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Editorial: Sharing knowledge in the spirit of Humboldt

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Abstract

This editorial introduction provides an overview of the design of the 2019 Biennial Symposium of the Australian and New Zealand Associations of von Humboldt Fellows, which took place at Macquarie University, 22–24 November 2019. Under the theme "Sharing Knowledge in the Spirit of Humboldt," the conference provided a space to reflect on Humboldt's legacy as a research communicator and to engage with contemporary challenges of research communication, dissemination, and impact.

Introduction

2019 marked the 250th anniversary of the birth of Alexander von Humboldt (1769–1859) and Humboldtians around the world took the opportunity to reflect on Humboldt's legacy. Humboldt Fellows in Australia and New Zealand came together during their biennial symposium (Macquarie University, 22–24 November 2019) to focus specifically on Humboldt as a research communicator in order to explore contemporary challenges related to research communication. These challenges relate to ongoing transformations of the academy brought about by the digital revolution, academic capitalism, and globalisation.

Humboldt as research communicator

Humboldt was not only a pioneering researcher, explorer and thinker but also an extraordinary research communicator. His book *Views of Nature* (2011 [1850]), for example, became an international bestseller, was translated into eleven languages, and continues to be published and widely read even today. In addition to his academic publications, he maintained a global correspondence: in one year alone, 1856, he wrote around 4,000 letters, which was both "a great burden and a great joy" to him, as his friend Rahel Varnhagen noted in her diary (Schwarz, 2018). Additionally, he was a passionate and popular public speaker: in Berlin, his public lectures held everyone enthralled, were the talk of the town, and made headline news. In Paris, he was the star of the salons and his half-hour talks — sometimes as many as five in one evening — dazzled fellow researchers and the fashionable world alike (Wulf, 2015).

Humboldt also pioneered science as spectacle through his organization of academic conferences, and his relentless lobbying for the renovation of Berlin's observatory or the construction of a zoo open to the public (Daum, 2018).

Humboldt lived at a time when the nature of knowledge itself was undergoing massive transformations. These included the popularization of knowledge as science came within reach of the emerging middle classes or the commodification of knowledge as science became an object of bourgeois consumption (Daum, 2018). While certainly independent of Humboldt, Humboldt's research and, even more so, the ways in which he communicated his research, fed these transformations throughout Europe.

Contemporary challenges in research communication

As in the early 19th century, the nature of knowledge itself is being transformed yet again in fundamental ways in the early 21st century. During Humboldt's time, scientific enquiry and rational thought became foundational to the constitution of knowledge. Today, we see the relegation of science to one opinion among many, in debates over matters ranging from climate change to vaccination.

During Humboldt's time, the challenge for researchers was to develop new channels through which to communicate knowledge. Today, the challenge is for researchers to make their voices heard in the noise of social media communications, which have created an "infodemic" every bit as dangerous as the Covid-19 pandemic in which we find ourselves (Zarocostas, 2020).

During Humboldt's time, science was the domain of bourgeois white men who had just cut knowledge loose from the shackles of Latin and communicated in the burgeoning national languages of Europe. Today, the legitimacy of the white male voice is being questioned but scholars from the global South, non-white scholars, women and scholars from non-English-speaking backgrounds are still struggling to gain authority in the academy (Piller, 2019a).

In the face of these challenges in research communication, the 2019 biennial symposium of the Australian and New Zealand Associations of von Humboldt Fellows aimed to rethink what "sharing knowledge" means in today's world. It was a forum for debating the role of academic publishing, media engagement, social media, academic networks, interdisciplinary collaboration, and the increasing linguistic and cultural diversity of the academy.

The 2019 Humboldt Symposium

To this end, the 2019 Humboldt Symposium had "Sharing Knowledge in the Spirit of Humboldt" as its guiding theme. This theme was addressed in five panels, which constituted the core of the academic program:

- Panel 1: Sharing knowledge through science communication;
- Panel 2: Sharing knowledge in a diverse world;
- Panel 3: Sharing knowledge beyond the academy;
- Panel 4: Sharing Knowledge between the Humanities and Sciences: Ethical treatment of the dead and dying;
- Panel 5: Sharing knowledge through academic networks.

In keeping with the conference theme, the symposium included a range of other formats, too. These comprised a public lecture, a series of eight speed talks, and an interactive workshop devoted to sharing knowledge through media engagement.

The academic program was complemented by a social program consisting of a welcome-to-country ceremony, a reception and concert with songs from the German Romantic Period, and a conference dinner in the iconic sandstone castle Curzon Hall, a converted former monastery. Additionally, the conference featured a visual artist, Sadami Konchi, who sketched conference participants. On social media, the Symposium was accompanied by a lively Twitter presence. Under the hashtag #AvHMQ, hundreds of tweets were published before, during and after the conference.

To view the full program, abstracts, photos, sketches, and tweets, see the conference report (Piller, 2019b).

The Special Issue

This special issues brings together some of the papers presented at the conference. Gabrielle McMullen, the president of the Australian Association of von Humboldt Fellows, opened the conference — and this special issue — by introducing Alexander von Humboldt as extraordinary research communicator. One of our keynote speakers, Professor Ingrid Gogolin, Hamburg University, also took her key from Alexander von Humboldt and examines how his lesser known ethnographic research was shaped by and continues to shape ideologies of national identity as expressed through national monolingualism.

Their papers are followed by a series of case studies of research communication in various contexts. Another of our keynote speakers, Professor Dietmar Höttecke, Hamburg University, examines who counts as expert and how trust is established in the debate over safe levels of nitric oxide emissions.

In another case study, Adrian Dyer, S.R. Howard, and J.E. Garcia show how they have been able to boost the impact of their research by strategically communicating through a variety of channels and flanking the traditional academic journal paper with a concerted promotion campaign in more widely accessible media. How to reach wider audiences is also the topic of the next case study, where Nathan Kilah describes a school outreach project in his field of chemistry. Although chemistry is often perceived as an advanced science, he shows that it is possible to share its fascination even with students as young as primary school age.

The next two case studies move away from research communication with the wider public and consider researcher-to-researcher communication across disciplinary and geographical boundaries.

Alexandra Grey and Laura Smith-Khan show how early career researchers identified a research gap related to language and the law and successfully built a research network connecting isolated researchers in the field. John Hearshaw introduces the International Astronomical Union, which aims to promote global collaboration in astronomy.

The special issue ends with a research paper in which Ronald Clarke re-visits Anfinsen's dogma in chemistry of "one sequence, one structure."

Abstracts of all conference presentations are available in Piller (2019b).

Acknowledgements

In the name of the Australian and New Zealand Associations of von Humboldt Fellows and all the conference attendees, and in my role as the conference chair, I gratefully acknowledge generous funding from the Alexander von Humboldt Foundation to make the "Sharing Knowledge in the Spirit of Humboldt" symposium and this publication possible through their "Humboldt Kolleg" program.

We also wish to express our gratitude to Emeritus Professor Robert Marks and the Royal Society of NSW for taking on the publication of this special issue.

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Alexander von Humboldt, scientific explorer and research communicator *par excellence*

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Abstract

In recognition of the 250th anniversary of Alexander von Humboldt's birth, this paper explores his achievements and impact as explorer, scientist and author.

Introduction[1]

In his day, Alexander von Humboldt is said to have been the most famous man after Napoleon Bonaparte (1769–1821) (Wulf, 2015). He was recognised for his preeminence as an explorer and as a scientist and his extensive writings for both general and academic audiences. During his life and ever since, honours have been bestowed on Humboldt. European and foreign academies and learned societies elected him to membership. More species have been named after him than any other individual (Wulf, 2015). He is also recognised in both geographical and astronomical features, and the names of places and institutions.

When Humboldt died in 1859, but also upon the centenary of his birth a decade later, both the Old and New Worlds marked these occasions with innumerable events recognising his achievements. In more recent times, particularly in the English-speaking world, Humboldt's significance has been largely forgotten. Two contemporary factors have seen him returning to prominence: in 2019, the 250th anniversary of his birth and, with climate change now so evident, the fact that it was Humboldt in 1800 who provided the first-recorded description of human-induced climate change.

This paper explores:

- Alexander von Humboldt's background,
- his achievements as explorer, scientist and author,
- why his prominence faded for a significant period, and
- his significance in the contemporary context.

Humboldt's background

Friedrich Wilhelm Heinrich Alexander von Humboldt (Botting, 1974; Wulf, 2015b) was born in Berlin on 14 September 1769. He was from a well-to-do and well-connected family and, with his older brother, Wilhelm (1767–1835), was educated by able and progressive tutors. Wilhelm is famous in his own right as an intellectual, statesman and diplomat as well as founder of the Humboldt University in Berlin.

[1] This paper has been adapted from my address, as President of the Australian Association of von Humboldt Fellows, at the 2019 biennial symposium of the Australian and New Zealand Associations, *Sharing Knowledge in the Spirit of Humboldt*, held at Macquarie University on 22–24 November 2019.

As a child, Alexander was a collector of plants, insects, rocks, shells and the like, perhaps foreshadowing his future calling. Nevertheless, marked for high public office, at 18 years of age he was enrolled at the University of Frankfurt on the Oder and studied government administration and political economics. One semester later, however, he transferred to the University of Göttingen. Here he spent two years focusing on sciences, mathematics and languages.

Significantly, in Göttingen, Humboldt met Georg Forster (1754–1794) who, as a young man, had accompanied Captain James Cook (1728–1779) on his second voyage to the Pacific. During his youth, Humboldt had read and been captivated by Cook's journals. Lively conversations with Forster intensified Humboldt's *Wanderlust* ('travel bug'). Subsequently, he relished four months of journeying with Forster in the Netherlands, England and France. While in England, Forster introduced Humboldt to Sir Joseph Banks (1743–1820), President of the Royal Society and botanist on Cook's first voyage. This 1790 encounter led to a supportive scientific friendship between Banks and Humboldt. It is worthy of note that Forster was not only a prominent scientific traveller but also a significant figure in the Enlightenment movement — in both spheres, he influenced the younger Humboldt.

Humboldt's intense curiosity, extraordinary memory and passion for travel were developing as a powerful combination. For example, he published a paper in 1790 on the several types of basalt observed during a scientific excursion up the Rhine River (*Mineralogical Observations on Several Basalts on the River Rhine*). In this period, he amassed a range of such experiences, which would see him well qualified as a scientific traveller. He also developed his knowledge of commerce, languages, anatomy, astronomy and the use of scientific instruments. Further, he undertook academic and practical studies at the renowned Mining Academy of Freiberg in Saxony.

At the age of 22 years, Humboldt gained a government appointment as mining inspector which gave him some scope for travel. He excelled in the role of mining inspector, increasing gold production, inventing safety equipment and, for the miners, improving their conditions through writing textbooks for them and opening a free school, the latter at his own expense. His diligence and capacity saw him promoted and also entrusted with diplomatic missions. At the same time, he continued his scientific interests, undertaking plant research and dabbling in animal electricity (galvanism). With his developing profile, he was introduced into the famous Weimar cultural and intellectual circle, which included Johann Wolfgang Goethe (1749–1832) and Friedrich Schiller (1759–1805). Humboldt continued to travel, including undertaking a geological and botanical expedition through Italy and Switzerland in 1795. The next year brought a life-changing development when, following his mother's death, he inherited the means to resource scientific travels and resigned from the public service.

Explorer of the Americas

Humboldt went to Paris, a major centre of contemporary intellectual life. There, he gained an invitation to join a five-year French voyage of exploration and was greatly disappointed when it was cancelled due to the outbreak of war. Having met the expedition's intended botanist, Aimé Bonpland (1773–1858), the two decided to set out in search of other options. Arriving in Madrid, they gained access to the King of Spain, who was open to Humboldt's proposal for a self-funded scientific expedition to Spanish America. Armed with the necessary authorisations and the best instrumentation of the day, Humboldt and Bonpland set sail in June 1799 and spent the next five years exploring the Americas.

Their travels commenced in Venezuela, took them twice to Cuba, included an extensive period of exploration in the Andes, and concluded with a visit to the United States, where Humboldt was received by President Thomas Jefferson. Humboldt's venture encompassed:

- some 10,000 kilometres across Venezuela, Columbia, Ecuador and Peru;
- a 6,000 metre climb in the Andes to just below the peak of what was then considered to be the world's highest mountain, Chimborazo;
- collection of 45 crates of specimens, including 60,000 plant specimens;
- recording of ground-breaking data encompassing astronomy, biology, geology, meteorology and oceanography;
- some 4,000 pages of notes in travel diaries, and
- expenditure of a third of Humboldt's fortune.

It is worthy of note that Humboldt was meticulous in recording his observations, without knowing whether or not he would need the material for subsequent analyses or publication. He wrote: "I have made it my duty to enter all my observations into my diary without any selection" (Leitner, 2005, p. 67).

The impacts of Humboldt's travels were profound. As well as the scientific knowledge distilled from the data sources highlighted above and applications thereof, his travels made available:

- ethnographic studies into the ancient civilisations of Spanish America;
- social research on the Spanish colonies;
- mineralogical surveys;
- assessments of agricultural and mining production and their enhancement, and
- improved maps.

Jefferson would acknowledge Humboldt as "the most scientific man of his age" (Wulf, 2015b, p. 102).

Visionary scientist and research communicator *par excellence*

In August 1804 Humboldt returned to Europe with one legacy of his expedition an international scientific reputation — he was a nineteenth-century superstar. His publications were to become another legacy — significantly, he wrote for both scientific and wider audiences, the latter transporting readers into Humboldt's adventures. Ultimately, 30 volumes, disseminating his observations and their interpretation, were published over the rest of Humboldt's life, consuming the remainder of his fortune. Thus, while Humboldt had been working from Paris, he needed to relocate to Berlin in 1827 for a salaried post. On occasions, interspersed with all his intellectual endeavours, Humboldt was called upon by the Prussian royal family for diplomatic duties.

