Institution: University of St Andrews

Unit of Assessment: 10 - Mathematical Sciences

Title of case study: Improving Public Awareness of Mathematics and its History –The MacTutor History of Mathematics Archive

1. Summary of the impact

The MacTutor History of Mathematics Web Archive at the University of St Andrews is one of the most accessed resources worldwide for mathematics and its history. The archive includes detailed biographies of 2740 mathematicians and over 2000 other pages of essays on specific topics and supporting material, presented in a readily searchable form which engages and informs. It has had great influence on popularising and communicating the essence and importance of mathematics, inspiring a broad audience across the world, as well as being a vast educational resource. The site has sustained an average of two million hits per week over the last six years. It has been the basis for college courses worldwide and numerous student and school projects on mathematics and its history, and it has served as a seminal resource for many popular science, reference, and academic books, TV and radio broadcasts and lectures. The Archive continues to grow, with new material continually being researched and added.

2. Underpinning research

A Research Group in the History of Mathematics was set up in 1995 by members of the University of St Andrews' Mathematics Department. Prof Alex Craik (1968- retired 2003, Emeritus Professor since 2003), Prof Edmund Robertson (1968- retired 2008, Emeritus Professor since 2008) and Dr John O'Connor (1970- retired 2010, Honorary Reader since 2010) were founding Group members, and more recently the Group has involved Dr Colva Roney-Dougal (2003- Senior Lecturer from 2010) and Dr Colin Bleak (2010-). These staff, all researchers in different fields of mathematics, are fascinated by the historical side of their subject and the evolution of mathematics. Some 6 research students have also made major contributions to the Group over the past 10 years. Since 1995 members of the Group have published over 30 research papers in highly-regarded peer-reviewed History of Mathematics journals, such as the British Society of the History of Mathematics Bulletin and Historia Mathematica, as well as invited historical papers in mathematics journals, obituaries and many other popular articles. Primary sources for the research include mathematical papers going back many years, contemporary accounts, and archival material from libraries and mathematical societies, for example, minutes of the Edinburgh Mathematical Society from 1883 (which are reproduced on the MacTutor History of Mathematics Archive) and recently discovered manuscripts of William Wallace.

Much of the research relates to UK, and in particular Scottish, mathematicians. For example, since 1999, Craik and O'Connor have authored a series of papers including [R1-R3] on William Wallace and his colleagues and contemporaries. The paper [R1] discusses the significance of Wallace's lengthy articles on 'Fluxions' in the early 19th century in the Encyclopaedia Britannica and the Edinburgh Encyclopaedia. These include the first complete English language account of the calculus using the differential notation which is now universally adopted, and which included what was, with hindsight, a very perceptive discussion on the nature of limits. The role of Wallace and other mathematicians, notably Leslie and Carlyle, in the introduction of modern analysis to Britain is examined in [R2], and some newly discovered manuscripts of Wallace are presented and critically analysed in [R3]. Craik's recent paper [R4] presents substantial research over several years on the mathematics of the little-known Scottish analyst William Spence, one of the earliest British mathematicians to become familiar with continental mathematics at the turn of the 19th century. Craik's book 'Mr Hopkins' Men' [R5] published in 2007 is the culmination of research on the many mathematicians taught or advised for the Cambridge Mathematical Tripos by William Hopkins in the mid-19th century, including Green, Adams, Stokes, Cayley and Kelvin, and considers their education and its impact on their later careers and their influence on mathematics

and the scientific community.

On the more applied side, Craik's 2004 paper on the origins of water wave theory [R6], which describes the contributions of the many mathematicians that set the scene for Stokes' work, has attracted 53 citations (WoS) mostly from papers on contemporary fluids research.

Papers by research students supervised by Group staff also range across a wide area of history of mathematics. For example, Ian Duncan presents new insights into Eddington's search for a theory of quantum gravity, a BSHM paper by Elizabeth Lewis considers early work of P. G. Tait, and in another BSHM paper Stefanie Eminger examines the importance of the first ICMS in Zurich in 1897 as a landmark in international mathematical collaboration.

These are samples from the considerable body of published research by the Group that has fed into the Archive. The Group has also undertaken a great deal of research specifically for the Archive. Researching new biographies and articles and refining existing ones, with input from active mathematicians, is an on-going process, to ensure that the material reaches the high standards expected by the mathematics and history of mathematics communities for dissemination to the wider public.

