Einstein_in_popular_culture)	Possible discussion about whether Einstein is considered to be a mathematician, either by mathematicians or by the general public.



Appendix 2 – Essay and PDP reflection topics

A list of possible essay titles is provided. Depending on the design of a degree programme, these might be appropriate in Personal Development Planning (PDP) work or in history of mathematics or 'mathematics in society' modules. The titles could be set as essay questions or for small group discussion. Once again, these are intended as suggestions which lecturers can adapt in any way they wish.

Points relevant to these topics can be found in the case study interviews and other resources: in addressing these topics students should be encouraged to explore these, using the cue points listed for each interview. Some topics are directly inspired by comments during the interviews, which are indicated below.

Employability

- What skills are needed by a professional mathematician or statistician?
- Do people doing mathematics in different sectors of industry and commerce call themselves "mathematicians"? If not, why not? What else do they call themselves?
- Do mathematicians in industry need different skills from those in academia?
- How soon in your mathematical studies can you choose your future career?
- Should a mathematician use LinkedIn?
- Is confidence desirable in a professional? Does mathematics build confidence (by helping you solve problems) or destroy it (by making you aware of what you cannot do)?

Professional bodies

- Which professional bodies aim to attract student members? How do they do this?
- Why do different professional bodies have different entry criteria?
- Is Chartered Mathematician status worth the effort?

Obstacles

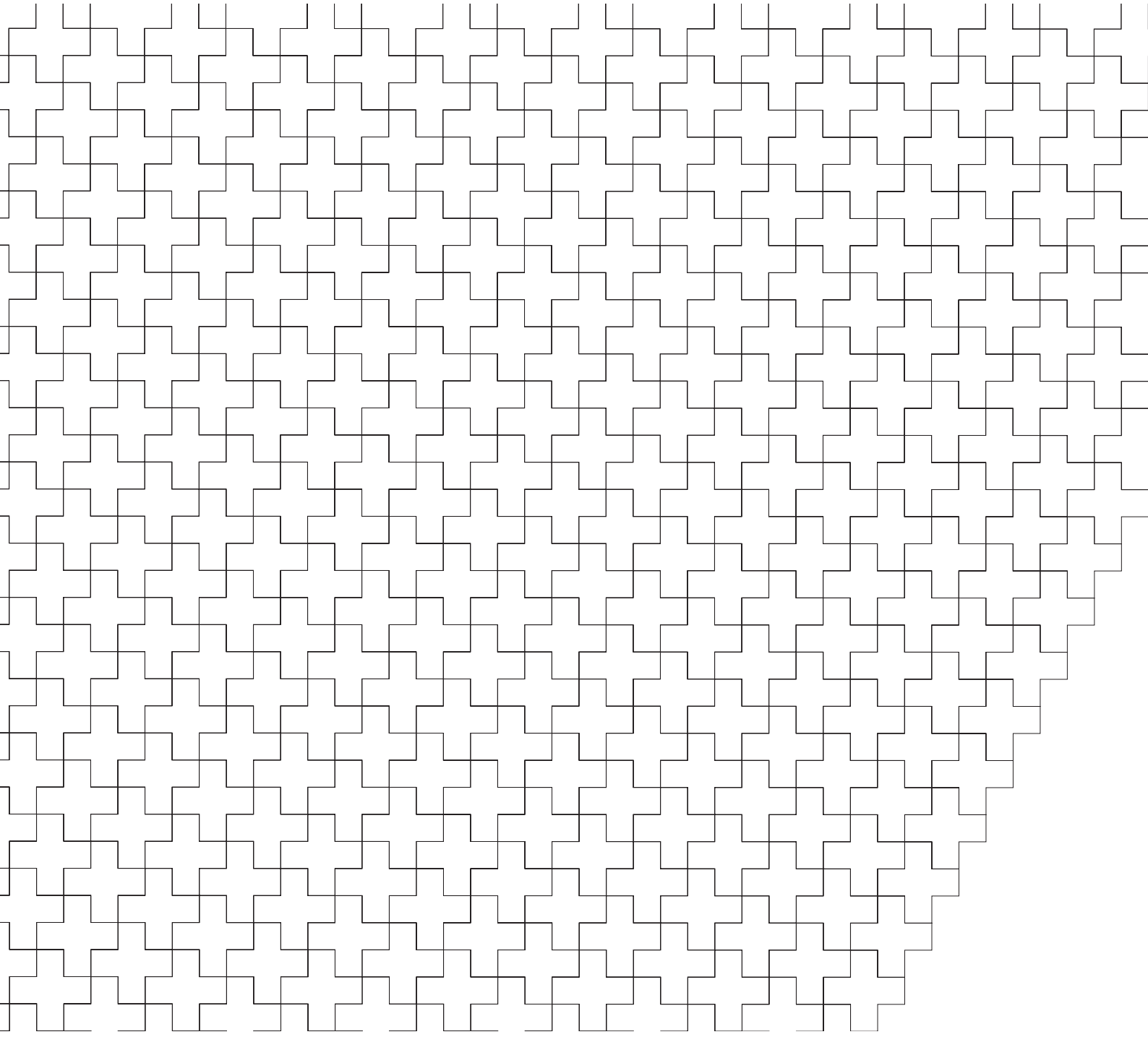
- Have you (the student) experienced or observed obstacles to your mathematical studies? How have they been overcome?

