Geoscience and Educational Research in Outreach Activities

Vincent C.H. Tong

Geoscience is distinctly multidisciplinary and interdisciplinary. Geoscientists study the Earth as a system characterised by a myriad of vastly interconnected components, and they use a variety of scientific tools in their investigations. Physics, chemistry, biology, mathematics, computation and engineering principles are all employed in order to push the boundaries of our understanding of the planet Earth. Apart from the intrinsic scientific interest, geoscience research also informs social and economic policymaking at national and international levels and often has profound geopolitical impact as a result. From energy and water resources to natural disasters, and from changing climatic patterns to the evolution of the Earth's deep interior, geoscience research is central to our understanding of our home in the universe.

It is therefore hardly an exaggeration to claim that geoscience research affects people's lives in many ways and on different levels. Given the significance of knowledge about the Earth, geoscience outreach is both important and necessary. It is not difficult to understand the reasons when we think about the strong demand for knowledge and new findings from geoscience research. Here are a few examples. Let us first consider the public reactions to natural disasters such as tsunamis, earthquakes, hurricanes and volcanic eruptions. Such events are made known to many around the world with minimum delay as media outlets monitor and report them continuously. Individuals witnessing these events upload photos and video footage onto social media sites. Together with the coverage by the mass media, they have enormous followings and generate fervent discussions on the web. Research geoscientists are always in demand to explain our current understanding of these phenomena and their impact to the public in these occasions across different platforms.

V.C.H. Tong (✉)
Department of Earth and Planetary Sciences, Birkbeck, University of London, London, UK
e-mail: vincent.tong@ucl.ac.uk

V.C.H. Tong (ed.), *Geoscience Research and Outreach: Schools and Public Engagement*, Innovations in Science Education and Technology 21, DOI 10.1007/978-94-007-6943-4_1,

Apart from the general public, there are many specific groups of consumers of geoscience research. Policymakers need to be better informed about the effects of rising levels of greenhouse gases on temperature, precipitation patterns and the acidification of the oceans. School children are excited about the discovery of previously unknown species from new fossil records. Farmers want to understand the effects of changing climatic patterns, groundwater levels and soil composition in order to optimise crop yields. Television programmes about the Earth attract huge numbers of viewers around the world, and there are channels that specialise in producing and broadcasting documentaries featuring different natural phenomena of the planet. Geoscience research provides the scientific basis in these policymaking and educational contexts. There is a genuine need for many to be effectively informed about the latest findings in both pure and applied geoscience for a variety of reasons.

Outreach is important and necessary not only to those on the receiving end but also to the generators and providers of new scientific knowledge. Many geoscience professors and researchers are keen to widen the impact of their work beyond their peers in the academic world. Inspiring the general public and the next generation through one's research is, after all, immensely rewarding. To others, engaging in geoscience outreach may be a matter of meeting the conditions set by their research funders. But this trend of being accountable and socially responsible is clearly pointing in one direction: researchers are now increasingly asked to include detailed plans about their outreach programmes when they apply for research grants to carry out scientific investigations. It is also becoming common that geoscientists are requested to demonstrate innovations in their outreach activities. In many cases, funding for linked science outreach programmes is allocated alongside financial support for the geoscience research. Apart from academics and researchers, many museums, universities, learned societies and public organisations are also keen to showcase their work by using geoscience research as an effective way to engage with schools and the general public, to widen participation, as well as to justify the public funding they receive. Geoscience outreach is therefore driven by both demand and supply.

Although it may be viewed as an interactive process between educators and participants, outreach requires considerably more effort from the educators conducting the outreach activities. In particular, communicating the huge range of scientific discoveries about our planet and explaining the diverse array of scientific methods are never easy. Not to mention the challenge in engaging school children of different ages and the general public in both formal and informal settings. In order to accomplish these mammoth tasks, both established and emerging approaches to designing and implementing outreach programmes are called for. Many programmes are based on field, workshop and laboratory activities. Online approaches are also routinely used for reaching a wider audience and for exploiting new technological possibilities, and it is not unusual to adopt mixed methods involving all these approaches in a single programme.