3. References to the research

[R1] Craik, A. D. D. Calculus and analysis in early 19th-century Britain: the work of William Wallace. *Historia Math.* 26 (1999) 239-267. DOI:10.1006/hmat.1999.2250

[R2] Craik, A. D. D. Geometry versus analysis in early 19th-century Scotland: John Leslie, William Wallace, and Thomas Carlyle, *Historia Math.* 27 (2000), 133-163. DOI:10.1006/hmat.1999.2264

[R3] Craik, A. D. D. & O'Connor, J. J. Some unknown documents associated with William Wallace. *BSHM Bull.*, 26 (1) (2011), 17-28. DOI:10.1080/17498430.2010.503555

[R4] *Craik, A. D. D. Polylogarithms, functional equations and more: The elusive essays of William Spence (1777-1815). *Historia Math.* Online 18 July 2013. DOI:10.1016/j.hm.2013.06.002

[R5] *Craik, A. D. D. *Mr Hopkins' Men. Cambridge Reform and British Mathematics in the 19th Century.* Springer-Verlag London, Ltd., London, 2007. xiv+405 pp. ISBN 978-1-84628-791-6. Available from the University library. [London Mathematical Society Newsletter review states, "This is an unusual, well-written and well-researched book. So favourably has it been received that a paperback edition appeared within just a few months of the original publication."

[R6] *Craik, A. D. D. The origins of water wave theory. *Annu. Rev. Fluid Mech.* 36 (2004), 1-28. DOI:10.1146/annurev.fluid.36.050802.122118 [highly cited paper]

*Three publications that best indicate the quality of the research.

4. Details of the impact

The History of Mathematics Archive (at http://www-history.mcs.st-and.ac.uk) is arguably the most widely consulted mathematics information resource in the world and one of the most accessed scientific websites. It has helped to popularise mathematics and science to the public in the UK and internationally, as well as to inspire future scientists. Its reach and significance have been considerable in stimulating public interest, engagement and understanding of mathematics and science across a world-wide arena that includes schools, colleges and the general public, contributing to a stated aim of government and other public and private bodies of raising public awareness of mathematics and science.

The Archive includes detailed biographies of 2740 mathematicians and over 2000 other pages of essays and supporting material. It is underpinned by a great deal of research including that described in section 2, was produced entirely by members of the University of St Andrews School of Mathematics and is located on the School's webserver. It is a direct and highly visible result of the School's research in the History of Mathematics, incorporating both research published in learned journals and material researched specifically for the Archive.

The reach of the web Archive is vast in terms of the number of hits and the countries from which they originate. The web statistics [3] show typically 2 million pages of downloads (about 4.5

Gigabytes of information) by about 150,000 users *each week* from 1st January 2008 onwards. For example, there were 11.6 million hits during May 2012. Whilst many hits on the site are from UK, USA and Russia, in a typical month hits are recorded from virtually every country in the world, with India, Brazil and China near the top of the list. A high proportion of downloads are from non-university users (e.g. with over 31% from .com domains).

The Archive is widely recognized as a major online educational resource; for example, it is included in MERLOT, California State University's *Multimedia Educational Resource for Learning and Online Teaching* [4]. A recent UK report History of Mathematics in the Higher Education Curriculum [5] by a working group set up jointly by the HEA MSOR Network, Mathematical Sciences Strand of National STEM Programme & BSHM refers to the Archive as *"A large and ever increasing repository of entries on a whole range of people and topics within the history of mathematics. An excellent and, in terms of search engine ranking, almost inevitable first port of call."* A recent article in *MSOR Connections* states *"There are many valuable resources on the history of mathematics, and in particular the MacTutor history of mathematics website is widely used by academics and students."* [6]. Many leading universities offer courses that depend heavily on the Archive, for example Teaching Math with a Historical Perspective at Harvard [7] and Mathematics and its History at the University of Florida [8]. Moreover, many lecturers use the Archive for supporting material to provide historical background when delivering mathematics and science courses; see [9] for an example of a mathematics course website with a direct link to the Archive.

The Archive is widely used for high school teaching and projects. The University of Chicago & Chicago Public Schools Internet Project states *"This is the most comprehensive site on the web for the history of math, biographies of mathematicians, and famous curves. It can be used as a companion piece for research and for helping students understand mathematical concepts."* [10] There are direct links to the Archive from the teaching and learning resource web pages of numerous high schools across the world, see [11] for one of many examples.