Role models

- Have you (the student) had role models in mathematics?
- Suggest suitable role models for a young mathematician
- Who is your favourite mathematician? In what ways do you identify with them?

Mathematics

- How do pure mathematicians differ from applied mathematicians?
- How do the attitudes of academic mathematicians differ from those of industry mathematicians?
- Are mathematicians different from statisticians? And from OR professionals?
- Is the best mathematics difficult mathematics? (Listen to Mason Porter from 2:04)
- Which is more important in mathematical modelling, deriving the equations or solving them? Which do you enjoy more? (Listen to Rosemary Dyson from 14:05)



Appendix 3 – Final year project suggestions

Many mathematics students undertake a final year project, where the student works independently with guidance from a tutor. It can be difficult to find suitable projects in mathematics, since few undergraduates are in a position to produce original work, but a successful individual project develops, and is evidence of, skills in time management, independent learning, and communication which are highly valued by employers. The topics with which 'Being a Professional Mathematician' is concerned provide a rich area for final year projects, involving research, critical thinking, and understanding of the mathematical community.

This list, which can also be found at www.BeingAMathematician.org, provides a variety of possible project ideas with, in many cases, suggested starting points.

Professional Mathematicians

The Professional Mathematician: how has the idea of a mathematician developed over the last four hundred years?

Start with the historical case studies at www.BeingAMathematician.org. When did the word 'mathematician' start defining a profession?

How do mathematicians think of the profession?

Start with Amir Alexander's book "Duel at Dawn" (see booklist at www.BeingAMathematician.org) which argues that the way mathematicians think of themselves changed after the time of Galois and Abel.

How do today's university mathematicians balance the demands of teaching and research?

Start with the case studies at www.BeingAMathematician.org of today's academics Dyson, Porter and Stallard and the historical case studies, especially Sylvester.

Is mathematics a solitary or collaborative activity? Has this changed over time?

Start with the case studies at www.BeingAMathematician.org

Professional Bodies

Why is the proliferation of professional bodies in mathematics so different from that in Physics, where the Institute of Physics speaks for the profession?

Starting point - the resources at www.BeingAMathematician.org on professional bodies and the worksheet on that topic. This project could look at the origins of the various societies and the subsequent relationships between them.

Obstacles

How have historical mathematicians overcome obstacles they faced because of their race, gender or religion? How was their mathematics influenced by these factors?

Start with the case studies at www.BeingAMathematician.org of Sylvester or du Chatelet, or research other mathematicians such as Emmy Noether or David Blackwell. Hersh and John-Steiner's book Loving + Hating Mathematics (see book list at www.BeingAMathematician.org) might be helpful.

Branches of Mathematics

When did statistics emerge as a discipline in its own right?