On his return 'home', Humboldt missed the intellectual stimulation of Paris but did not rest on his laurels. He offered popular free public lectures which were immortalised in his last major publication, the 5-volume *Cosmos: A Sketch of a Physical Description of the Universe* (1845–1862). He also furthered his interest in terrestrial magnetism, which led to a chain of magnetic and meteorological stations across the globe. As exemplified by this initiative, Humboldt promoted free exchange of knowledge and his project was one of the earliest examples of international scientific collaboration.

Humboldt continued to undertake travels in Europe but only one other major expedition, in his sixtieth year, to Russia. He and his party traversed over 15,500 kilometres by coach in eight weeks. The journey's focus was to assess mining prospects for the Russian Government. While the travel was too rapid to be very profitable scientifically, Humboldt did gather some comparative data for his later works. Further, his observations corrected an exaggerated height estimate for the Central Asian plateau and predicted the discovery of diamonds in Ural gold washings.

This gifted man also had the ability to draw, a talent which enabled him to generate visual records of his observations and subsequently illustrations for his publications. With maps and diagrams, Humboldt sought to present complex information in an accessible manner. His illustrations were enhanced by a significant contribution based on his observations of temperature, pressure, humidity and flora and fauna against elevation. Thus, informed by his research into the geographical distribution of plants, he introduced the concept of isotherms, lines on a map connecting points of the same temperature. He similarly instituted isobars to connect points of the same pressure.

Humboldt's studies into climatology included early work on atmospheric disturbances and recognition of comparable climate zones across continents and flora and fauna distributed accordingly, with the conclusion that nature was a global force.

His magnetic studies demonstrated the decrease in the Earth's magnetic field in moving from the poles to the equator. He also discovered that the Earth's magnetic equator was some 800 kilometres south of the geographic equator.

Thus, Humboldt had a major impact on the evolution of a number of sciences, in particular, physical geography and meteorology. Key to this were:

- his mastery of relevant contemporary instrumentation,
- his painstaking collection of wide-ranging data sets,
- his studies of flora and fauna *in situ*, and
- the meticulous publication of his observations and their interpretation.

His insights led him to a recognition of the sciences' interconnection and to the promotion of a holistic view of the natural world, the unity of nature. His quantitative methodology is characterised as Humboldtian science. In line with his view of nature, Humboldt advocated for *Reisekünstler* (artist travellers) to present scientifically accurate *Naturgemälde* (nature painting); they were to be precise natural historians (Heathcote, 2001; Pullin, 2011).

His wide-ranging studies and integrated view of nature enabled this visionary thinker to develop an ecological understanding that recognised the interconnectedness of life on Earth. In 1800 he provided the first-recorded description of human-induced climate change. In South America, he saw the impacts of colonisation — deforestation for the introduction of agriculture with consequent soil erosion and altered climate patterns. Linking social and economic factors with environmental issues, he highlighted the importance of forests to the ecosystem.

Humboldt not only spoke out against environmental concerns but also against slavery, colonialism and other social issues. Familiar with the repressive Prussian state, he sought to promote a more democratic society.

Humboldt as mentor

Significantly, Humboldt's travelogues inspired the youth of his day. German Australian explorer Ludwig Leichhardt (1813–ca. 1848) wrote that Humboldt was:

> one of those men … whose deeds sounded like legends to the boy, filled the youth with rapture and finally drew him to follow a similar direction (Fiedler, 2007, p. 75).

Young scientists looked up to Humboldt and sought to emulate him. Renowned Australian botanist Dr Ferdinand von Mueller (1825–1896) stated:

> Humboldt's works … inspired me to contribute to investigations of the realms of nature, drove me as well, with endless longing, to distant places in order to give the great master a few, potentially valuable stones for the construction of the palace of science (*Melbourner Deutsche Zeitung*, 1859).

Similarly, the young Charles Darwin (1809–1882) had read Humboldt's *Personal Narrative*. He indicated that, without Humboldt's influence, he would not have undertaken his *Beagle* voyage or written *On the Origin of Species* (Worrall, 2015). Darwin described Humboldt as the "greatest scientific traveller who ever lived" (Wulf 2015b, p. 282).

Through his publications, prolific correspondence, accessible lectures, gift for languages, and lively personality, Humboldt profoundly influenced the scientific community of his day. He also generously supported and mentored young scientists and scientific travellers. The Alexander von Humboldt Foundation,[2] which similarly fosters young researchers, is thus aptly named in his honour.

Conclusion

Humboldt died in Berlin in May 1859, in his ninetieth year, and was honoured with a state funeral. Innumerable tributes were paid to him in both the New and Old Worlds. For example, in Melbourne, the German community held a dinner to honour Humboldt (McMullen, 2012; *Melbourner Deutsche Zeitung*, 1859b). With the passing of this great polymath came the end of a scientific era "when you could hold all the world's knowledge in your head" and a time when science was "hardening" into specific disciplines (Worrall, 2015; Wulf 2015b, p. 335).

That phenomenon of specialisation and increasing Anglo-Saxon dominance were reasons why Humboldt generally faded into obscurity outside Germany. A more significant cause, however, was anti-German sentiment arising especially from the two World Wars, but already evident in Australia in the 1880s, when Germany was developing as a colonial power in our region, and again during the Boer War (Tampke & Doxford, 1990).

Further, Wulf has noted that Humboldt:

> invented the web of life … We are shaped by ideas from the past, and Humboldt gave us the very concept of nature that we hold today. But ironically, his views became so self-evident that we have largely forgotten the man behind them (Wulf, 2015c).

[2] The Alexander von Humboldt Foundation promotes "academic cooperation between excellent scientists and scholars from abroad and from Germany", particularly through provision of research fellowships and research awards, https://www.humboldt-foundation.de/web/about-us.html.

In a recent Humboldt Foundation magazine, the editor asks: "What if Humboldt were a researcher today?" The editor then fantasises — Humboldt:

> was a marketing genius. A networker who never stopped writing letters. He loved succinct sentences and punchlines. He held lectures for a wide audience. He took a stand on slavery, colonialism and environmental destruction. Today, he would probably tweet — against climate change sceptics and fake news mongers. He would appear on talk shows and have his own YouTube channel.
>
> Which area would this polymath choose to specialise in today, where would his adventures lead him?
>
> Perhaps he would study the melting permafrost in Siberia. He would certainly be attending international conferences all over the place. Or he would be on the first manned flight to Mars (Scholl, 2018).

If Humboldt was with us today, I think that his focus would be on contemporary environmental and climatic issues — he would likely home in on the fires in the Amazon basin and, in the engaging style for which he was renowned, admonish us for failing to heed his forewarnings of 1800 in relation to the impacts of "meddling with the environment" (Wulf, 2015d).

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Einheit in der Vielheit (unity in diversity) — On the topicality of Humboldt's ethnographic reflections for today's world

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Abstract

My contribution is based on Alexander von Humboldt's essay *Die Einheit des Menschengeschlechts* (1852). This is a wonderful example of the humanistic ethos in the mindset of the time, yet it is also an excellent illustration of a Eurocentric perspective. In a similar way ambivalent is the position taken by Alexander together with Wilhelm von Humboldt on the role of language in a community. On the one hand, they praised comparative language studies (*das vergleichende Sprachstudium*) as the ideal way of understanding not only "the other," but also "the own" language. On the other hand, they were strong advocates of the development of a monolingual (German) nation. I wish to illustrate in my contribution that this ambivalence is a feature of not only Germany's national self-conception until today — which is a challenge for language politics and education in a migration society.

Historical encounters and perspectives

Alexander von Humboldt was a personality who tirelessly sought to decipher the mysteries of animate and inanimate nature. His paradigm was that of traveling and collecting evidence by field observations and the collection of samples. It is not surprising that this method involved encountering a multitude of people who also posed mysteries to the observer.[1]

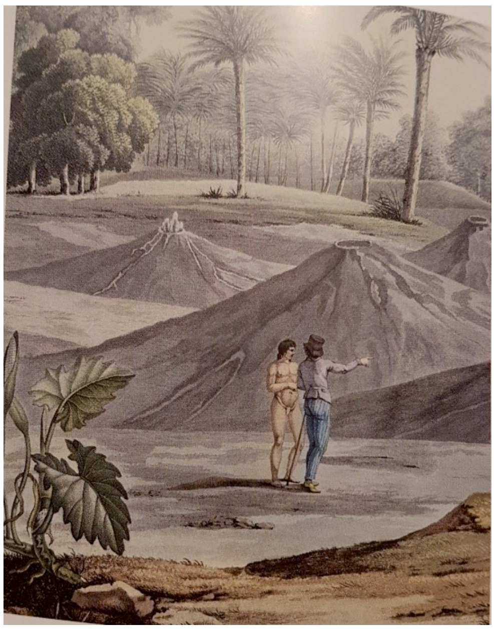

Figure 1: Humboldt in conversation with an indigenous man in Turbaco/today: Colombia (from Wulf 2015, p. 272b).

[1] The illustrations in my contribution are taken from: Andrea Wulf (2015).

The overwhelming abundance of his discoveries of nature may, however, have led to the result that his observations related to encounters with human beings have received relatively little attention — and continue to do so to this day. Another reason may be that the remarks "about the human species" (*über das Menschengeschlecht*, translation I.Go.) make up only a small part of his complete œuvre, which, moreover, he only partially published himself (Holl 2004).[2] Yet in retrospect, Humboldt's reflexions also in this respect bear witness to a tremendous innovation in the views that were common sense in "Europe" at the time. Not even in the humanistic discourse of the day, the conviction was obsolete that humankind could be divided into "higher and lower races." And even Humboldt himself had let this view be echoed in some of his early notes.[3] It took him an ample amount of personal encounters and observations of social conditions on his travels before he surprised his contemporaries by stating the unity of the human species.

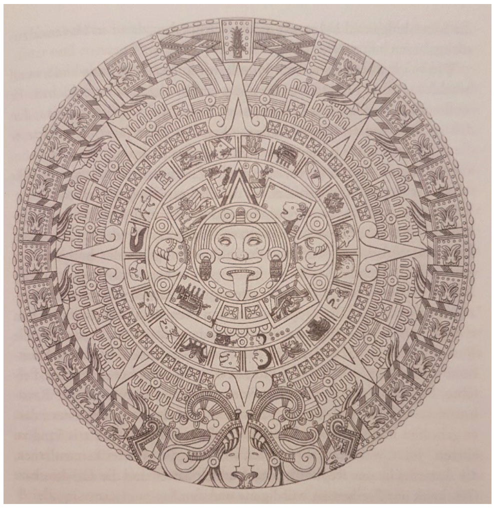

Figure 2: A Mexican calendar, which for Humboldt built the epitome of a highly advanced antique culture (from Wulf 2015, p. 129)

All peoples, so his dictum then, are equally destined to freedom.[4] As evident by artefacts, he considered humans in all parts of the world capable of culture and education (*Bildung*). And he went beyond a mere ethical commitment to equality and denounced the — so one might say today — responsibility of "Western" societies for creating inequality and misery in other parts of the world. He became a sharp critic of colonialism and stated that the colonial powers had an interest in the impoverishment of the colonized peoples. "The larger

[2] Cf. Frank Holl (14.2.2004): Alexander von Humboldt — "Geschichtsschreiber der Kolonien". In: Goethezeitportal. http://www.goethezeitportal.de/db/wiss/ahumboldt/holl_kolonialismus.pdf (retrieved 01.11.2019)

[3] Hans Sarkowitz et al. (2019): Alexander von Humboldt — Der unbekannte Kosmos. Feature in 8 chapters. Chapter: *Die Einheit des Menschengeschlechts*. Hörverlag HR2 Kultur.

[4] "Indem wir die Einheit des Menschengeschlechtes behaupten, widerstreben wir auch jeder unerfreulichen Annahme von höheren und niederen Menschenracen. Es giebt bildsamere, höhere gebildete, durch geistige Cultur veredelte, aber keine edleren Volksstämme. Alle sind gleichmäßig zur Freiheit bestimmt; zur Freiheit, welche in roheren Zuständen dem Einzelnen, in dem Staatenleben bei dem Genuß politischer Institutionen der Gesammtheit als Berechtigung zukommt." — Alexander von Humboldt (1845): *Kosmos*, Erster Band. Stuttgart & Tübingen (J. G. Cotta'scher Verlag), S. 385.

the colonies are, the more consistent the European governments are in their political malice, the more the immorality of the colonies must increase."[5] It is noteworthy that he went beyond ethical positioning and observation-based assessment by considering how this "immoral" situation could be brought to light and what possibilities there were to change it. In his respective considerations, he referred to insights into education and language which he found in the works of his brother Wilhelm. Both brothers considered education in general, but especially language education as appropriate means for understanding and respectfully recognising diversity in the encounter with "the other." Language education was not merely understood in a pragmatic sense, i.e. as the guidance to the use of the "own" as well as "foreign" languages. Rather, Wilhelm von Humboldt (and in accord with him also Alexander) saw in-depth "comparative language studies" as a path to knowledge and wisdom, awareness and recognition — of the "self" as well as of the "other."

