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SINGAPORE

An evolving and increasingly complex relationship

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1. Introduction

The development of scientific communication in Singapore can be described in terms of an evolving and increasingly complex relationship between discourses *about* science and its role in society, and the communication *of* science and its ideas, through formal education and other forums. From early beginnings with top-down government-initiated promotion of science for pragmatic societal ends, discourses about science have broadened to now incorporate multiple voices, including more ground-up ones emerging from an established scientific community as well as members of the public. In tandem with this, the communication of science has also grown from early basic concerns with extrinsically motivated promotion of scientific literacy for economic needs to include more mature intrinsic concerns such as helping developing and established scientists to communicate their work more effectively. This chapter traces this evolution, highlighting the ways in which extrinsic and intrinsic motivations, as well as top-down and ground-up movements have shaped discourses about science, and the communication of science, in Singapore.

2. Historical background

Singapore's present commitment to science, technology and the achievement of excellence can be traced to overarching discourses built around the official histories of the founding of Singapore in 1819 by Sir Thomas Stamford Raffles and Singapore's former status as a British colony. Politically sanctioned

discourses depict Singapore as a quiet fishing village that developed quickly into a thriving centre of *entrepot* trade,[1] made possible by forward-looking colonial policies that supported the growth of commerce. These early influences provide the backdrop of circumstances that helped to generate a rhetoric of change, vulnerability and uncertainty upon which the need to establish firm policies for Singapore's future growth, stability and economic prosperity were then based.

Singapore's early developmental trajectory, for over a century, drew on the benefits of its strategic geographical location and the trade and commercial activities this enabled, ostensibly with less emphasis placed on scientific and technological development and advancement (Tan, Wee and Subramaniam, 2017). However, the unfolding of political change—brought about by the traumas of the Cold War and decolonisation, leading to self-governance in 1959, the Malayan emergency and Singapore's separation from the Malaysian Federation in 1965—resulted in the need to address the urgent, pragmatic and complex constraints that followed. This was done under the leadership of the People's Action Party (PAP), which was voted into power in 1959. Constantly stressing the importance of political stability for 'existential matters of national survival and economic prosperity' (Tan, 2018, p. 1), the party has chosen to interpret this as an 'abhorrence of parliamentary Opposition' (Mutalib, 2004, p. 28). To date, while negotiations of political culture and ideology are ongoing, this narrative has enabled it to retain a strong grip on power. The PAP's nearly six decades of governance has enabled the fairly coherent and smooth implementation of policies and programs, with significant opposition stemming more from external rather than internal forces.

From the outset of independence, two ongoing constraints facing Singapore have been the heavy reliance on Malaysia for the provision of water (Tortajada, Joshi and Biswas, 2013) and the lack of access to a previously available supply of natural resources that resulted from the breakaway from Malaysia. At that time, this precipitated the need to look for alternative resources and discourses that could sustainably support an agenda of economic development, excellence and prosperity. Science and technology were identified as prospective areas to realise this quest for development (see Lau, 1998; B. T. G. Tan, 2017).

The importance of both science and technology was recognised in the early years of nationhood, as is evident from the formation of the Science Council of Singapore on 30 October 1967, just two years following Singapore's

1 *Entrepot* trade refers to a port, city or trading post where merchandise may be imported, stored or traded, usually to be exported again.

independence from Malaysia. The council was then assigned the significant role of overseeing research and development and promoting Singapore's indigenous capabilities in both science and technology (B. T. G. Tan, 2017).

3. Laying foundations (1965–80)

The term 'science communication', during the modern period, took on two meanings as it influenced two spheres of public life in Singapore: the communication of science within educational institutions as the formal learning of science; and the communication of science to the general public through less formal institutions and means (Tan, 2011). Prior to Singapore's independence, the establishment of the University of Singapore in 1905 and Nanyang University in 1956 focused on communicating science primarily through education and training, with less emphasis placed on research and development, or on communicating science to the general public (Tan et al., 2017). Tan (2011, p. 15), however, notes that 'This was recognised as a limitation since the majority of the population was not science literate when Singapore became a nation'. Measures were subsequently undertaken to remedy this situation.

The prevailing perception up to the 1980s was that Singapore, with its long history as a trading port, comprised a population accustomed to business and commercial activities more than science and technology. One expressed function of the Science Council of Singapore, therefore, was to make Singaporeans more comfortable with embracing the potential and imminent scientific and technological transformations (Glauberman, 1985), and to ensure that young people would, in the near future, be encouraged to take up careers in these fields.