Start from the Wikipedia article "History of Statistics"

You could also study the emergence of operational research, financial mathematics, actuarial mathematics, or subjects like topology, analysis, etc.

The Impact of Mathematics

How does mathematics developed for its own sake come to find applications?

Start from the Plus magazine article at http://plus.maths.org/content/unplanned-impact-maths, which links to Peter Rowlett's article in Nature, and find further examples of planned or unplanned impact of mathematics.

The Undergraduate Curriculum

Where is the mathematics you have studied during your degree actually used?

You might focus on one module and find examples where its ideas and methods are used in industry or do an overall study of the whole curriculum.

Mathematics Education

Have initiatives like the Undergraduate Ambassadors Scheme helped address problems in maths education in the UK?

There is valuable background material in the report of Adrian Smith's 2004 inquiry, "Making Mathematics Count", and in Carol Vorderman's recent report on maths education.

How does maths education in the UK compare with that elsewhere?

Compare curriculum, numbers, outcomes

Representations of Mathematics

How are mathematicians depicted in fiction? OR How is mathematics used by fiction writers?

Alex Kasman maintains a list of mathematical fiction at http://kasmana.people.cofc.edu/MATHFICT/ and Tony Mann's list of mathematical fiction is at http://staffweb.cms.gre.ac.uk/~A.Mann/Fiction/. See also Tony Mann, 'From Sylvia Plath's The bell jar to the Bad Sex Award: a partial account of the uses of mathematics in fiction', BSHM Bulletin: Journal of the British Society for the History of Mathematics, 25 (2010): 2, 58 - 66. See also Wikipedia on The Oulipo.

How are mathematicians depicted on screen?

See Oliver Knill's web page "Mathematics in Movies" at http://www.math.harvard.edu/~knill/mathmovies/