The time for my contribution is too short to outline the twists and turns that this conception has experienced in the European, namely the German, context. The following is an actually inadmissibly short version of the story. The Humboldts' reflections on the unity of the human species and on a general education conducive to this idea were driven by a cosmopolitan sentiment. But over the course of the 19th century, this perspective did not prevail in social practice and in the emerging systems of nation states in Europe and their general education systems. Instead, the view of *superior and inferior nations* has become prevalent, which in their respective linguistic textures were considered to be monolingual quasi by nature (Gogolin, 2008).

Living in a diverse world

It does not take much research to realise that fundamental views such as those exposed and denounced as "immoral" by Alexander von Humboldt are still — or perhaps even increasingly — relevant today. But unlike Humboldt and his contemporaries, today almost nobody has to travel far and dangerously to experience the diversity of people. For almost everyone this is an experience to be made in the immediate environment. As it was often the case in history, dangerous journeys are today demanded of many who do not strive for discovery but fight for survival. And these "travellers" contribute to the experience of diversity by those who can afford a sedentary lifestyle, but also mobility when they feel like it. As has historically been the case, inequality is cause as well as consequence of this constellation.

The reality of today's societies is substantially influenced by mechanisms which foster the diversification of diversity. Not the only, but important factors driving this constellation are increasing individual mobility (an element of this is migration) as well as globalization. As I mentioned, this development is by no means new. What is new, however, is the speed and complexity of the process we face today, not least due to technical developments and powered by transnational economic interests. Today, we witness increasing numbers of net out- and in-flows in many

[5] My translation of: "Je größer die Kolonien sind, je konsequenter die europäischen Regierungen in ihrer politischen Bosheit sind, umso stärker muß sich die Unmoral der Kolonien vermehren." Faak, Margot (1982): Alexander von Humboldt: *Lateinamerika am Vorabend der Unabhängigkeitsrevolution. Eine Anthologie von Impressionen und Urteilen, aus seinen Reisetagebüchern zusammengestellt und erläutert*. Berlin (Akademie-Verlag). Quoted from Holl 2004, op.cit.

areas of the world, multiplied migration channels, and immigration status. Migrants represent increasing numbers of countries of origin, of languages, religions, concepts of gender, age, space and place, and practices of transnationalism. Steven Vertovec offered "super-diversity" as a heuristic "summary" term. It should encapsulate a range of changing variables surrounding migration patterns — and, significantly, their interlinkages. Today, these amount to a recognition of complexities that supersede previous patterns and perceptions of migration-driven diversity." (Meissner and Vertovec, 2015).

Just for illustration, I briefly refer to some figures from Germany. Actually, people from about 190 countries of origin live in Germany and contribute to the economic, social, linguistic and cultural diversification of the population. According to official counts (i.e. by the US government), fewer than 200 sovereign states exist worldwide. Thus, we can put it in short: People from almost everywhere in the world live in Germany. In the bigger cities of the country, roughly 50 per cent of newborns have parents with a migrant background (first or second generation). Different from the Australian situation, no census data is available on language diversity in Germany, but is more than likely that a large proportion of children and youth live in more than one language at home. And given the fact that roughly 7000 languages exist in the world (according to Ethnologue, www.ethnologue.com), it is most likely that several hundreds of them are spoken in German cities — just as they are in Sydney or Melbourne …

So we live in a state of diversity on our own doorstep that Alexander von Humboldt would never have imagined. His fundamental observation, however, that there is a lack of recognition of diversity and a lack of fair and equitable ways of dealing with it, is by no means outdated — at least not in Germany and other European migration countries. This can be shown by a number of indicators, denoting inequality of persons who are attributed as being "strange[rs]." They experience unequal treatment in the workforce, in apartment or house hunting, in educational success — to mention just some examples. According to relevant research, the disdain for languages and their speakers as well as the unwillingness to communicate across language boundaries are among the significant causes of the perpetuation of inequality (Piller, 2016).

In educational research on migration, to which I attribute myself, attempts are being made to clarify whether it would not be worthwhile to take up the original observations and considerations of the Humboldts once again — approaches that have never been given the benefit of being consistently translated into societal practice. A starting point for revisiting is the reversal of the signs in views of language (and social, cultural …) diversity: from negative (as it is actually common sense) to positive, as Alexander and Wilhelm considered it to be. Alexander von Humboldt did not regard the indigenous peoples of the countries he visited as "barbaric" (as it was common in Europe), but was impressed by the diversity of their cultures, beliefs and languages. He admitted that diversity sometimes caused inconvenience — for example in situations in which he needed a whole group of translators in order to transfer his questions from one of the local languages into the manifold others. Nevertheless, he maintained his openness and curiosity about the diversity of expression — just as he, together with his brother, was convinced of the creative power and cognitive potential of language differences. In understanding the "diversity of human language construction,"[6] both brothers saw an entrance ticket for all members of a society to gain the chance of equal participation in its social goods. And they saw it as the responsibility of public educational systems — which of course still had to be developed — to open up precisely this possibility to all of the children and young people living in a society.

Alexander von Humboldt was convinced that the international community of scientists was capable of overcoming all "wars and national interests;" and that their findings could contribute to a world of greater equity and justice. I am grateful for the chance to be part of this event and share my thoughts in the spirit of Humboldt.

[6] Wilhelm von Humboldt (1836): Über die Verschiedenheit des menschlichen Sprachbaues und ihren Einfluß auf die Entwickelung des Menschengeschlechts. Berlin (Druckerei der Königlichen Akademie der Wissenschaften, in Commission bei F. Dummler).

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The mediation of science in the age of social media

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Abstract

Science communication is changing in the age of social media. Gatekeeping is a classic function of quality journalism that influences communication and mediation of science in society. The changing media landscape leads to new phenomena such as filter bubbles, echo chambers, spirals of silence and the rapid spread of fake news on the Internet. This paper analyses the transformation of how science and society are mediated and draws conclusions for learning and education.

The mediation of science and science education

Traditional views of scientific literacy have predominantly focused on scientific content and methods and were aiming at teaching students to think and act like scientists. The idea for active citizenship then roughly spoken means that a competent lay person in science should be sufficiently equipped to make well-informed judgements and decisions about problems concerned with science. Then, scientific knowledge might be very helpful as far as it allows for the generation of a basic understanding of the problem at issue and what constitutes appropriate evidence to support a particular scientific claim. It is crucial, therefore, that informed citizens understand how data are collected and interpreted in a reliable and valid manner and that an interplay exists between theory and evidence in science. It might also be relevant to recognize the tentative character of scientific knowledge or how scientific investigations were conducted and reported might be shaped by human interests or cultural peculiarities. These are all aspects of an established view on nature of science (NOS) as an important domain of learning in science which aims at fostering scientific literacy (e.g. Lederman, 2007; Hodson, 2008; McComas, 1998; Erduran & Dagher, 2014).

Next to the fact that NOS is neither very well implemented in standard documents across the world (Olson, 2018) nor in the practice of teaching (Herman, Clough & Olson, 2013; Höttecke & Silva, 2011), another problem with NOS arises. When people deal with socio-scientific issues (Ratcliff & Grace, 2003; Sadler & Dawson, 2012; Hodson, 2003) like climate change, electromagnetic pollution or vaccination in order to make preferably scientifically well-informed judgments and decisions, content knowledge (e.g. the physics of the greenhouse effect) is often too complex for lay persons. Even a scientific literate person with a basic scientific understanding about climate change or electromagnetic pollution is not an expert in any of these fields. Otherwise he or she should be able to recalculate and check a professional climate model, or should be able to develop a model for estimating patterns of electro-magnetic radiation as well as strength and patterns of magnetic fields around high-voltage wires either transferred below or above ground.

These are highly professionalized activities and beyond the competencies of average lay persons.

Science is a complex endeavour and this is why experts have to put much effort on their education, work hard on earning their degrees and the development of their research capabilities, and this process sometimes even takes decades. Knowing when a scientist should count as a credible 'expert' in a particular field or when his/her intentions, actions or methods should better be questioned is a key element of functional scientific literacy (Allchin, 2011; Höttecke, 2017; Höttecke & Allchin, accepted; Hodson, 2011). As has been discussed elsewhere (Allchin, 2012; Höttecke & Allchin, accepted), science has to be understood as a social and communicative practice within a system of distributed expertise. This system is characterized by epistemic dependence and trust (Hardwig, 1991) on the one hand and a system of checks and balances (e.g. peer-review) on the other.

Socio-scientific issues are usually more concerned with science-in-the-making and less with ready-made-science (Latour, 1987), but only the latter is usually taught at school. A functional scientific literate citizen therefore needs capabilities to deal with science in his or her everyday life (Allchin, 2011). The so-called "informed citizen" should be able to participate in discussions, negotiations, and decision-making about actions to be taken to prevent climate change or to mitigate its outcomes, the adoption of laws and regulations for or against nanotechnology, genetically modified food or the determination of critical values for toxic gases and aerosols in the air in urban areas. School science education may contribute to the preparation of students' present and future lives by promoting basic scientific understanding of core concepts and methods of science, knowledge about NOS as well as capabilities for moral reasoning (e.g. Hodson, 2011, 2013; Dittmer, Gebhardt, Höttecke & Menthe, 2016). However, when citizens are concerned with socio-scientific issues and the appraisal of new technologies during their lives, the science involved is hardly ever communicated to them directly, but via media. From a lay person's perspective, science is inevitably mediated (Höttecke & Allchin, accepted).

In the following, the role of media will be discussed and how they might function or disfunction as gatekeepers of information about socio-scientific issues. I draw upon the example of climate change as one of the most challenging issues of our time where discourses in science, the media, political decision-making and a wider public are intersecting.

The role of journalistic media for the mediation of science

Beginning with the 1930s, a new kind of journalism has been established which was concerned with the popularization of science. Since then, journalism has developed towards its role as a critical observer and commentator of science (Weingart, 2017). In this regard the media play the role of gatekeepers. Gatekeeping in mass media traditionally consists of 2, respectively 3 objectives which can be identified with 'gates' allowing information to be selected, prepared and transformed for feeding public discourse: A first gate describes the process of selecting information from various sources by professional journalists. Here information has to be strongly reduced and focused to the needs and character of a particular newspaper, magazine, radio or TV program. Through a second gate information is prepared and presented in specific ways and either becomes a news, a report, an editorial comment or any other journalistic text. It is the second gate where news at least in high-quality media undergo certain levels of factual verification, analysis of content, and editorial review. As long as consumers of media are allowed to give feedback (e.g. letters to the editor), a choice of answers and reactions from either readers, listeners or viewers is passing a third gate and will either be published or rejected (Bruns, 2009). Gatekeeping of media in this way are controlling the interface between science and the public.

Next to the parental home and the educational system (most of all schools), journalistic media are of general importance for opinion-making and catching up on scientific information towards active citizenship in democratic societies. Media like newspapers, magazines, books, TV programs and radio stations play a major role in directing attention, setting agendas and trigger alarm if needed. This not only means that information e.g. about climate change or ozone depletion in the upper atmosphere are provided. Moreover, journalistic media are convincing people about the relevance of particular issues, select, control and direct information, reduce complexity and contextualize scientific information (e.g. cumulative climate reports in the context of extreme weather conditions). They mediate between science, policy-making and the wider public by reducing the differences between scientific knowledge of experts and immediate experience (Weber, 2008). They control and criticize political discourse and contribute to and reflect upon public opinion-making (Schweiger, 2017). 40% of American adults agree to the statement that it is a big problem that there are so many findings that it's hard to distinguish between high- and low-quality studies in science (Funk, Gottfried & Mitchell, 2017). It is therefore evident that many people are well aware of the importance of media for connecting science and the public.

Modern societies are deeply characterized by the necessity of identifying and negotiating risks which substantially threatens and even imperils society (Beck, 1986). As a result, societies strongly depend on the advice of experts in science or other professional domains. Beck highlights the peculiar nature of contemporary risks as invisible. It is again the media which help to visualize and symbolize risks and their consequences (Cottle, 1998). Media have established metaphors in public discourse which mediate everyday and scientific discourses (Weingart, 2015). Here is an example: Through the last decades scientists as well as journalists have made wide use of the metaphor of *tipping point* (Hel, Hellsten & Steen, 2018). This metaphor expresses the dramatic and irreversible character of climate change, stresses the need for immediate action, and became a bridge between science and the public. Within the scientific domain, the metaphor is driving empirical and theoretical research. The *tipping point* metaphor turned into a rhetorical device to enhance comprehensibility as well as communicate patterns of risk in terms of "before" and "after". After having passed the *tipping point* in climate change, the earth system has changed beyond human influence. The time before is the time when climate change might still be prevented as long as appropriate actions will be taken. The metaphor of *tipping point* thus allows for a mediation of scientific results from expert climate science to everyday discourse and at the same time is communicating an urgent need for action.

Mass media are depending on economic resources in order serve their purposes. Therefore, they have to acquire and secure resources by maximizing public attention. As a consequence, media are not just mirroring reality. This is even not the case because of their restricted capacities to pick up and transform information through their first and second gate. Moreover, media reports are inherently driven by norms to present narratives as dramatic, personal, emotional, astonishing, new, uncertain, full of conflicts and controversies, balanced, and with a preference for a local focus (Boykoff, 2011; Luhmann, 2017; Schweiger 2017). In this way media are causing a second shaping of science (Feinstein, 2015).

It is the media which ultimately transforms scientific understandings in socio-scientific issues. Climate change for instance is initially turned into an environmental and into a societal crisis thereafter (Weber, 2008). Because people hardly realize how the climate is changing with a naked eye, media are transforming climate change into a sequence of events (Weingart, Engels & Pansegrau, 2000). If the media do not manage well, the transformation of science into socio-political action might be substantially hampered.