In the early years of independence, this possibility was realised through establishing the Singapore National Academy of Science (SNAS), which promoted the advancement of science and technology. An informal science education centre was built to popularise science and generate awareness about advancements, and science-related educational entertainment in the mass media was introduced. These initiatives were influential in promoting science and fostering scientific literacy amongst the general public.

The SNAS was established by, and comprised, credentialed locally based scientists. Inaugurated at the end of July 1967, the SNAS organised its First Science Congress in August 1968. There, the important role of science and technology in Singapore's industrial, commercial and economic development was emphasised to the professional and academic community of scientists attending the congress. Dr Toh Chin Chye, then Minister for Science and

Technology, concluded his opening address by asking the delegates, 'How can science and technology be applied towards our economic development? That is the challenge we face today' (as cited in B. T. G. Tan, 2017, p. 14). The proceedings of this first congress, as well as the opening address, were subsequently communicated through the newly introduced, Singapore-run *Journal of the Singapore National Academy of Science*, which published its first issue in 1969 (B. T. G. Tan, 2017). In 1976, SNAS was reorganised as a broader umbrella organisation with the responsibility for overseeing all other scientific societies in Singapore. The task of promoting science and technology in Singapore was then transferred to the newly formed Singapore Association of the Advancement of Science (SAAS).

Apart from supporting the advancement of science and technology amongst the professional and academic community, the SAAS also made efforts to promote science to the general public. The proposal to establish an informal science education centre was sanctioned in the 1970s (Tan, 2011). From the literature available, the Science Centre was assigned two roles, both clearly motivated by concerns extrinsic to science itself. The first was to generate public interest that could support scientific and technological development for the sake of economic growth. In 1971, Dr Toh Chin Chye announced that Singapore's industries must be supported by a strong foundation and sustained interest in those two areas. An over-reliance on science and technological expertise imported from overseas was deemed undesirable and unhealthy, so the ministry and the Science Council of Singapore worked towards developing indigenous capabilities. Having seen similar developments taking place overseas, the Science Centre Board was established in November 1970 with the aim of promoting science and technology to the general public (Singapore Parliamentary Report, 1971).

The second role of the centre, targeted at school-going children and youth, was to highlight the relevance and applicability of science and technology to everyday life (Tan, 2011). The centre aimed to 'promote interest, learning and creativity in science and technology through an imaginative and enjoyable experience and contribute to the nation's development of its human resource' (Science Centre Singapore, 2018a). Although the idea of the Science Centre was mooted in 1967, it took 10 years of lobbying, fundraising and development before the centre opened its doors to the public officially on 10 December 1977. That same year, Singapore's first popular science magazine *Singapore Scientist* was launched with the goal of communicating interesting scientific issues, experiments and quizzes to school children (Dairianathan and Lim, 2014; Subramaniam, 2014). The writing in the magazine was pitched at the level of school students and was meant to communicate challenging topics in a way that they could comprehend.

Another key activity initiated by the Science Council of Singapore, with the help of the local media, was the Science and Industry Quiz. The quiz was introduced because of its potential effectiveness in educating and entertaining the public and thereby popularising science and technology (B. T. G. Tan, 2017). The program, publicly broadcast as a televised series by Radio Television Singapura, aired from 1972 to 1977. Its popularity reportedly 'grew to phenomenal proportions well beyond … most optimistic projections' (p. 6). The annual quiz competition featured teams from Singapore's elite schools competing keenly 'in fierce battles' for the prestige of winning the top prizes and was viewed by large audiences (p. 7). Three other programs that followed after the series ended, *The Innovators* (1979), *Top of the Trade* (1977–79/1980, 1983) and *Science Challenge* (1980, 1989), similarly highlighted and legitimated the importance and prominence of science, technology and innovation to the public. This importance was clearly reflected in the involvement of both the national broadcasting authority and well-known academics from the then University of Singapore, who were the quizmasters and judges in these competitions (B. T. G. Tan, 2017).

The existence of these government-driven efforts at promoting science, however, does not mean that there was no pre-existing interest in communicating science to the general public. Pre-dating the Science Centre as an informal science education centre, though much less prominent, was the Raffles Museum, first conceived in 1823 as the library of the Singapore Institution (later the Raffles Institution) (Y.-L. K. Tan, 2017). The museum specialised in the study of fauna from the Southeast Asian region. Since Singapore's independence in 1965, the collection has moved from place to place before finding a permanent home in a corner of the campus of the National University of Singapore. In 2015, it appeared in its current reincarnation as the Lee Kong Chian Natural History Museum. Arguably, the museum can be said to have represented a less pragmatically motivated forum for the communication of science in the early period of Singapore's history.