Visual images of mathematicians

Start from the worksheet at www.BeingAMathematician.org on this topic

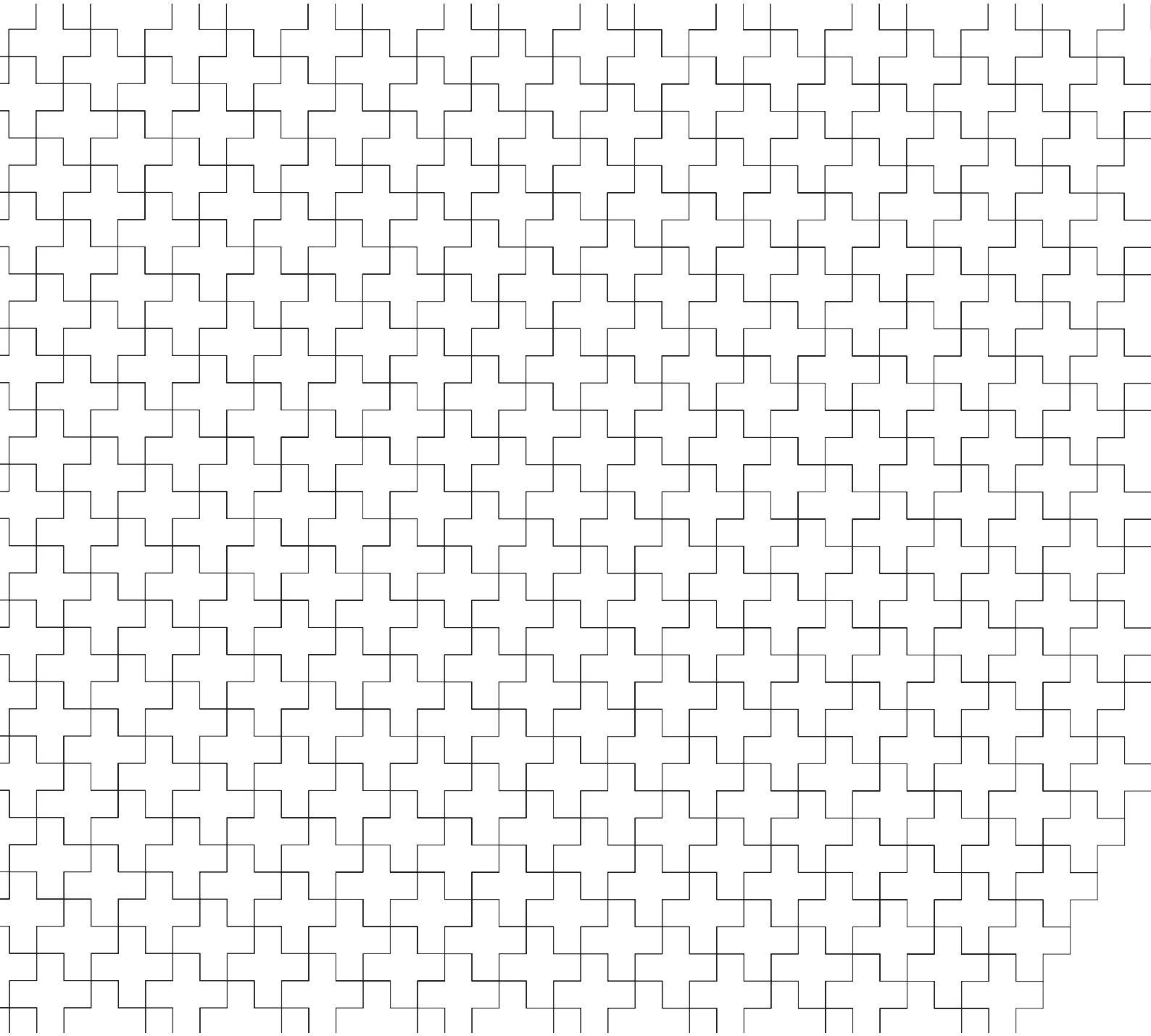
Mathematics in the Press

How accurately is mathematics or statistics) represented in the press?

Start by finding recent reports.

How could mathematicians improve public awareness of their subject?

What attempts do mathematicians currently make to put their subject before the public? Think about popular books, newspaper articles, British Science Festival, Stand-Up Maths and so on.