How can we best facilitate and evaluate education based on geoscience research and knowledge? How can we design and implement effective outreach programmes?

How can we train school teachers in outreach activities and teach new geoscience findings to school children? These are important questions constantly asked by educators, including geoscience academics, school teachers and outreach programme directors and organisers, and are actively investigated by researchers working on geoscience education. Indeed, geoscience education research is an integral part of geoscience outreach. Geoscience academics and researchers are, therefore, by no means the only key contributors to research and outreach in geosciences. Informal educators, schoolteachers and science education researchers are vital in bringing geoscience research and outreach together.

As geoscience outreach involves contributors with different perspectives, how can we understand the relationship between geoscience research and outreach? Whilst outreach has the potential to influence geoscience research, it can be argued that outreach programmes are more likely to be based on or enhanced by geoscience research. How can outreach be enhanced by geoscience research? One of the traditional approaches may involve a scientist talking passionately about her/his geoscience research in an invited public lecture. However, this is a restrictive way of looking at outreach enhanced by scientific research. It is restrictive because of the limited type of contributor involved (i.e. scientist) and the limitations in the mode of communication (i.e. invited lecture). Perhaps more importantly, the question of how much value is attached to programme evaluation and pedagogical enhancement should be considered. A more inclusive view of the relationship between geoscience research and outreach should incorporate a broader understanding of the term 'outreach' as a form of research-enhanced education, which should ideally be characterised by the following elements:

1. Geoscience research findings and knowledge, or enquiry-based activities in geoscience are featured.
2. Geoscience researchers are actively involved in the programme design or implementation.
3. Educational research is conducted on geoscience outreach programmes or on how to evaluate and best support the pedagogy.

What is important is that both scientific research and educational research enhance school and public outreach. This framework reflects the view that outreach is an ultimate objective, rather than starting from geoscience researchers as the key contributor and bearing a perspective that is centred on scientific research. This model also marks a departure from the idea that outreach is (merely) one of the many ways of disseminating research findings. This 'research-enhanced outreach' model, as opposed to the 'research dissemination model', therefore views outreach as the goal with scientific and educational research employed to facilitate the activities. It is clear that pedagogical considerations and geoscience research are both key ingredients to effective outreach programmes and activities. Geoscience researchers themselves may act as educational researchers or educators at the same time in some outreach programmes. In other outreach projects, scientists and informal educators work with researchers who specialise in educational research. In other words, outreach based on or enhanced by geoscience research should involve building

multiple identities (i.e. being a scientist and an educator at the same time) or forming cross-disciplinary, collaborative partnerships.

The objective of this book is to show how geoscientists, education researchers, school teachers, informal educators and outreach programme organisers from different countries have contributed to the design, implementation, evaluation and enhancement of outreach activities associated with a wide range of geoscience research. The intended readership obviously includes this group of scientists and science educators who are already active or interested in participating in geoscience outreach. But it is hoped that those from other academic disciplines as well as educators in the wider higher education community will find this book useful, too. Policymakers and research funders operating in the field of energy, natural resources, climate change, and other geoscience-related areas may also be interested in this book. Moreover, the chapters in this book are likely to be directly relevant to public organisations such as meteorological offices and natural hazards units. Whilst it is impossible to capture the full range of the types of work on geoscience research outreach in a single volume, this book aims to show some recent examples of innovative outreach approaches as well as challenges and recommendations for good practices in geoscience outreach. Together with the companion book entitled *Geoscience Research and Education: Teaching at Universities* (edited by Tong and published by Springer), this volume shows how geoscience research has played an important part in a wide spectrum of educational settings.

Two types of chapters are featured in this book: (1) full chapters showing innovative design and implementation in specific outreach activities or programmes and (2) shorter perspective chapters highlighting current trends, challenges and solutions on more general issues in geoscience research and outreach. A bullet-point overview appears towards the end of all chapters for easy references to the key points discussed by the authors. In terms of the organisation of themes, this book consists of six parts. In Part I, Bowring shares his personal passion and conviction in outreach programmes as a geoscience professor from a leading research-intensive university, and explains, in his opinion, why geoscience outreach is important. Together with this chapter, it provides some relevant contextual background for the book.