In general, science communication in the modern period may be described as being shaped by the Singapore government's attitude towards, and interest in, science and technology in terms of the economic benefits that competencies in both could bring to Singapore in its early developmental phases. Science and technology were, and still are, accorded priority of place in Singapore, and this is reflected in the practices and discourses of the system implemented by the People's Action Party. Brown (2000) observed that in the early years of nationhood, an ideology of survivalism was set in motion and a siege mentality was inculcated through emphasising Singapore's economic vulnerability and susceptibility to threats due to its size and geographical location (Lee, 1996). As such, there has been an overwhelming tendency for the government to

collocate science with technology. Official rhetoric tends to naturalise this collocation and associate the necessity of both for economic growth and for moving Singapore forward, thus serving also to advance the legitimacy of the ruling party.

4. Later developments (1981 onwards)

4.1. The 1980s: Addressing teething problems

In the early 1980s, it was observed that the effectiveness of Science Centre Singapore as an informal institution for communicating science to the general public was limited. The inaccessibility of the centre, resulting from the lack of proper roads to its then remote location, made visits difficult for local schools and the public. Professor Leo Tan Wee-Hin, then the CEO of the centre (1982–92) and a prominent and esteemed Singaporean scientist and educator, was tasked with remedying this situation. He contacted schoolteachers that he personally knew and offered to pay for chartered buses to ferry students to and from the centre and their schools. He subsequently initiated discussions with Singapore Bus Services to provide a bus service to improve access to the centre. However, a number of years passed before the area around the centre was developed and a public bus route was added, raising the centre's accessibility and profile. These and other efforts to address teething problems enabled and eventually led to more demotic, ground-up and less extrinsically driven attitudes towards science and the communication of science.

To attract more visitors, the first interactive science show in Singapore (performed by communicators from the Royal Institute, UK) was staged during Professor Tan's tenure. Demonstrating science through live entertainment was a novelty then, and these shows became extremely popular among students, popularising the use of similar demonstrations for both teaching science in the classroom and learning science in public spaces.

Like the Science Centre Singapore, the popular science magazine *Singapore Scientist* also suffered a variety of problems in its early years. These challenges included a shortage of funding, writers and contributors, the lack of a full-time editorial staff and the absence of keen interest from schools. To address this, Professor Tan persuaded and encouraged his colleagues at the Faculty of Science in the National University of Singapore to contribute to the magazine by writing about their research or current scientific issues of interest. He also sent the Science Centre staff to all schools as part of its outreach efforts, to promote and popularise the reading of this magazine. School libraries were encouraged to subscribe to the magazine to enable

access to all students, regardless of socioeconomic status. The magazine was subsequently published by Science Centre Singapore for a total of 38 years. To refresh and re-align the content of the magazine with the current school curriculum, an overhauled and rebranded version of *Science Spy* was launched in 2015 in collaboration with a commercial publisher, Marshall Cavendish Education (Times Publishing Group, 2017), thus marking a step towards devolution of responsibility for science promotion and education away from the government.

Sustaining curiosity in science beyond the occasional Science Centre visit was also important, and the Young Scientist Badge Scheme was initiated to encourage young students to continue to engage in self-directed activities in an area of science that was of interest to them (Science Centre Singapore, 1983; Dairianathan and Lim, 2014). The badge scheme, launched in 1983, required students (with guidance from a teacher or a parent, if needed) to complete science activities listed in an activity card to earn a badge. To date, more than a million badges have been awarded since the launch of the scheme, a testament to the scheme's popularity and its success in nurturing interest in science. Some prominent scientists in Singapore have acknowledged that their interest in science began by participating in this scheme (Lim, 2017).

Overall, despite its early teething problems in the 1980s, under Professor Tan's leadership Science Centre Singapore established itself as a hub for the public to engage with science and technology and became a credible source for promoting the informal learning and communication of science both within and beyond the confines of the centre.

4.2. Mid-1990s and early 2000s: Mass media communicates science

In the first years following Singapore's independence, scientific communication centred on government-led efforts to promote science and technology and to advance scientific literacy among the general public as a key means of economic growth and survival. This led ultimately to more intrinsic interest in science, and arguably the beginnings of more ground-up participation in communicating science.