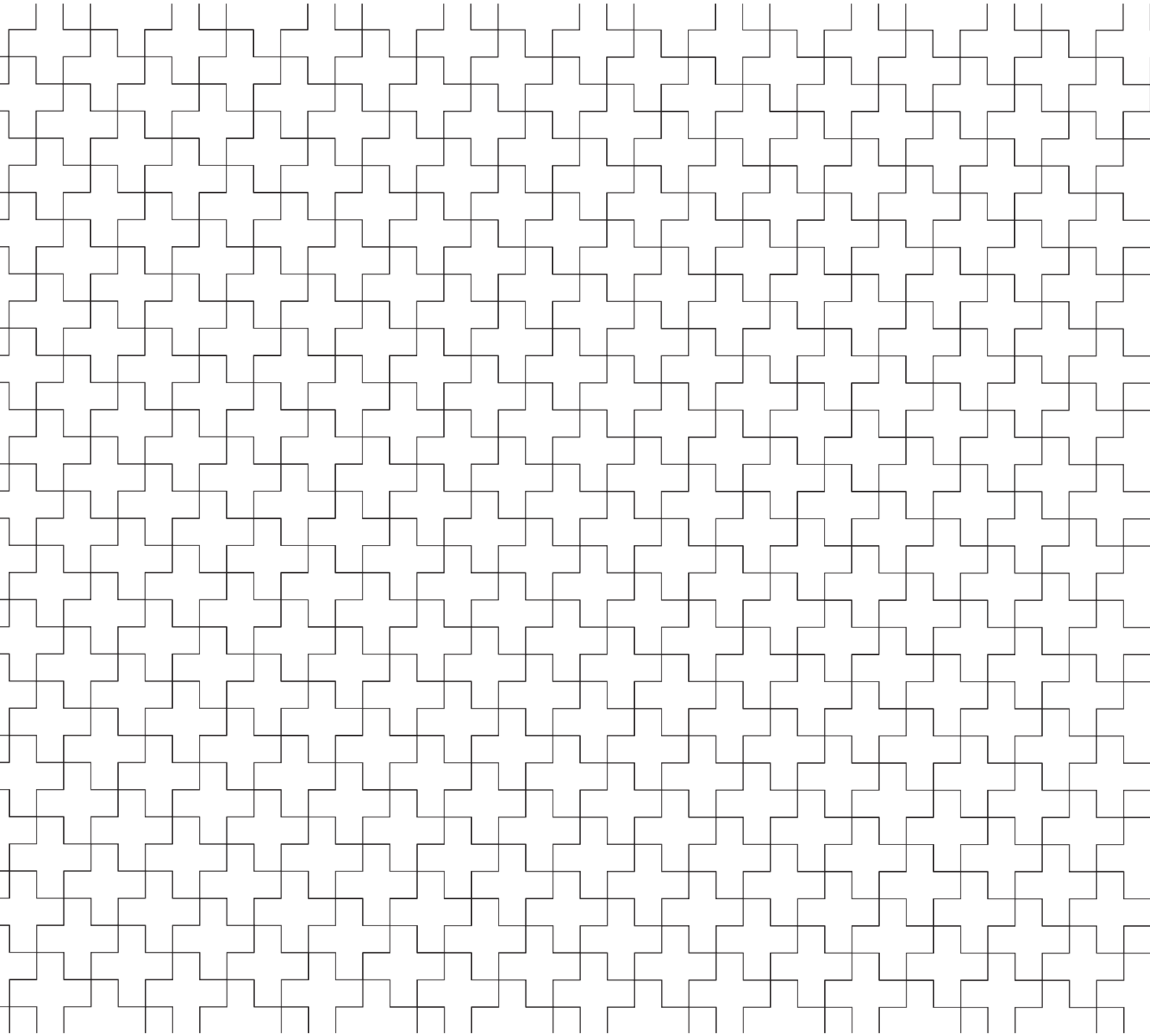


Appendix 4 – Case studies and the curriculum

The participants in the case studies were not in general asked to talk in detail about the mathematics they do. However in order that lecturers can use clips from the interviews as illustration during mathematics lectures, we have indicated some of the subject areas to which each interview might be relevant.

The areas naturally overlap and the terminology is not intended to be in any way definitive.

Danny Brown:	Geometry Mathematics education
Nira Chamberlain:	Mathematical modelling Engineering mathematics Industrial applied mathematics
Rosemary Dyson:	Applied mathematics Mathematical modelling Mechanics
Peter Furness:	Operational Research Data mining Modelling
Jay Jobanputra:	Statistics Actuarial mathematics Risk modelling
Sue Merchant:	Operational Research Statistics
Mason Porter:	Applied mathematics Non-linear and complex systems Mathematical modelling
Gwyneth Stallard:	Pure Mathematics Chaos Theory Complex Analysis
Thomas Harriot (1560-1621):	Astronomy Solution of equations Sphere-packing
Emilie du Chatelet (1706-1749)	Newtonian dynamics
James Joseph Sylvester (1814-1897):	Algebra Algebraic geometry Invariant theory
Florence Nightingale (1820-1910):	Statistics Data visualisation
Hugh Everett III (1930-1982):	Quantum theory Game theory Operational Research



Appendix 5 – An annotated list of books about doing mathematics

This is simply an annotated list of (generally) recent books about recent and contemporary mathematicians and doing mathematics, with some annotations suggesting issues to think about while reading the book.

G.H. Hardy: *A Mathematician's Apology* (Cambridge University Press: first published 1940, frequently reissued.)
The book is usually published with an introduction by the writer C.P. Snow. Wikipedia says that *A Mathematician's Apology* "reflects Hardy's increasing depression at the wane of his own mathematical powers." (http://en.wikipedia.org/wiki/Mathematician's_Apology) But the mathematician Peter Neumann argues that Snow's preface has coloured the way in which Hardy's text comes across to many readers, focusing on the negative aspects of what is largely a joyous celebration of a mathematical life and the beauty of mathematics. Do you agree?