The interfaces of science, policy-making and society are mediated by the media. As a consequence, for public debate and opinion-making it is less important, if a scientific idea is regarded as valid and confirmed within science. Instead, it is more important, if and to which extent a wider public agrees on a particular scientific idea as it was mediated by the media (Weingart, 2015: 239). Boykoff (2011) is presenting a good example and summarizes results of two studies about how newspapers and TV programs contributed to a distorted presentation of the scientific consensus about anthropogenic climate change. A first study was based on an analysis of 3,500 articles from high quality US newspapers from 1988 to 2002 and the second study assembled a database of nearly 300 segments that had appeared on US TV 1995–2004. Both studies show that a majority of articles and TV segments followed a balanced reporting approach. This means that independent of an already established wide agreement among scientist about the human impact on the climate, the media payed equal attention to the view that humans contribute to global warming as well as to the view that their role was negligible. This *bias as balance* of the media negatively affected their gatekeeping function and strongly influenced the public discourse as well as political action taking about climate change in substantial ways (see example, fig. 1). Nevertheless, research has indicated that climate journalism has recently moved beyond the norm of balance towards a more interpretive pattern of journalism where most journalists are aware of the broad scientific consensus about an anthropogenic climate change (Brüggemann & Engesser, 2017).

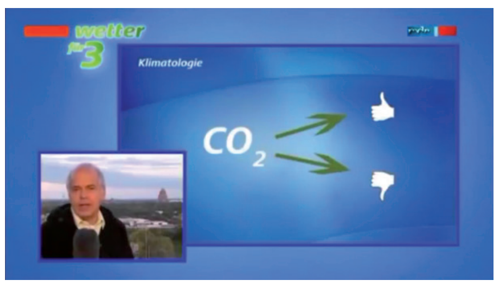

Figure 1: Weather forecast on German television suggests that scientists' opinion on the role of CO_2 in climate change is balanced.
https://youtube.com/watch?v=Ru1S0wauCbY
(Retrieved 2019-12-04)

Because of their gatekeeping function, journalistic media are serving several purposes in democratic societies most of all connecting societal sub-systems like policy-making and science to a wider public. Journalistic media therefore contribute to how society observes itself (Luhmann, 2017). Therefore, it is not surprising that the media are exposed to campaigners and their efforts to influence the interfaces between science, policy-making, the media, and a wider public. Even though a wide agreement among scientists about the human role in climate change has been established for more than a decade (Oreskes, 2005), climate change is the most commonly cited topic among US-Americans when asked for the role of disagreement among scientific experts (Funk, Gottfried & Mitchell, 2017). The way how the public perceives climate science has been strongly affected by campaigning which was driven by economic interests and aiming at an amplification of doubt in climate science (Oreskes & Conway, 2010; Dunlap & McCright, 2011; Hoggan & Littlemore, 2009; Boykoff, 2011). In this respect the "merchants of doubt" (Oreskes & Conway, 2010) have been more effective "educators" of the public than climate science itself (Cooper, 2011) and their effort went pretty well together with the above-mentioned *bias-as-balance-problem* of the media.

Given this, it is evident how vulnerable the interfaces between the media and other societal sub-systems are for being influenced by partisan economic interests. For an informed citizen this might mean that he or she does not only have to understand the basic science behind a socio-scientific issue, but also how science is portrayed, presented, transformed, sometimes distorted or even misused by the media. The gatekeeping function of the media might be helpful to protecting science against distorted presentations, as long as critical journalists dispose sufficient resources to do their jobs and as long a wider public is trusting not only in experts in science, but in how science in portrayed in high quality media in general. As we will see, both is a problem at present and the outstanding role of the media as gatekeepers is generally fading (Höttecke & Allchin, accepted).

Media in many countries are suffering from an economic crisis of decreasing budgets which strongly restricts investigative journalism. Under an increasing economic pressure, time and resources for thorough investigations are limited. This leads to an amplification of how media depend on public relation agencies or the advertising industry (Steindl, Lauerer, & Hanitzsch, 2017). The economic crisis of the media finally contributes to eroding trust in the media, depending on country and political orientation. As an international survey indicates (Newman, et al., 2018), on an aggregate level only 44% of the people express trust in the reliability of media. The situation varies strongly from countries of general high trust (Finland, 62%) to low trust (South Korea, 25%). In strongly polarized countries like the US, trust in media varies from 49%/17% according to a left-wing/right-wing orientation. In the US, Republicans and Democrats are equally likely to be active science news consumers, but Republicans are less likely to be convinced that the media are doing a good job on covering science (Funk, Gottfried & Mitchell, 2017). Hence, the polarization of a society is even mirrored by different ideas about how reliably the media are presenting science.

While traditional journalistic media like newspapers, TV or radio play important roles in mediating science, policy-making and a wider public of citizens, they are at the same time facing an economic crisis and a crisis of vanishing trust. Today, political stake-holders, companies and other organizations can provide citizens directly with their own websites, YouTube and Twitter channels and Facebook pages. As a result, the traditional role of the media as gatekeepers and curators of the mediation of science in society is declining. This process has been generally called 'disintermediation' (e.g. Schweiger, 2017: 16).

The mediation of science in a disintermediated society

The distribution of scientific knowledge and information online seems to be a big achievement. The internet potentially contributes to the emancipation of citizens. Misleading or falls information might quickly be identified and criticized by online communities. However, the actual situation seems to be different. Online discussions are rather conducted among people, which share the same ideas and predominantly agree with each other. Controversial discussions are less common (Schweiger, 2017). While it has been never before so easy to get access to a rich variety of information, positions or opinions, this sheer endlessness of opportunities also bears problems for the communication of science. In the early days of the Internet, it was still hoped that the social media would have a self-correction function, but this hope has largely not been fulfilled. Are internet users essentially prepared and willing to check plausibility and trustworthiness of the information they find? Are they able to realize conflicting evidence and find out which online source should be estimated as more or less trustworthy?

On the internet journalistic media have to increasingly compete against social media, which recently led to a substantial and quick change of adolescents' information and communication practices. A German study about media use of adolescents (Medienpädagogischer Forschungsverbund Südwest, 2017) pointed out that almost all of the 12–19-year-old do have internet access. Smartphones are the most important device for going online and are therefore used intensively by 92% of the 12–13 old people and even 99% of 18–19-year-old. When using media in their free time, being online is at the top. The most popular internet offers for young people are YouTube, WhatsApp, Instagram and Snapchat while the relevance of Facebook is rapidly declining. When asked where adolescents are searching for information at least several times a week, 85% indicate to use Google, 2/3 use YouTube and about half of them use Wikipedia. A quarter of them receives news and up-to-date information via social networks such as Facebook or Twitter or online offers of newspapers. Only a fifth use online offers of news magazines. 1/4 of adolescents and young adults (14–29 years) used the internet as primary source for searching for news, which is a high rate compared to people aged 30+. Overall, the importance of the internet for adolescents for up-to-the-minute information is increasing (Allensbacher Markt- und Werbeträgeranalyse, AWA, 2017). Across eight Western European countries, adults aged 18 to 29 are about twice as likely to get news online than from TV (Matsa, Silver, Shearer & Walker, 2018). It is likely that adolescents are using the internet not only for social purposes — most of all staying connected to their peers — but for retrieving information with scientific and political relevance.

A German survey about adolescents (Bravo & YouGov, 2017) shows 1/3 being interested in politics on a high and another 1/3 on a medium level. The prejudice of a politically disinterested youth is therefore wrong. School and family are the most important influences for political opinion-making, but only the group of highly interested adolescents is actively engaged in online discussions about political issues. On the other hand, international comparative studies of young people's media literacy show that young people are not well prepared to deal with the information overload of the Internet. Students in class 8 rarely exhibit the highest level of competence (EU: 1.5%, USA: 2.3%), indicating that they cannot securely evaluate and organize information independently. (Eickelman, Bos, Gerick & Labusch, 2019). In a nutshell, young people are interested in politics and public decision-making and increasingly draw on the internet and social networks as primary tool to get informed and participate in public debate while at the same time they are lacking competencies of media use.

Among the distinctive features of the internet is its relative lack of professional gatekeeping. Web-based information is not always subject to the same level of scrutiny as high-quality journalistic media are, which undergo restricted review and gatekeeping processes. Of course, websites of major magazines or broadcast services often invoke the same editorial attention as their traditional counterparts, but these sites constitute a minority among all kinds of internet sources which provide information (Metzger, Flanagin, Eyal, Lemus & Mccann, 2003). As a consequence of the general change in media use in society, traditional journalistic media are increasingly turning form their traditional role as gatekeepers to gatewatchers (Bruns, 2009, 2018). This means that material that passes through the output gates of news outlets online and offline is continuously observed, selected and assemble for publication in the gatewatcher's own site.

Social media on the first sight allow for a better communication of science towards a wider public of lay persons and informed citizens. Citizens might for instance use explanatory YouTube videos, make comments and discuss scientific issues with a wide audience including scientists. On a second sight, social media lead to a blurring of boundaries between public and professional discourses. Lay persons increasingly become informed by social networks, but may allegedly appraise themselves as experts. As a result, the extension of the passive reception of information and active communication in social networks by lay persons exacerbates the crisis of confidence in scientific expertise (Weingart, 2017). In this way, social networks do have the potential to amplify a general crisis of expertise in society (Nichols, 2017).

Searching, selecting and evaluating news on the internet and social media compared to traditional media reveals to quite distinctive features. News aggregators like Google News or Yahoo News became quite popular. They are searching and assembling news and information from several websites including online newspapers, blogs, videos or podcasts. Based on an analysis of a user's interests and attitudes, aggregators provide selected, personalized and tailored information. As a result, the use of non-aggregated offers is declining. The aggregation of news on the internet leads to a distortion of information because of at least two reasons. First, people predominantly pick up information which already fits to their pre-existing ideas and beliefs, and second the information provided is often decontextualized (Schweiger, 2017). As a result, internet users are more and more trapped in so called *filter bubbles*. There, they are fed with information which meets what they already know, and communicate with people which already share their views and perspectives. Social media often present tailored narratives and are hiding at the same time what they do not tell.

Next to the aggregation effect, members of social networks like Facebook have so called friends which contribute to the amplification of one's beliefs and opinions: The chance that somebody's friends share a wide array of ideas and beliefs about a certain topic together with the chance that friends send and share news and information accordingly is high. As a result, social networks function as so-called *echo chambers* where ideas, beliefs and opinions have a high chance to be confirmed, instead of being challenged. At the same time, the willingness to articulate ideas and opinions against the mainstream in a social network is rather low (e.g. Hampton, et al., 2014). This self-amplifying effect has been called a *spiral of silence* (e.g. Walter, Brüggemann & Engesser, 2018; Schweiger, 2017). The basic mechanism behind these communication pattern in social networks is not only driven by technical algorithms (e.g. by aggregation), but by the psychological trait of humans to avoid cognitive dissonance. This effect initially investigated by Festinger (1957) means that people are basically striving for a reduction of contradictions among knowledge, beliefs, and attitudes towards a certain topic which might lead to feelings of discomfort when confronted with opposing views. Personal cognitive filters are protecting one's identity against otherwise threatening information (Kahan, 2017). As a result, the cognitive architecture of the so-called *cognitive bias* (Nickerson, 1998; Kahneman, 2012) fits very well to the architecture of social media and aggregated news platforms where news and information is recommended in tailored ways (see extended discussion: Höttecke & Allchin, accepted).

What does all this mean to the communication of science? An analysis of comments to online articles about climate change shows that challenging comments which tend to deny the anthropogenic climate change are less likely from Germany, Switzerland, UK, USA to India (Walter, Brüggemann & Engesser, 2018). Sharing skeptical comments is significantly lower and sharing of supporting comments significantly higher in countries that are generally considered to be more doubtful of anthropogenic climate change. It seems to be the case that in countries like Germany, where public opinion widely agrees on the scientific consensus, skeptical voices are marginalized in a broader public debate, but still very active in social media. The public sphere is therefore disintegrated into different spheres representing different communities. Sub-communities either supporting or denying anthropogenic climate change, each evolve into consonant echo chambers, where either supporters or challengers dominate. Due to the above-mentioned effects of filter bubbles, echo chambers and spirals of silence, users of either of the groups tend to an overestimation of the number of people supporting their own views. This effect has been called a *false consensus effect* (ibid.). In our age of social media we observe several spirals of silence on different levels which are likely to compete with each other (Schulz & Roessler, 2012).

Surprisingly, an analysis of climate skeptical blogosphere let to the identification of only three central blogs (Sharman, 2014). Either they are directly challenging mainstream climate science, or they criticize how the system of climate science is generally conducted. At the same time the blogs present themselves with a scientific appearance, while less explicitly highlighting differences in values, politics, or ideological worldviews. Such central blogs are online key players in de-legitimization and contestation of scientific experts. They do not contribute to a properly working interface between science and the public, but demonstrate themselves as alternative scientific experts for a climate skeptical audience. An analysis of comments on YouTube videos about climate change which either argued for or against the scientific consensus, shows a similar pattern: it is a limited number of key players which strongly influences the public discourse of online-communities and aggregate the power to form opinions in the public (Shapiro & Park, 2018).

Another phenomenon increased by social media is the effectiveness of how *fake news* are travelling through the internet. Fake news is often purposefully launched and aims at affecting public opinion-making and enforcing partisan interests. Among the most cited fake news about climate change is the idea that a wide consensus about anthropogenic climate change has not yet been achieved. The basic problem of fake news is that compared to non-fake news they appear to be more reliable, more interesting and more surprising at least on a first sight. In a recent study about fake news travelling on Twitter (Vosoughi, Roy & Aral, 2018), it turned out that true news needed six times longer to reach the same amount of people compared to fake news. One might conclude that people sharing fake news are more active in sharing internet content, but this actually was not the case. The increased chance of fake news to be shared was due to their novelty and attractiveness only. Even if fake news is revoked after some time, the revocation is reinforcing and stressing the formerly released fake news, because it is less attractive compared to the fake news itself. As a result, revocation of fake news leads to a boomerang-effect, where fake news is amplified even by its own refusal (Wormer, 2017). This is why fake news are such powerful tools for affecting public attention and opinion-making.