Social networking now plays a role in disseminating the Archive. The twitter feed @mathshistory mainly provides a daily tweet linking to a mathematician of the day on the Archive, and the number of followers has rapidly grown to over 16,000 at the time of writing [12].

The Archive is frequently used as a source for popular scientific writers, lecturers and broadcasters. Best-selling writer Ian Stewart writes *"As a writer of popular science, specialising in mathematics, I have found the MacTutor archive to be of great value when researching or checking historical events and people. Since 2008 I have made extensive use of it when writing the following 8 books..."* [1]. The Archive is cited as a web-reference in many popular science books, e.g. *A Very Short Introduction to Numbers* by Peter Higgins (OUP, 2011). It is a resource for media presentations, such as Melvyn Bragg's Radio 4 *In Our Time* series which has featured Roney-Dougal on several occasions [13]. Indeed, as a result of the Archive, Research Group members are approached virtually every month to advise for radio and television programmes [2] as well as for journal and magazine articles.

MacTutor has received many internet and other awards, including in 2012 the Comenius Medal of the Societas Comeniana Hungarica (The Hungarian Comenius Society) for *"contributions to education particularly for the MacTutor History of Mathematics Web Archive".*

The development of the web Archive is a dynamic and on-going process. It is updated in minor or major ways almost daily and additional biographies and other material are added regularly, with feedback and input from users and mathematicians contributing to its breadth and efficacy. This provides the impetus for further research and ensures that the vitality, utility and impact of the Archive will continue into the future.

5. Sources to corroborate the impact

[1] Letter on file from a well-known popular mathematics writer. (Corroborates use of the Archive by popular science writers.)

[2] Request on file from a history editor, BBC, 30 March 2010. (Corroborates media requests for information as a result of the Archive.)

[3] Statistics on web usage: http://turnbull.mcs.st-and.ac.uk/analog_res.html (Corroborates the website access figures quoted.)

[4] MERLOT - Multimedia Educational Resource for Learning and Online Teaching: http://www.merlot.org/merlot/viewMaterial.htm?id=89142 (Corroborates the use of the Archive as an online higher educational resource in the U.S.)

[5] *History of Mathematics in the Higher Education Curriculum* Report by a working group HEAMSOR Network, the Mathematical Sciences Strand of National STEM Programme & BSHM, May 2012 http://mathcentre.ac.uk/resources/uploaded/historyofmaths.pdf (Corroborates the visibility and quality of the Archive in Higher Education.)

[6] Mathematical Motivators: Using the history of mathematics to enrich the curriculum M. McCartney, N.-A. Bradshaw and T. Mann, *MSOR Connections*,**11** No.2 (2011) 14-16 http://journals.heacademy.ac.uk/doi/abs/10.11120/msor.2011.11020014(Corroborates the widespread use of the Archive by students.)

[7] Teaching Math with a Historical Perspective, Harvard University http://www.math.harvard.edu/~knill/teaching/mathe320_2013/links.html (An example of the Archive as a resource for a university history of mathematics course.)

[8] MA6932 Mathematics and its History, University of Florida http://www.math.ufl.edu/~kees/MAT6932History.html (An example of the Archive as a resource for a university history of mathematics course.)

[9] Lectures on Classical Mechanics, University of Cambridge http://www.damtp.cam.ac.uk/user/tong/dynamics.htm (An example of a mathematics course web page with a link to the Archive to provide biographical information.)

[10] University of Chicago & Chicago Public Schools Internet Project http://cuip.uchicago.edu/websift/math/mactutorhistory.html(Corroborates the use of the Archive as a resource in high school teaching.)

[11] Christopher Columbus High School, Miami, Teaching and learning resource page http://www.columbushs.com/page.aspx?pid=410 (An example of a high school web page with a prominent link to the Archive.)

[12] Maths History on Twitter https://twitter.com/mathshistory (Corroborates the popularity of the Archive by twitter users.)

[13] Radio 4 *In Our Time* programmes featuring Roney-Dougal: 29 May 2008 (Probability - Heads or Tails?), 11 February 2010 (The Unintended Consequences of Mathematics),13 January 2011 (Random and Pseudorandom). (Corroborates the participation of History Group members in popular science broadcasts.)