Marcus du Sautoy, *Finding Moonshine: A Mathematician's Journey Through Symmetry* (Fourth Estate, 2008)
A diary of a year in the life of a contemporary mathematician.

Ian Stewart, *Letters to a young mathematician* (Basic, 2006)
Strongly recommended – the letters offer advice and insights to a fictional young mathematician as she goes through her mathematical studies.

Reuben Hersh and Vera John-Steiner: *Loving + Hating Mathematics: Challenging the Myths of Mathematical Life* (Princeton, 2011)
A very entertaining, wide-ranging book which looks at the culture of mathematics, issues regarding equal opportunities with respect to race, gender and age, and issues in maths education.

Peter Byrne: *The Many Worlds of Hugh Everett III: Multiple Universes, Mutual Assured Destruction, and the Meltdown of a Nuclear Family* (Oxford University Press, 2010)
A biography of the quantum theorist whose subsequent career included Cold War game theory, the book perhaps makes too much of his allegedly dysfunctional family life but gives a fascinating picture of a mathematical career.

Paul Hoffman: *The Man Who Loved Only Numbers: The Story of Paul Erdös and the Search for Mathematical Truth* (Fourth Estate, 1998)
A very entertaining biography of the great Paul Erdös. What does the focus on an eccentric mathematician do for the public image of mathematics and its practitioners?

Masha Gessen: *Perfect Rigour: A Genius and the Mathematical Breakthrough of the Century* (Icon, 2011)
About Grigori Perelman and his proof of the Poincaré Conjecture, with insights into the late Soviet mathematical system. Once again, is it the case that the mathematicians who are chosen to be the subjects of biography are the most eccentric? If so, does it matter?

Alexander Masters: *The Genius in my Basement: the Biography of a Happy Man* (Fourth Estate, 2011)
This new book about the group theorist Simon Norton has been well reviewed in the literary press. While sympathetic to its subject, it makes no attempt to hide his eccentricities. Is it fair? Does it help the public image of mathematics?

Andrew Hodges, *Alan Turing: the Enigma* (most recent edition Vintage, 2012)
A biography of Alan Turing which has received great critical acclaim since its first publication in 1983.

Graham Farmelo, *The strangest man: the hidden life of Paul Dirac, quantum genius* (Faber and Faber, 2009)
An excellent recent biography of the mathematician Paul Dirac.

Loren Graham and Jean-Michel Kantor, *Naming Infinity: A True Story of Religious Mysticism and Mathematical Creativity* (Belknap, 2009)
A book which argues that human elements influence the development of mathematics. Covers a wide range of topics: the chapter "Lusitania and After", about the Moscow Mathematical School in Soviet times, is particularly effective in showing how human factors affect mathematics.

Simon Singh: *Fermat's Last Theorem: The story of a riddle that confounded the world's greatest minds for 358 years* (Fourth Estate, reissue 2002)
An account of one of the biggest mathematical stories of recent times.

Apostolos Doxiadis: *Uncle Petros and Goldbach's Conjecture* (Faber & Faber, most recent edition 2011)
A 1992 novel about doing mathematics. At the time of publication the publishers offered a million dollars for a proof of the Goldbach Conjecture within a year. The prize was not awarded.

Apostolos Doxiadis, *Christos Papadimitriou and others: Logicomix: an Epic Quest for Truth* (Bloomsbury, 2009)
A post-modern graphic novel about Bertrand Russell and mathematical logic.

This booklet details the curriculum resources created by the project 'Being a Professional Mathematician'. This aimed to produce a collection of teaching resources on the development of mathematics - stories from history and more recent development of the discipline. These aimed to counter a view of mathematics as a static, completed body of knowledge and instead encourage awareness of the process of doing mathematics. They aimed to develop students' awareness of the culture of mathematics. This booklet gives details of the material created and discusses how this material may be used in the curriculum.

This work was supported by the Mathematical Sciences HE Curriculum Innovation Project, operated by the Maths, Stats and OR (MSOR) Network as part of the Mathematical Sciences Strand of the National HE STEM Programme. Find out more at **www.mathstore.ac.uk/hestem**