Conclusions

As we have seen, the disintermediation of society caused by a growing lack of gatekeepers at the interface between science and the wider public leads to several substantial problems. They have to be considered by science educators: Social media are of increasing importance for adolescents towards being informed about science. Since socio-scientific issues are often concerned with science-in-the-making, the process of science and how it is portrayed in the public do matter for opinion-making. News providers on the internet and social media are characterized by certain traits like the aggregation of news, information bubbles, echo chambers, spirals of silence, false consensus-effect and the effectiveness of fake news. All these traits contribute to the fact that a person's opinion about a socio-scientific issue like climate change, vaccination or air pollution is more likely to be amplified instead of being challenged. As a consequence, societies at present are increasingly polarized which is among the major side-effects of the disintermediation of society. Without functioning mechanisms of gatekeeping, the quality of information about science will decrease, especially in the age of purposefully launched disinformation (fake news).

As has been argued in the introduction, citizens making informed decisions about socio-scientific issues require more than scientific content knowledge. Even a basic understanding of traditional NOS is not sufficient. We have to consider instead that any simplified model of "dissemination" or "diffusion" of scientific knowledge from science to society is rather limited and is neglecting the fact that scientific knowledge becomes actively transformed and recontextualized as it travels through communication networks (Latour, 1987; Höttecke & Allchin, accepted). Traditional approaches to NOS focus on how science is embedded in society in a rather general sense (e.g. dependence of science from funding) and how scientists justify claims within their own professional discourse. This paper argues instead that from a functional scientific literacy perspective we have to consider not only how science is produced and communicated within science. We have to consider instead the active and transformative practice of the media (gatekeeping!) when science is communicated to the public. Media use is rapidly changing. Social media more and more take up the role of communicating science in society. Here, we have seen that the gatekeeping role of traditional media is in decline and social media instead lead to distorted communicative practices in society (filter bubble, echo chamber, spiral of silence, false-consensus effect, fake news). As has been argued elsewhere (Höttecke & Allchin, accepted), students need to develop *science media literacy* in order to become *scientifically literate* and *media literate* at the same time. Science media literacy bridges the three domains of discourse: science — the media, and the citizen-consumers in their world of social media.

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Balancing research excellence and media impact: a multistage approach

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Abstract

The communication of research in an electronic age presents numerous opportunities to engage with the general public and/or industry that might directly benefit from new findings. The use of social media outlets typically has a narrative of better enabling connection between people, independent of distance or socio-economic factors. Recent USA-based research suggests that despite drops in the frequency of people who trust elected officials or the media to act in the best interests of the public, there remains a constant and considerably higher confidence in scientists. This suggests that direct communication from scientists can enable better public outreach on important issues. Drawing on several well-known historical examples of how high impactful science has been previously conducted and communicated, we provide a model of how combining quality peer review and a multi-stage communication strategy enables effective and constructive communication. Key to this is a capacity to engage with skilled journalists and the general public via several platforms to explain findings in an unambiguous fashion that enables translating the complexity required in a scientific journal into a digestible accurate representation. This model of research communication can enable end users to evaluate, process and apply information without filters that may intentionally bias findings.

Introduction

In a hypothetical, parallel world, if Galileo Galilei, Alexander von Humboldt, Charles Darwin or Albert Einstein were to put out social media disseminations about their respective key research findings, what might this look like? Certainly, it is beyond question that their findings have had a long lasting and impactful outcome on the world (Hawking 2002; Wulf 2015). It is also well documented that Humboldt was an excellent communicator in several languages, and was a prolific letter writer during the pursuit of his collaborative research that included a multi-year journey (1799–1804) to the South American continent to collect extensive portfolios of data (Wulf 2015). Humboldt was also one of the first researchers to organise an academic conference (Wulf 2015), and indeed communication of science through the networks of the Alexander von Humboldt Foundation continue well into the 21st Century. Albert Einstein was also a prolific communicator about science and society, and extensive archives of his communications (Einstein Archives Online 2020) still serve as a source of inspiration for providing insights into the thinking about his scientific innovations. Centuries earlier Galileo Galilei had chosen to write his influential book *Discourses and Mathematical Demonstrations Relating to Two New Sciences* in vernacular Italian rather than the more specialised language of Latin. This decision by Galileo to publish in a more widely read language better allowed the general public at that time to readily access the new information. Galileo himself had incurred some resistance to the sharing of his research findings by authorities within Italy at that time, and so had to enable the work to be published in Holland (Galileo 1638). The findings of Galileo went on to become instrumental to the development of scientific progress for centuries to come, and indeed in the book *On The Shoulders of Giants* by Stephen Hawking he quotes Einstein as saying "Galileo … is the father of modern physics" (Hawking 2002).

Good communication allows others to benefit from and drive innovation. Having been inspired by the exploratory travels and communications of Alexander von Humboldt, Charles Darwin travelled extensively on board the HMS Beagle to collect large amounts of empirical data to subsequently develop his theory of evolution. Simultaneously, Alfred Wallace was collecting data in the tropics on the geographical distribution of animal species and had quality data to independently arrive at a theory of evolution through natural selection. The independent findings were published as a co-authored manuscript (Darwin and Wallace 1858) and revolutionised the study of natural history and biology. A year later Darwin also published his famous book *The Origin of Species*, making the scientific findings readily available to a wide general audience around the world (Darwin 1859). A common theme on the research conduct of these giants of science is that they balanced scientific excellence with open and good communication, well before almost instantaneous global communication was made possible by the digital revolution.

In the mid 1990s several user-friendly web browser tools like Netscape and Internet Explorer began to enable a broader range of people to start using the internet for communication. Popular, easy to use search engines like Yahoo and Google were released between 1995–1998 quickly allowing information to be sourced by millions of people worldwide. Social media networking tools like LinkedIn started to gain popularity in 2002, and over the next decade new platforms including MySpace, Facebook, YouTube, Twitter, Instagram and Snapchat quickly gained widespread use due to the rapid improvements in computer power, accessibility and reducing costs for technology (McCullough 2018). By 2018 the use of social media communication tools had reached in excess of 2 billion people (Iyengar and Massey 2019). Thus, in a relatively short period of time since the 1990s there has been dramatic changes in world-wide communication networks, including how research is communicated and discussed in a digital world (McCullough 2018; Iyengar and Massey 2019).

In their article *Scientific communication in a post-truth society* Iyengara and Massey (2018) discuss the contributions of social media to society and warn that within America there has recently been a decline in public confidence for several publicly funded institutions, potentially including science. In particular, the authors discuss how for some scientific fields like climate change, vaccines, and genetically modified foods there is a growing disconnect between the views of scientists and some sections of the general public. Interestingly however, underlying survey data on public confidence shows that trust in science has remained constant over the past couple of decades, and perhaps even shows a slight rise in recent years (Funk and Kennedy 2019), whilst there has been a steady decline in trust for both media reporting and also politicians. Interestingly, as a result of these changing perceptions on how research is communicated, there is much higher trust in scientists to act in the best interests of the public (Fig. 1). Thus, any disconnect on important issues like climate change are likely fuelled by unscrupulous actors (Iyengar and Massey 2019) with ulterior motives that may benefit from spreading misinformation (circulation of materials to confuse issues) and disinformation (circulation of information with the intention to deceive).

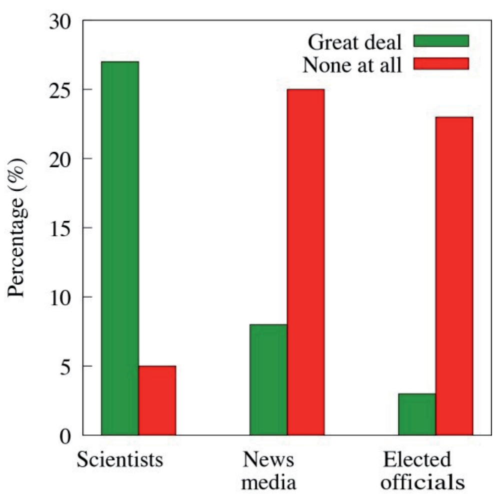

Figure 1: The percentage frequency of USA adults who say they have either a "Great deal" or " None at all" confidence in how scientists (left hand columns), News media (middle columns) or Elected officials (right hand columns act in the best interests of the public. Data from Funk and Kennedy (2019).

How then can the promise of social media enabling connection between people be used constructively to enhance the public understanding of work done in research to improve our understanding of the complex natural world? The promise of social media may allow better direct communication with the public and industry stakeholders, and avoid the possibility of misinformation highlighted above, if other sources relay important information that can have several background actors pulling strings. However, such direct communication must be done with care to maintain the scientific integrity of research findings: much like the giants of old did when they enabled good communication of their impactful research that changed our world.

Below we present a case study of a successful research project to solve important questions of broad benefit to several sectors of society, and a multi-stage communication process that was developed in tandem with the research to use social media to enable clear circulation of information to a very broad audience. This is not the only way to use social media to provide direct communication, but the model was successful and may provide useful insights for developing research dissemination strategies.

Our collaborative research sought to address important questions of what size of animal brain is necessary to enable the processing of mathematical type problem-solving. This was an important research question as classically it had been assumed that a capacity to process numerosity concepts should require both a human brain, and a reasonably sophisticated culture to enable the development of maths skills (Núñez 2017a, b). However, in recent times independent experiments have shown that several other vertebrate species like fish and birds also have a capacity to process numbers, including a concept of zero (Nieder 2005, 2016a, 2016b, 2017).

We thus wished to experimentally determine through carefully controlled behavioural experiments, if an invertebrate could solve problems that required mathematical type thinking. The European honeybee (*Apis mellifera*), in particular, is an accessible animal model for testing research questions due to their lifestyle of individual bees collecting food rewards for the entire colony, which enables long training and testing. Following a series of careful experiments with individually trained bees using both established and innovative methodologies (Nieder 2016b; Nieder 2018), our findings were presented at scientific conferences to receive critical expert feedback that was then incorporated into manuscripts. Following a full peer review of manuscripts by journals, the research was next published in leading journals including *Science* (Howard et al. 2018a), *Science Advances* (Howard et al. 2019a), *Proceedings of the Royal Society* (Howard et al. 2019b) and other top journals (see Giurfa 2019 for review). The important step, especially in the context of this current manuscript, is that simultaneous with the official publication data for each of the respective detailed peer reviewed research papers, we prepared resources suitable for a broad general audience to digest the information. We additionally, where resourcing was available, made our research open access including all raw data linked to the original studies, and for studies like Howard et al. (2019b), reviewer comments and author responses were also made public to increase transparency of the entire peer review process.

One main public dissemination stage for these respective studies was the simultaneous online publication of our research in "The Conversation" for "*Bees join an elite group of species that understands the concept of zero as a number*" (Howard et al. 2018b), "*Can bees do maths? Yes — new research shows they can add and subtract*" (Howard et al. 2019c) and "*We taught bees a simple number language — and they got it*" (Howard et al. 2019d). Each of these articles was thus prepared with advice from a professional editor at "The Conversation", to ensure that the language used could reach out to a broad public audience. We also translated research into foreign languages like Spanish and Indonesian, and enabled interviews with journalists from many different language backgrounds. This vehicle of communication was then easy for newspaper, television, radio, and broadcaster journalists to access; promoting cross platform interest in our research findings whilst also giving interested readers access to both the general study overview in "The Conversation", and easily linked access to the original studies and evidence for more interested readers. In a social media age, the information is then rapidly picked up through Facebook, Twitter, and LinkedIn plus other online platforms; but readers can still source original material and even directly contact authors. This thus enables readers direct access to information they require to make decisions, potentially avoiding some gate keeper and potentially biased actor concerns that appear to have developed in the modern age (Iyengar and Massey 2019) where adults in the USA show much higher confidence in scientists to act in the best interests of the public as compared to either the media in general, or elected officials (Fig. 1). An important stage of this process is that members of the public could use the online forums to directly communicate with us, helping to make sure that interpretations made from the work are as accurate as possible as the research impact spreads further afield.

This multi-stage approach was very successful. The example studies discussed above resulted in about 100,000 direct readers via "The Conversation" (Howard et al. 2018b, 2019c, d), then coverage worldwide by over 150 news outlets with an RMIT University media office estimated reach exceeding 750 million people worldwide. The Discover magazine[1] special issue "The Science that Matters in 2020", which highlighted the 50 most important research stories of 2019, included our research on bees and math along with NASA mars exploration and insights into how black holes work as the most important recent findings worldwide. Efficient dissemination of results and readily available access to methodological details and supporting results facilitated independent scientists to repeat the experiments and replicate the research findings in other animals, like ants being shown to also be able to process numbers including zero (Cammaerts and Cammaerts 2019).

How did we develop this plan to do both research excellence, and excellence in communication? Well, we stood on the shoulders of giants and used the strategy of (i) doing high quality research, (ii) discussing with colleagues at conferences (e.g. Dyer and Garcia 2019), (iii) writing papers that go through full peer review (Dyer et al. 2019; Howard et al. 2018a; Howard et al. 2019a), (iv) writing about the research in a form that enables the general public and other stakeholders easy access to information (Howard et al. 2018b; Howard et al. 2019c), (v) directly engaging with the public either via online forums or more traditional media like radio (e.g. see "Info and Metrics" and "Altmeric" online link for Howard et al. 2019a), visiting industry, specialist and community groups and (vii) providing online resources to enable other researchers to replicate and extend research findings (Howard et al. 2019a,b).