Parts II, III and IV of this book focus on the links between geoscience research and schools/public outreach. The chapters in these parts show the main types of outreach activities in different areas of geoscience, and these field-, online- and workshop/laboratory-based outreach programmes underline the multidisciplinarity and interdisciplinarity of contemporary geoscience research. The rationale for presenting the diverse range of geoscience outreach programmes under these parts is to foreground the main approaches commonly adopted in outreach activities in geoscience. Note that some programmes involved adopting multiple approaches, in which case they are grouped according to the key approach featured.

Field-based activities are important to many geoscientists' research, and there is no better way to get students and others involved by having hands-on experience in the field. These activities are special to geoscience as a scientific discipline that often requires work outside a laboratory. Part II comprises three field-based

contributions with fieldwork performed in very different physical environments. Yoshikawa et al.'s study of the permafrost and surface soil layers (Chapter 'Engaging Alaska Communities and Students in Cryospheric Research') shows how students and teachers in rural Alaska helped establish long-term monitoring sites. Novel use of manga and video series were featured alongside the fieldwork and educational activities in this project led by the Japanese professor. The impact of the outreach project on the communities in the remote regions is discussed. Westnedge and Dallimore describe their experience in a marine geoscience outreach programme in Canada (Chapter 'The Salish Sea Expedition: Walking the Gangplank of Science Outreach'), and they explain the importance of effective communication between scientists and the general public in their perspective chapter. Their project involved designing a map and guidebook as part of the marine expedition, putting geoscience research in the local contexts. In Chapter 'Problem-Based Learning in the Field Setting', Chan and Ho detail the integration of problem-based learning (PBL) in field-based education in Hong Kong. Their project involved the design and implementation of enquiry-based learning and teaching for high school students, and detailed evaluation on the pedagogical impact of this approach is also included. The authors demonstrate that the use of PBL in the field has the potential to be adopted widely in school curricula.

Online methods play an important part in education, and geoscience outreach is no exception. Part III consists of four chapters showing a variety of outreach programmes that were facilitated by the use of the Internet. In their perspective chapter (Chapter 'From Local to Extreme Environments (FLEXE): Connecting Students and Scientists in Online Forums'), Carlsen and his US-based colleagues discuss the use of online forums that helped link ocean scientists, teachers and students from around the globe. The authors highlight how the use of online forums allowed them to address various difficulties faced by research scientists in their outreach efforts. Barrett et al. explain the challenges with regard to the use of social media and the web in communicating scientific research (Chapter 'Communicating Scientific Research Through the Web and Social Media: Experience of the United Nations University with the Our World 2.0 Web Magazine'). Based at the United Nations University's headquarter in Tokyo, they share their experience with the development of an online magazine featuring environmental topics. In Dengg et al.'s chapter (Chapter 'Marine Geosciences from a Different Perspective: "Edutainment" Video Clips by Pupils and Scientists'), they showcase the production and hosting of YouTube-style online video clips on cutting-edge research topics in geoscience. This German project brought scientists, educators and students together to undertake this technically and scientifically challenging project. In Chapter 'Small, Subject-Oriented Educational Resource Gateways: What are Their Roles in Geoscience Education?', Cattadori et al. explain their development of an open-source online teaching resource in geoscience for school teachers in Italy. The project involved educators from a science museum, school teachers and research scientists in the construction of the information gateway.