So, in our hypothetical, parallel and spinning world within an ever expanding universe, if Galileo Galilei, Alexander von Humboldt, Charles Darwin or Albert Einstein were to put out social media disseminations about new research findings, we think their communication strategies might be similar to those discussed above; as we actually borrowed and modified their strategies for the tools available in our digital era. Indeed, principles of good communication about research will probably remain a re-assuring constant, regardless of the medium used. Recent discoveries about how spinning stars can drag the very fabric of space and time (Krishnan et al. 2020) confirm a key element of Einstien's General Theory of Relativity, and this exciting finding enabled by standing on the shoulders of giants, was made directly available to the public via social media outlets (Bailes and Krishnan 2020). The general public wants to have access to quality information about important issues that may affect all our lives, or help all of us better understand the universe in which we live. Providing such information can enable processes to find solutions to the challenges facing our contemporary world.

[1] Discover (Jan. 2020) "The Science that Matters" www.discovermagazine.com

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Bang! Crackle! Pop! Fizzle? — Chemistry outreach and fireworks

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Abstract

Chemistry is regarded — primarily by chemists — as the central science. Advancements in chemical knowledge have propelled developments in biology, physics, engineering, and medicine that now define our modern era. But chemistry has a significant image problem, with many public fears and misconceptions regarding the prevalence and uses of chemicals, and the roles of chemists in society. In my science communication practice, I endeavour to highlight and explain the everyday roles of chemistry. This may be through descriptions of the chemistry of commonplace objects, or through dramatic chemical reactions on fast timescales. Fireworks provide a unique opportunity for both approaches, as they are integral to many cultural celebrations and childhood experiences, but few people understand or appreciate the fundamental chemical principles at play in each pyrotechnic. Herein I have outlined my science communication practice, engagement strategies, and interrogate the challenges of measuring the outcomes of science engagement.

Introduction

Chemistry is often referred to as the central science as it bridges the biological, life, physical, and applied sciences. This position within the academic literature is clearly reflected from the citation metrics of academic publishing, with analyses of cross citations between over 16,000 journals indicating chemistry is highly interconnected to the other sciences (Börner et al., 2012). The standing of Chemistry with members of the public is less clear, and the "Decadal Plan for Australian Chemistry," published by the Australian Academy of Science, noted the general perception of chemistry to be negative (National Committee for Chemistry, 2016). Unfortunately, when most Australians think of the word "chemist" they likely think of someone selling medicines, vitamins, sunglasses, or perhaps jellybeans at a multicoloured warehouse. A 2015 report entitled "Public Attitudes to Chemistry," commissioned by the UK's Royal Society of Chemistry, found very poor recognition of chemists and chemistry as a profession and discipline of study respectively (TNS BMRB, 2015). The top 5 responses to the question "When I talk about a chemist what comes to your mind?" were: pharmacies/pharmacists; medication/medicines; prescriptions; drugs/tablets/pills; and shop/chemist's shop, while the responses to the question "When I talk about chemistry what comes to your mind?" were: school/teachers; science; chemicals/elements; drugs/tablets/pills/medication. These responses highlight the significant disconnect in the recognition of the chemical sciences as an essential influence on our modern lives, with clean water, synthetic materials, fuels, batteries, pharmaceuticals, and more relying directly on research, development, and manufacture by chemists.

An additional problem is the rise of chemophobia, where all manner of chemicals are vilified, including, but not limited to, gluten, fluoride, fats, sugars, nebulous "toxins", and more. This mistrust of chemicals has led to an increase of products promoted as "chemical free", from garden products, barbecue fuels, cleaning products, personal care products and more. To a chemist, "chemical free" is a complete misnomer as everything we interact with in our daily lives is made of chemicals. The ease of falling into the trap of chemophobia is highlighted in the infographics of James Kennedy, as illustrated in Figure 1, where the components of a commonplace object, such as a banana, are listed in full detail (Kennedy, 2013). To the uninitiated, this extensive list of chemicals, expressed in their full nomenclature, is challenging at best and terrifying at worst, however, this chemical cocktail is essential to make a banana a delicious and nutritious banana.

Alongside the rise of chemophobia is the decreasing engagement of students with high school mathematics and science subjects. A 2014 report highlighted the continuing decline of enrolments across mathematics and science in Australia, with perceptions of difficulty and usefulness identified as the most likely causes of the decline (Kennedy, et al., 2014). These diminishing enrolments will inevitably lower the scientific literacy of the general public. This decline runs concurrently with the continuing refusal of politicians to accept (and act) on the science of anthropogenic climate change as an imminent threat to our climate and ecosystems. The decline in scientific literacy, and continuing science denial has an immense impact on public trust in science. Serious questions are then raised regarding the social license of science, and highlight the need for scientists to build public trust in science and technology (Leach et al., 2019).

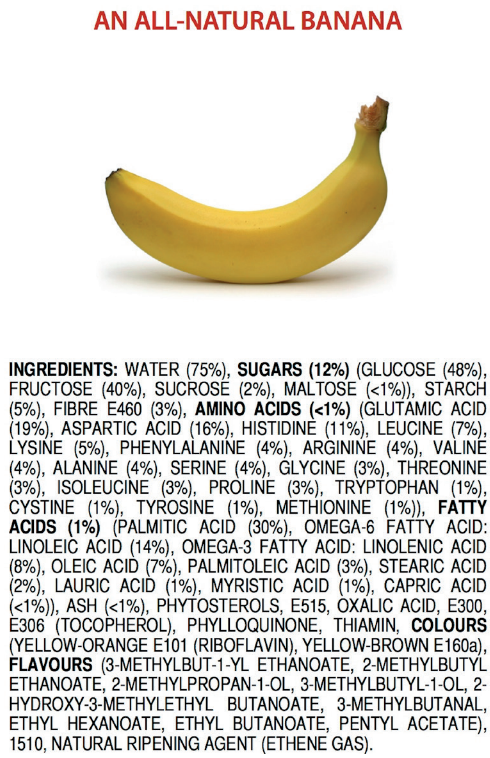

Figure 1: An All-Natural Banana — a chemophobe's worst nightmare (Kennedy, 2013). Image reproduced with permission from James Kennedy.

Fireworks?

Where and how do fireworks fit into this picture? The definition of a firework is a device using chemicals that when lit emits coloured flames, whistles, bangs, or sparks which can be made to rocket high into the sky before exploding, used for entertainment or celebration. Looking at this definition we can see some clear motivations for using fireworks to promote an interest in chemistry. First, they are used for numerous cultural and entertainment purposes, and many people have strong childhood experiences and memories of fireworks. Second, the chemical components are fundamental to the properties that are displayed and can be used to explain the chemical principles on a rapid timescale. To this end, I have developed a lecture featuring chemical demonstrations where the components of fireworks are highlighted through explanations and demonstrations of the fundamental reactions in a lecture theatre (Figure 2). The lecture is followed by professional fireworks featuring commentary on the individual pyrotechnic effects, followed by a 10–15 minute display.

There are numerous chemical demonstrations that can be made to highlight everyday objects and the chemistry they share with fireworks. This can begin with the simple chemistry of lighting a match, where components on the box and on the match head combine to give the desirable property, namely the safe and timely ignition of the match (Kilah, 2019). This chemistry can be demonstrated safely and explained in depth, and then related to other familiar objects such as party poppers (with similar chemistry to matches) and sparklers (incorporating metals and oxidants).

Figure 2: A chemical demonstrations performed at "The Periodic Table of Fireworks". Left to right: Chloe M. Taylor, Nathan L. Kilah, Adrian V. Wolfenden. Image reproduced with permission from Tayla Chick.

Slowly more chemistry can be introduced including chemical reaction schemes for the combustion of gunpowder, and the colours from the individual metal salts added to pyrotechnics. Having discussed and demonstrated the components of the firework, the nuances of the environmental impacts of fireworks can be discussed, specifically around issues of chemical pollution, and the prudence of fireworks during increasingly long bushfire seasons. The lecture also provides a platform to share a very strong safety message, as there are many risks to be managed with the chemical demonstrations and fireworks more broadly.

Target audience

So, who is the target audience for this show? My employer might hope for soon-to-be school leavers to be enrolled into degree courses in the next couple of years. However, it is my opinion that it is too late to motivate students in science and chemistry at such a late stage. My target audience is younger children around 8 to 12 years old who are more open to suggestions and encouragements towards new areas of interest. In reality, my fireworks event attracts a diverse audience of young families, parents with older children approaching university age, and significantly older attendees.

How does one seek to judge the success of such an outreach event? First and foremost is the need for the event to operate safely, with no incidents or concerns in the lecture theatre or at the outdoor fireworks display. Surveys have been considered as one approach to investigate the outcomes of the event, but how does one ask appropriate questions to gauge success? Survey instruments are increasingly used to understand the impacts of outreach (Vennix, 2018, and Wahono, 2019), but they are often narrowly defined to ask specific questions on desired outcomes, and avoid overwhelming the audience with myriad survey questions. And what would one ask for my firework event? Is this science outreach as a form of entertainment? As inspiration? As education? Or as student recruitment? Should success be judged by how many students show up to my lectures in the near or distant future as newly enrolled students? Attendees may also remember an obscure fireworks fact, but has that changed their perspectives on chemistry and chemicals? Thus far a single overarching focus of success has not been settled, and the best way to measure engagement remains unclear.

Looking for multipliers

One important lesson that I have learnt from undertaking this science outreach event is the need to look for multipliers from the input of a single activity. One theme or topic, once well research, can be communicated in many different ways to reach many different audiences. For example, the firework event has been run twice with over 700 attendees resulting in: interviews on nine radio programs; an article for The Conversation on the chemistry of lighting a match (Kilah, 2019); a published chemical demonstration which was developed during the planning of the event (Wolfenden and Kilah, 2017); and most recently an article in COSMOS magazine (Kilah, 2019a). Each of these activities has allowed for the same message to be communicated to many different audiences, from the casual radio listener, through to academic audience, and highly motivated science readers.

Conclusion

Fireworks are an effective outreach technique, but they can only ever form a small part of the need to communication chemistry to the general public. The curator and artist Kirsha Kaechele (of Hobart's famous Museum of Old and New Art) once presented at my institution on the topic of science communication. To paraphrase her conclusion, a member of the general public's impression of science is like a digital photo — it is formed by a number of pixels. Any one science communication activity can only ever be a single pixel in that image. Therefore, when engaging the public with science communication make sure your pixel is bright.

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Reflections on developing enduring research collaborations across law and linguistics

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Abstract

Scholarship focused on language in legal settings and in laws themselves is an emerging field that involves diverse research across a variety of disciplines. This research, as a body of work, has a range of potential applications beyond academia across policy-making, professional practice and the interpretation and creation of law. However, the disparate nature of this area of research creates challenges for collaboration and for the accessible and impactful dissemination of findings.

This paper was originally presented at the 2019 biennial symposium of the Australian and New Zealand Associations of von Humboldt Fellows, following the theme of "Sharing Knowledge". In it, we share our experiences establishing an interdisciplinary researchers' network, the Law and Linguistics Interdisciplinary Researchers' Network (LLIRN). This initiative was a means of addressing some of these concerns and realizing this potential by strengthening collaboration and cooperation across institutions and disciplines, and by including academics at every career stage. Here, we reflect on the opportunities and challenges arising out of this experience and consider how they could inform researchers with similar goals in other research contexts.

Introduction

Over the last few years, we have read, applied and contributed to international research at the intersection of law and linguistics. Our contributions began as we undertook our doctorates together at Macquarie University's Department of Linguistics, our new "second home" as we were both teaching in law schools at the time.

While each of our doctoral projects involved law and language, their diversity hints already at the vast array of scholarship that falls within these interdisciplinary intersections. One was a legal and ethnographic examination of China's constitutional minority language rights (Grey in press). The other examined discourse, power and language ideology in official asylum seeker application processes and political and media discourse about refugees in Australia (Smith-Khan, 2017a, 2017b, 2017c, 2018, 2019a, 2019b, 2019c, 2020).

We came to realise that there are important strands of research underway in which linguistic and legal scholarship and practices are made relevant to one another. But we also noticed that this research was disparate and that opportunities for interdisciplinary scholars to meet, collaborate and publish together were sporadic. It seemed to us that one common term for interdisciplinary law and linguistics work, "forensic linguistics", was sometimes a narrow and sometimes a broad term (Heydon, 2019, p. 3). Further, neither of us would say our kind of interdisciplinary law and language research was *forensic* in the sense of investigating crime, or even in the broader sense of relating to courts. And yet we had a lot of interest in other researchers we chanced upon combining law and language studies, and oftentimes we shared their methods, background readings, and problems.

Despite this real shared interest, we found there was little in the way of a cohesive articulation of how (or whether) there are theoretical and methodological bases upon which a field — sometimes also called 'legal linguistics' — is developing. We believed that this was limiting collaboration and limiting the strength with which researchers could present their work to audiences from distinct disciplines. It was particularly restricting the influence of linguistic research on legal scholarship and practice.

Therefore, we decided to start building a cohesive base ourselves, through face-to-face meetings and discussions, including by inaugurating an annual workshop-format symposium and arranging conference panels, both in 2019. We also started building up our base online, by administering an international email Listserv and establishing an online repository for sharing papers and expressions of interest in collaborative projects. We hoped that intellectual discussions and collaborative projects would follow, between ourselves and our new community but also independently between members of our new community. In this paper, we share our approach.