Apart from field- and online-based outreach, workshops remain an important traditional approach in science outreach. There are four chapters in Part IV showing

the range of possibilities with different scopes and scales of outreach activities that were based on workshops or laboratory experiments. Zollo et al. describe in Chapter 'The European Experience of Educational Seismology' their long-running school outreach programmes in seismology and detail their experience in Italy, France, the UK and Switzerland. The development of seismometers and the use of school-based monitoring stations are discussed. In addition, the authors propose that online-based activities will further enhance the communication between researchers, teachers, students and educators in their outreach programme. Bookhagen et al. discuss their US-based outreach programme involving principles and research in geochronology. The laboratory-based workshops for students and teachers are described in their chapter (Chapter 'EARTHTIME: Teaching Geochronology to High School Students in the US'), and both quantitative and qualitative evaluations were carried out for this school outreach project featuring challenging geoscience concepts. Čanić and Rasol showcase their workshop designed to raise awareness in meteorological principles and research findings in Chapter 'Little Meteorological Workshop: An Extracurricular School Activity for Pupils'. Their project was originally developed as a public outreach project in a science festival in Croatia, and is now incorporated as an extracurricular activity for primary school children and their teachers. In Chapter 'Grasping Deep Time with Scaled Space in Personal Environs', Jacobsen describes his Danish project that aimed to help develop a better understanding of the idea of geological time. His outreach project involved the use of physical installations on a university campus and in a science festival, as well as virtual installations on Google Earth and YouTube. His project clearly demonstrates the importance of using multiple methods in outreach activities.

Part V and VI of the book feature chapters showing how outreach activities associated with geoscience research may be enhanced. Chapters in Part V share a special focus on the importance of pedagogical considerations by taking a deeper look at the educational rationales behind the design of geoscience outreach programmes. These chapters highlight the significance of science education research in improving the theoretical rigour and quality of geoscience outreach activities. Last but not least, Part VI aims to provide ideas about how geoscience outreach programmes, on the whole, may be better supported and promoted.

In Chapter 'Integrating Geoscience Research in Primary and Secondary Education', Sparrow and her US- and Thailand-based co-authors discuss their programme on monitoring seasons through global learning communities, which was part of the International Polar Year project. Apart from the implementation, they show details of their comprehensive and detailed evaluations of their outreach programme. Barber shares her experience with the Canadian programme involving outreach on board a research icebreaker (Chapter 'Bridging Scientific Research and Science Education in High Schools Through Authentic and Simulated Science Experiences'). She explains the pedagogical rationales behind her project whose goal was to connect schools to climate change research. Details on the theoretical framework that underpinned the planning of the project are described. In Chapter 'Using Guided Inquiry Tools with Online Geosciences Data from the Great Lakes', Rutherford discusses her enquiry-based online outreach project. The chapter

outlines the implementation of the outreach programme that featured online research and required students and teachers to formulate testable questions. The author invokes an extensive range of science education literature in her discussion.

There are two perspective chapters from the USA in Part VI. Rogers highlights the fundamental differences between how scientists present research findings and how the public understands research findings and explains how these differences often result in misunderstanding and miscommunication (Chapter 'Communicating Climate Science from a Data-Centered Perspective'). He advocates the use of observations based on scientific data as a good context for enhancing the communication between research scientists and the public. In Chapter 'Geoscience Outreach Education with the Local Community', Saltzman outlines her case for building on the strength of the institution and forging collaborations across the institution in geoscience outreach programmes. Her chapter focuses on her experience of designing and implementing outreach activities in a leading research-intensive university. She also shows the importance of being transparent in what can be expected of the researchers and educators in outreach programmes. The full chapter by King (Chapter 'Using Research to Promote Action in Earth Science Professional Development for Teachers') demonstrates the importance of supporting the professional development of Earth Science school teachers in the UK. He highlights the need for using research to enhance the professional development programmes and explains the reasons behind a successful programme, which is supported by an academia-industry partnership.

A diverse range of perspectives are featured in this book, including those from geoscience academics working in research-intensive and teaching-led institutions, science education researchers, educators, outreach programme directors from museums, public organisations and universities. There is a huge variety in the types of approaches used in their programmes, spanning different areas of geoscience research, and were implemented around the world. Despite these diversities, there is one unifying theme, which is loud and clear: outreach based on or enhanced by geoscience research is important and necessary. Underlying this belief are the passion and conviction behind those who want not only to convey geoscience research findings and their excitements to the outside world but also to share the vision that geoscience outreach should be implemented in effective and innovative ways. It is a multidisciplinary and interdisciplinary endeavour, as they unmistakably show.