Existing research and teaching in language and law

Before conducting our symposium, we reflected on the different disciplinary, methodological and thematic approaches to research relating to language and law. This conceptualization provided a foundation for the symposium's facilitated discussions. Below, we provide a brief overview of how we conceptualize this interconnecting yet diverse scholarship.

Research

To guide our symposium discussions towards greater mutual understanding, and drawing on what we had learned about our participants in the lead-up to the event, we presented a proposed conceptualization of the emerging shape of the language and law research field.

Our heuristic organizes the field around three main subject matter/research question nodes, rather than around adherence to particular methodologies or legal or linguistic theories. Each node anchors a range of more specific topics found in the literature. The first is the language in legal or bureaucratic processes node; the second is the language-related social justice node; and the third centres on the regulation of language. We explain this theorization further in (Grey and Smith-Khan, under review).

University teaching

While existing research demonstrates a rich diversity of scholarship related to both language and law, this is not equally apparent in current course offerings. Some, but not many, of LLIRN's members in Australia already teach in such courses. Our network members have been discussing possible collaborations to increase the translation of this research into teaching. We have also discussed whether there is a market for such courses in either linguistics or law departments, or as institutionalized partnerships between the two. There is some indication that there is a market: since establishing our symposium and network, prospective and current higher degree researcher candidates have contacted us explaining that their own interest is in the intersection of linguistic and legal research but they had been unaware that interdisciplinary researchers interested in language and law even existed, and expressing relief to find that we do. This suggests that there is room for further development of electives or the inclusion of material in existing core subjects that at least identifies interdisciplinary research about linguistic issue in law, or vice versa. It also demonstrates the potential for networks like ours to support future researchers who may otherwise remain unaware of the depth and breadth of research, and to aid them in finding opportunities to pursue their passions, or peers.

Developing collaboration

Collaboration is a valuable way to respond to some of these needs. We have both come to appreciate the value of collaboration and peer support. This began primarily during our doctorates at Macquarie University. Both under the supervision of Distinguished Professor Ingrid Piller, we were introduced to the Language on the Move research group. Language on the Move brings together Piller's current and many of her former — and sometimes also future — higher degree research candidates. Together we hold regular meetings in which we discuss various research-related topics — everything from providing feedback on a colleague's paper, through to sharing advice on submitting a book proposal, to reading and discussing a topical publication. Language on the Move also forms the organizing committee for academic conferences and symposia (including the international *Sharing Knowledge in the Spirit of Humboldt* symposium at which we delivered a presentation on which this paper is based). It maintains a social media presence via Twitter and Facebook, with a substantial international following (over 20,000). Finally, the group runs an online research portal, attracting contributions and readership from scholars around the world; its peer-reviewed research blog was the first non-traditional output to be reviewed by the *Journal of Sociolinguistics* (Nylund, 2018).

The incredibly enriching experiences we have had as part of Language on the Move means that we have developed a strong appreciation of the value of building research networks of peers, mentors and mentees, sharing research findings, and building research leadership skills.

When we each finished our doctoral research and secured research fellowships in law faculties in two different universities — Alex at the University of Sydney and Laura at the University of Technology Sydney — we were keenly aware that our interdisciplinary approaches and particular focus on language made us unique. But it also meant that there was no obvious pre-existing network or group to support our research agendas and career progression. We had to learn to explain to many law colleagues exactly what we do and why it is important, because this has not previously had a profile as an interdisciplinary area (unlike well-established interdisciplinary legal research fields, such as criminology or environmental law).

Given our positive experiences collaborating, we were inspired to start building our own network: one that could help us build a community of like-minded though diverse scholars, make sense of the multifaceted research intersections of language and law, and share strategies for expanding and integrating our work into existing disciplinary structures. This began with an inaugural symposium in April 2019, and was followed by establishing a network, via a Listserv.

Language and Law Interdisciplinary Researchers' Symposium

Purposefully expanding beyond our scholastic comfort zone, we sought to bring together researchers with varied approaches to combining language and law, including scholars of language rights and policy; forensic linguists; court translation and interpretation specialists; discourse analysts looking at varied state processes and state agencies, legislative corpus researchers, those concerned with diversity and equality, and those who teach university courses about language and the law. We identified and invited researchers from around Australia, at all career stages. Our international keynote speaker was Professor Katrijn Maryns, from the University of Ghent, a scholar whom we would place within our first node. Her expertise is on language issues (miscommunications, language beliefs and language policies) in official asylum-seeking processes in Europe (see e.g. Maryns 2006). We ended up with 31 participants for our April 2019 symposium. Many had tertiary qualifications in both law and linguistics/languages.

To start building up awareness and community between these diverse participants, the theme of our inaugural Law and Linguistics Interdisciplinary Researchers' Symposium was: 'What do we share?' A seemingly simple, sometimes stupefying question! At the very least, we believe that we share an emerging interdisciplinary field.

Symposium structure

To help shed some immediate light on this question, we sent out a 10-question survey, asking our inaugural symposium's participants about their qualifications, affiliations, their theoretical approaches, and subject matter. We then reported back with an overview of this data as part of our introductory presentation at the symposium. We also collected research outputs and biographies from each participant to share with the group as a whole. These provided stimulus to moderate a discussion around what our symposium participants identified as common ground or an identity of the group as a whole.

Rather than designing the symposium to involve traditional conference-style presentations, we opted for an interactive workshop approach, with just two individual presentations to complement these, along with our own introductions and report-back on the participant survey. The interactive sessions included a collaboration fair. Writing onto large posters around the room, participants could identify projects on which they would like help or for which they would like to collaborate with others, and 'sign up' to cooperate in others' proposals. We then migrated all the expressions of interest and suggested collaborative projects into a shared and editable online folder, so that people could go back to it later, add themselves or contact others who had expressed a shared interest.

Another session at the symposium focused on identifying key challenges for language and law research and workshopping opportunities to address these. The final session of the day brought together the results of these sessions to discuss and identify key next steps for the group.

Building a network

After the symposium, and based on the identified desire for ongoing collaboration and networking, we set up a Listserv mailing list.[1] We call ourselves the Law and Linguistics Interdisciplinary Researchers' Network (or LLIRN) and as of February 2020, our Listserv has over 100 members around the world, not just in Australia! The list has provided the foundation for sharing research activities to the group as a whole. It has also been a valuable means of developing a group identity and identifying ourselves as researchers who have an active interest in the intersections between language and law. This especially benefits early career researchers.

Since establishing this network, we have each been invited to participate in a number of related research activities, such as the International Association of Forensic Linguists' biennial conference (Grey & Smith-Khan, 2019; Smith-Khan & Grey, 2019), the Language Policy Forum of the British Association of Applied Linguistics, the Humboldt Symposium and a workshop on 'Language and Law' at Melbourne University (Smith-Khan & Grey, 2020). Moreover, through LLIRN, and with the support of the Humboldt Symposium's organisers, we were able to competitively select and sponsor two postgraduate LLIRN members' attendance.

In December 2019, we ran a panel at Macquarie University for the Australian Linguistics Society's annual conference.[2] Our panel members were all researchers we identified through the LLIRN, either as existing members, or through our members' recommendations. The panel's discussant was a former Federal Court judge and executive member of the International Association of Forensic Linguists, Peter Gray AM. Questions for the panel discussion were collected via the LLIRN Listserv. We have an ongoing, open call for LLIRN members to propose guest speaker events in order to build up a regular series, and we have successfully proposed a special issue for LLIRN contributors to a legal journal (the Griffith Law Review, expected publication 2021).

We have witnessed the ongoing expansion of the network, with the recent addition of a number of undergraduate, masters and higher degree research students. As two early career researchers who are keen to expand our research leadership experience, we can appreciate the value of the network as a platform to develop mentoring, and its potential to create postgraduate research supervision opportunities. In fact, it has been very gratifying to us to have become ad hoc mentors to even earlier career researchers who have approached us through the network to ask for guidance or seek our PhD supervision. Nurturing this community is especially important given that this intersecting research area is not always well known or represented. Having a group identity and receiving recommendations and introductions through our members is so valuable in this respect. It means that we are able to reach out to future researchers who share similar interests but frequently report simply not knowing that such a research focus was even possible, or that there was anyone already working at these intersections. It also enables us to bring existing researchers' work to a wider, keen audience.

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[1] https://mailman.sydney.edu.au/mailman/listinfo/law_linguistics_network

[2] Details of the panel can be downloaded here: https://als.asn.au/Resources/PageContent/Files/d304bf47-5619-4527-a090-29bc22561c93.pdf

Next steps

Ongoing challenges for us as a network of interdisciplinary researchers with interests in effecting change include improving our communication about our research to key stakeholders in other research disciplines or beyond academia, for example in legal practice, and policy making. Given the challenges of working within existing, often disciplinarily divided institutional structures, we also continue to seek innovative ways to find funding and collaborate, and to establish lines of communication for sharing our skills, ideas and successes with each other and with those whom our work could benefit or should influence. It is for this reason that we cannot over-emphasize the importance of events that advocate and facilitate the sharing of knowledge.

Acknowledgements

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The International Astronomical Union and its work to promote collaboration in research among astronomers world-wide

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Abstract

The IAU is celebrating its centenary in 2019, and is one of the oldest scientific unions. In this article I describe its work to promote collaboration in research among astronomers world-wide. The IAU also promotes astronomy education, astronomy outreach to the public, the careers of young astronomers and equity, inclusivity and diversity for those pursuing astronomy as a career. In its 100 years it has become a world leader for reaching out and promoting astronomy for the betterment of society as a whole.

Introduction

The International Astronomical Union (IAU) was formed on 28 July 1919 at a meeting of the International Research Council in Brussels, Belgium. It was the first of seven scientific unions to be established in the aftermath of the Great War, and is therefore the oldest of some forty international scientific unions that exist today. It was the only scientific union to have both national and individual members, a circumstance which has shaped its history and development and has led to a high level of individual involvement in the union's affairs.

At first the IAU operated as a closed "club" for about 200 individual members, who discussed classification schemes in astronomy, the adoption of standard stars for calibrating observations and other topics which helped optical astronomers collaborate. By 1925 there were 288 members, coming mainly from western Europe and North America. Germany and its allies in the War (Austria, Hungary, Bulgaria and Turkey) were excluded from membership, a situation which continued until after WW2.

Fig. 1. The first IAU General Assembly, held in Rome in 1922.

The IAU organized General Assemblies every three years. The first was held in Rome in 1922 with just 83 participants (Fig. 1), nearly all of whom were elderly and male. It was the first of just six general assemblies prior to WW2.

Early evolution of the IAU after WW2

After WW2, the IAU began to evolve in its function and outlook, so as to involve astronomers as people, as well as to be concerned with astronomy as a scientific discipline. The first sign of this evolution came in

1946 when a commission was created for the Exchange of Astronomers (Commission 38). It was one of about 50 commissions established over the years in different branches of astronomy. Some modest levels of funding were available to this commission, which promoted scientific exchanges of astronomers between countries for research visits of a few months. Most of these exchanges were within Europe or between Europe and the United States, but a few astronomers came from China to visit Europe or the U.S.A.

The Exchange of Astronomers programme was continued for 63 years from 1947 until 2009, by which time 558 grants had been made to support the travel expenses of astronomers on exchanges to other countries. At its height in the 1960s, between 15 and 20 awards were made annually. The programme slowly declined thereafter, probably because of the ready availability of travel funding from within institutional research budgets.

The next significant advance for the IAU came in 1964 with the establishment of IAU Commission 46 for the Teaching of Astronomy. This commission received some funding from the IAU's Executive Committee and ran a number of programmes, the most notable of which was launching the International School for Young Astronomers (ISYA) in 1967. About 30 graduate students doing PhD or MSc thesis research were accepted into the school where they received high-level lecture courses and practical classes from expert astronomers in various branches of astronomy. Typically one or two schools have been held annually since that time; the 42nd ISYA concluded in Kunming, China, in November 2019. About 1500 students have participated in the ISYA schools, and many are prominent professional astronomers still active today.

Another initiative of Commission 46 was the Working Group for the World-wide Development of Astronomy (WGWWDA, later known as Program Group WWDA). This committee helped promote the world-wide development of astronomy in developing countries, by undertaking visits to universities and observatories in the third world, giving lectures, assisting with teaching curriculum development and encouraging international collaborations. The present author chaired PGWWDA from 2003–10, after which these activities were absorbed into the new Office of Astronomy for Development (OAD).

These two commissions, C38 and C46, were the only ones of the IAU to be accorded funding and a budget. They helped transform the union from an inward-looking society for putting astronomical research on a more international basis to a more outward-looking organization involved with both people and research.

New IAU offices established from 2010

A major event in the IAU's history was the International Year of Astronomy (IYA) in 2009. It was proposed to celebrate 400 years since Galileo's first use of a telescope in astronomy in 1609. The IYA was a major success involving thousands of public outreach events in over a hundred countries, which reached millions of people world-wide.

The IAU produced its first Strategic Plan (Miley, 2009), also in 2009. This marks the time when the IAU reached out beyond the ranks of the about 10,000 professional astronomers who were IAU individual members, and started on an ambitious programme to influence the scientific and economic well-being of society as a whole through the promotion of astronomy to the public and to students.

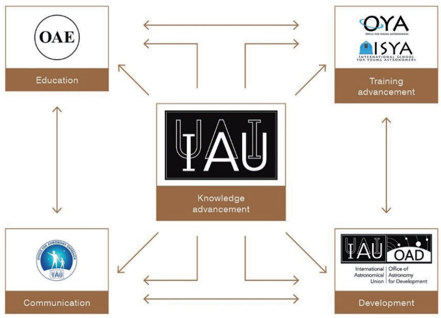

Fig. 2. Relationship between the IAU and its four offices, for development, outreach, young astronomers and education.

The Strategic Plan 2010–20 resulted in the establishment of the Office of Astronomy for Development (OAD) in Cape Town. The OAD is based at the South African Astronomical Observatory with support from South Africa's National Science Foundation. It has a small contingent of professional staff who promote astronomy-based projects, often in developing countries, with the aim of social and economic development and the training of students at all levels.

OAD was the first professional office of the IAU (other than the IAU headquarters and secretariat in Paris). In 2012, a second office was established for public outreach, especially for communicating to the public the many amazing discoveries being made by astronomers. This was the Office for Astronomy Outreach, OAO in Tokyo, based at the National Astronomical Observatory of Japan.

A third office was established in 2015 in Oslo. This was the Office for Young Astronomers, OYA, based at the University of Oslo and supported financially by the Norwegian Academy of Science and Letters. The main function is to support the ISYA schools for young astronomers.

Finally, in 2020 the IAU will establish a fourth office, this time the Office for Astronomy Education, OAE. It will be based in Heidelberg, Germany, at the Max Planck Institute for Astronomy. OAE will help train teachers at high schools and universities to teach astronomy and give support with curriculum development and resources. It will be supported by the Klaus Tschira Foundation and by the Karl Zeiss Foundation.

All four of these offices (Fig. 2) are based in astronomical institutes and are supported financially by academies or foundations in their host countries, which form a strong partnership with the IAU. They represent the future for the IAU in reaching out to students, young people and the public to use astronomy for the betterment of society as a whole.

The IAU and its working groups

The IAU has a structure of an Executive Committee overseeing nine Divisions, about three dozen Commissions and some 54 Working Groups. These last mainly concern themselves with specific projects in astronomical research. However, several Working Groups are engaged in helping people. One of them is the WG for Women in Astronomy, established in 2003 to help promote the careers of female astronomers.

Overall, 18.3 per cent of the IAU's 13,665 individual members are women. The percentage is growing, though there is still much work to do to achieve anything like equality. Argentina (40%), Italy (27%), France (26%) and Turkey (28%) are examples of countries with higher percentages of female astronomers than the average.

As for the IAU Executive Committee, it is notable that that three successive presidents have (or will be) women, and soon there will be four female IAU presidents or

Fig. 3. The IAU has had (or will have) four female presidents, including three in succession from 2015–24.

past presidents (Fig. 3). They are Catherine Cesarsky (France, 2006–09), Silvia Torres (Mexico, 2015–18), Ewine van Dishoeck (Netherlands, 2018–21) and Debra Elmegreen (USA, 2021–24). The current IAU General Secretary, Teresa Lago from Portugal, is also female.

In 2015 a Working Group for equity, diversity and inclusion was established. The WG's objective is to address the systemic structure, functions, processes and attitudes that result in the exclusion or restricted participation of under-represented groups in the field of astronomy. Key to achieving this goal is research into and the development of strategies, tools and resources that will enable the equal participation in astronomy of people of different ethnic, cultural, religious background, gender and disability identities.

In 2018 a Working Group was established for Junior Members of the IAU. This was a new category of membership to encourage young astronomers in their first few postdoctoral years to join the union. At the present time there are 534 IAU Junior Members, and hopefully many will become full members after a maximum of six years.

These developments represent something of a social revolution in the way the IAU is engaging with people and leading the way for promoting a better society both within and beyond the bounds of the Union.

Throughout the world there are hundreds of thousands of amateur astronomers, some of whom own their own telescopes and undertake useful research. The IAU has engaged with this large group in a rather perfunctory way in the past. An IAU workshop for amateur astronomers was held in April 2019 in Brussels, as part of the Union's centenary celebrations, and at the 2019 Executive Committee meeting in Rome in 2019, a proposal was made for a new Working Group to engage with this group. It could be one of the next big developments for the IAU in reaching out beyond the membership of professional astronomers.

A social revolution has been launched

This article has shown how the IAU has evolved dramatically since WW2. It is hardly recognizable in terms of its original organization and goals of a century ago. What was once an inward-looking body engaged purely with the procedures of astronomical research is now a dynamic and outward-looking organization, interacting with people, especially students and the public.

A large part of this success must be attributed to the IAU's unique body of individual members, whose number has grown strongly in recent decades. It is the individual members, especially through the Commissions and Working Groups, who have promoted these enormous changes in the outlook of the Union. This is a model for other scientific unions to follow, and especially for the work to promote the careers of women in science, for promoting the careers of young astronomers, for bringing students into astronomy or into science in general, for helping people with disabilities to have careers in astronomy, for engaging with the public, and for helping to develop astronomy and science in developing countries.

Looking to the future, the IAU has recently published a new Strategic Plan for the years 2020 to 2030 (van Dishoeck & Elmegreen, 2018). There are five major goals for the coming decade:

1. The IAU leads the worldwide coordination of astronomy and the fostering of communication and dissemination of astronomical knowledge among professional astronomers.
2. The IAU promotes the inclusive advancement of the field of astronomy in every country.
3. The IAU promotes the use of astronomy as a tool for development in every country.
4. The IAU engages the public in astronomy through access to astronomical information and communication of the science of astronomy.
5. The IAU stimulates the use of astronomy for teaching and education at school level.

Future developments will be engaging with the large number of amateur astronomers and helping to promote astro-tourism, which is perhaps the new frontier now growing rapidly around the world (Fig. 4).

More about the history, centenary celebrations and development of the IAU can be obtained from the IAU Centenary Symposium, held in Vienna in August 2018 (Sterken, Hearnshaw & Valls-Gabaud, 2019), and from a recent book to mark the IAU centenary (Andersen, Baneke & Madsen, 2019).

Fig. 4. Astro-tourists on a star-gazing tour at Mt John Observatory, New Zealand. Astro-tourism has become one of New Zealand's principal tourist attractions, and may a focus for the IAU in the years to come.

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One sequence, one structure: demise of a dogma, or fake news

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Abstract

For the last 50 years Anfinsen's dogma of one sequence, one structure has been a central principle of biochemistry and molecular biology. However, the inability of X-ray crystallography to resolve structures of many proteins and protein segments, leads naturally to the conclusion that proteins can also exist in intrinsically disordered states. This necessarily requires a revision to Anfinsen's dogma. Thus, the amino acid sequence of a protein must encode for both order and disorder.

Introduction

Since the discovery of the double-helical structure of DNA by Watson and Crick (1953) and the subsequent resolution of the genetic code (Leder and Nirenberg, 1964), it has been known that each amino acid residue in a protein is encoded by a sequence of three nucleic acid bases (a codon). Thus, the sequence of DNA bases in a gene determines the amino acid residue sequence, i.e., the primary structure, of the protein for which the gene encodes. In 1956, Christian Anfinsen, a biochemist with the National Institutes of Health U.S.A., carried out a very influential experiment linking the amino acid sequence to the protein's final three-dimensional folded structure, i.e. its tertiary structure (the term secondary structure is reserved for local polypeptide chain conformations). What Anfiinsen did was to first denature and reduce the protein ribonuclease by treating with the denaturing agent urea and the reducing agent β-mercaptoethanol. Following this, he dialysed the protein to remove both the urea and β-mercaptoethanol. After the dialysis he found that the protein regained its full activity and, therefore, must have spontaneously re-folded into its native active state. Based on this result, Anfinsen proposed that the entire information for the correct folding of a protein is contained in its amino acid sequence. This can be simply summarized in the phrase "one sequence, one structure". For this work Anfinsen received the 1972 Nobel Prize in Chemistry. "One sequence, one structure" has been a central principle of biochemistry and molecular biology ever since, and it is commonly referred to as "Anfinsen's dogma". However, evidence is now accumulating that Anfinsen's dogma may be in need of a revision.

Protein X-ray crystallography

The first three-dimensional protein structure to be determined was that of myoglobin (Kendrew et al., 1958), for which John Kendrew of the University of Cambridge received the 1962 Nobel Prize in Chemistry. This structural determination was based on the fundamental foundation of X-ray crystallography that exposure of an ordered array of atoms produces an X-ray diffraction pattern. Every different structure creates its own characteristic pattern. Therefore, if the mathematical relationship between the structure and the pattern created is known, by analysis of the pattern one can solve the structure. The mathematical relationship is known as Bragg's Law, and was discovered in the early 20th century by the father and son team William and Lawrence Bragg. At one stage in his career William Bragg had been professor of physics at the University of Adelaide and his son Lawrence grew up in Adelaide. Lawrence was later the head of the Cavendish Laboratory in Cambridge where Kendrew and also Watson and Crick worked.

Since the determination of the myoglobin structure, three-dimensional structures of numerous proteins have been solved at the level of atomic resolution. Membrane proteins proved to be particularly hard nuts to crack because of the surrounding lipid. However, by replacing native lipids with detergent, even membrane protein structures are now being solved at an ever increasing rate. The first to be solved was that of the photosynthetic reaction centre of the bacterium *Rhodopseudomonas viridis*, which was published by Hartmut Michel, Johann Deisenhofer and Robert Huber from the Max-Planck-Institute of Biochemistry in Munich (Nobel Prize for Chemistry, 1988). The first crystal structure of the Na^+,K^+-ATPase, the ion pump responsible for maintaining cell volume in all animal cells, was published in 2007 (Morth et al.).

In spite of the success of protein X-ray crystallography and all the protein structures which have been successfully solved, it has become increasingly clear that some proteins or some segments of proteins still elude structural determination. For example, although structures of the Na^+,K^+-ATPase have now been published in a number of different conformational states, no-one has yet succeeded in resolving the structure of the cytoplasmic N-terminal tail of the protein's α-subunit. If this segment of the protein doesn't produce a diffraction pattern, the most likely reason is that it is too flexible on the time-scale of the X-ray crystallographic method, i.e. it can be classified as an intrinsically disordered segment of the protein.

Entropy

Entropy, or in layman's terms disorder, is a fundamental concept of physical chemistry, being the topic of both the Second and Third Laws of Thermodynamics. Under constant temperature conditions, the change in free energy and consequently the distribution of a protein between two states (e.g. two protein states in an enzymatic cycle) are determined not only by the change in the strength of intermolecular bonding forces (reflected in the enthalpy change, ΔH), but also by the change in entropy (ΔS). Thus, a change in the degree of disorder of an intrinsically disordered segment of an enzyme could have a significant effect on an enzyme's kinetics.

Again using the Na^+,K^+-ATPase as an example, recent evidence (Garcia et al., 2017; Jiang et al., 2017; Nguyen et al., 2018) suggests that this protein's N-terminus switches between two states where it is either bound to the neighbouring membrane or freely moving in the cytoplasm, i.e. from a low to a high entropy state. Based on the amino acid content of the N-terminus, the free energy change associated with a transition from a completely ordered to a completely disordered state can be estimated using the PLOPS server of Baxa et al. (2014) to be -234 kJ mol^{-1}. This is a larger free energy decrease than that released by ATP hydrolysis, i.e., approximately -50 kJ mol^{-1} (Clarke et al., 2013). Although a partial rather than a complete disordering of the N-terminus is more likely, this comparison demonstrates the potential of entropy changes to contribute significantly to the stability of protein conformational states.

Revision of Anfinsen's dogma

Just as amino acid sequences can cause protein segments to fold in particular ways to generate a three-dimensional structure, the existence of intrinsically disordered protein segments indicates that amino acid sequences can also code for disorder. Because disorder necessarily implies more than one possible local conformation of a protein segment, the concept of "one sequence, one structure" is no longer tenable. However, rather than discard Anfinsen's dogma entirely, a better solution would seem to be to expand it to include disorder as well as structure. Thus, one could say that the amino acid sequence of a protein contains all the information to generate both its order and disorder.

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Archibald Liversidge: Imperial Science under the Southern Cross

Roy MacLeod

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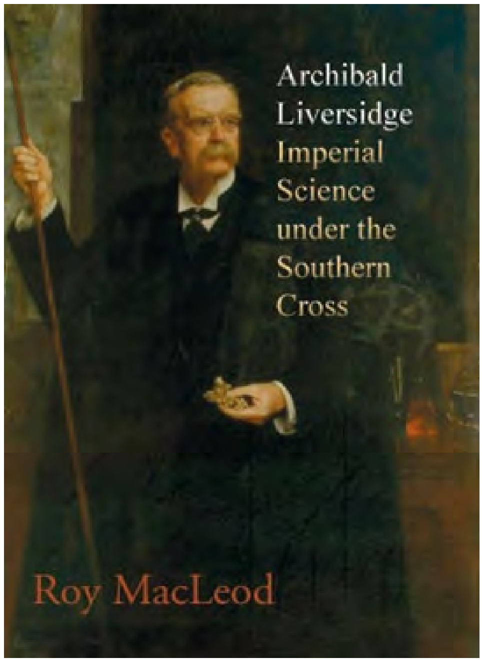
When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology and Mineralogy and by 1879 he had persuaded the University Senate to open a Faculty of Science. He became its first Dean in 1882.



In 1880, he visited Europe as a trustee of the Australian Museum and his report helped to establish the Industrial, Technological and Sanitary Museum which formed the basis of the present Powerhouse Museum's collection. Liversidge also played a major role in establishing the A*ustralasian Association for the Advancement of Science* which held its first congress in 1888.

This book is essential reading for those interested in the development of science in colonial Australia, particularly the fields of crystallography, mineral chemistry, chemical geology and strategic minerals policy.

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