In the mid-1990s and early years of the 20th century, an interesting development was how scientific communication was used in the mass media to shape public opinion and attitudes towards events in which politics and advancements of science and technology were enmeshed. One event revolved around Singapore's ongoing problem of access to fresh water. To date, Singapore imports a large part (up to 60 per cent) of its fresh water from

Malaysia (Ghangaa, 2015; Law, 2003; Tortajada, Joshi and Biswas, 2013) and, based on four agreements signed in 1927, 1961, 1962 and 1990, can do so up to 2061 (Tortajada et al., 2013).

While the existence of the agreements highlights bilateral cooperation between Malaysia and Singapore, this relationship has not been free of disputes (see Tortajada et al., 2013, p. 152). Between 1997 and 2004 the Singapore–Malaysia water relationship was tested, in part, by Malaysia's desire to renew discussions about reviewing the price of water under the prevailing agreements and to increase it by at least 600 per cent. Singapore responded by announcing its intention to seek legal advice on whether Malaysia had a right to do this.

It was also during this time that Singapore publicly announced that alternative sources of water were being considered. While local research into water reclamation began in the 1970s, concerns about costs and technological reliability had hindered its development till the 1990s—when evidence that other countries were engaging successfully in water reclamation and treatment became available. Despite concerns about high costs (Srinivasan, 1997), during Singapore's water dispute with Malaysia in 1998, the NEWater Study on wastewater recycling was sanctioned and jointly undertaken by the Public Utilities Board of Singapore and the Ministry of Environment and Water Resources (Leong, 2010). Construction of the first desalination plant was also to begin in 1999 and was projected to be completed by 2003 (Lim, 1998a). It was eventually opened in 2005.

Apart from commissioning such projects to secure Singapore's long-term access to potable water (Lim, 1998b), a public communication plan was also developed. It strategised an approach to educate and convince the general public that it was safe to drink recycled water (Tortajada et al., 2013). One of the main challenges, when attempting to implement water-reuse policies has been helping the general public to overcome the 'yuck' factor associated with the notion of consuming 'sewage' or 'wastewater'. Leong (2010; also Lee and Tan, 2016; Tortajada et al., 2013) observes that, in Singapore's case, the media played an important role as a strategic partner in educating and garnering support and acceptance for NEWater by the time it was launched in 2003. This was done systematically by minimising the use of negative terminology associated with wastewater recycling during reporting. Instead, public attention was drawn to the treatment process rather than the water source, and the successful use and implementation of water recycling in other countries were also highlighted. The 'yuck' element was addressed by adopting 'a rational, scientific approach to the topic' (Leong, 2010, p. 124). In framing their science communication to the public, the media adopted the theme of 'Social Progress', foregrounding NEWater technology as a modern-

day solution that would benefit Singaporean society and be a viable, self-sustaining alternative for replacing fresh water sources from Malaysia in the long term, thus diminishing Singapore's strong reliance on Malaysia's supply of water.

Through the media's communication of the science behind, and importance of, reused wastewater to water sustainability in Singapore, the process of getting Singaporeans to accept NEWater was made much smoother than experiences observed in similar projects by USA and Australia (Tortajada et al., 2013). This acceptance has not been an accidental phenomenon. It has been attributed, in part, to the very strong support the government has from the media in Singapore, efficient media management by the Public Utilities Board (Lee and Tan, 2016; Leong, 2010; Tortajada et al., 2013) and subsequent buy-in from Singaporeans who have embraced NEWater as one of four 'National Taps' that ensures the nation has a sustainable and diversified supply of water (Public Utilities Board, 2018). Science communication, in other words, was strategically used in the media to gain public support for addressing potential national difficulties.

5. From communicating science to nurturing science communicators (1990s to 2010s)

In comparison to how mass media used the theme of 'Social Progress' to frame science communication to the public, science communication in the field of education saw continuities of old discourses about science as well as newer developments. Broadly speaking, preoccupations over the teaching and learning of science, in this period, have been reflected in three dominant areas of discussion: (1) nurturing curiosity, nimble-mindedness and giftedness in students; (2) guiding students early on into 'the positive end of the attitude continuum' with regard to the importance of science; and (3) foregrounding the potential benefits of science to the future of Singaporean society and consequently, the need 'to be better "consumers" of science in the future' (Caleon and Subramaniam, 2008, p. 950). While the third continues a long-running narrative, the first two appear to have constituted emerging central discourses. To address these concerns educationally, what counts as science teaching and learning has progressively broadened to encompass more informal science teaching and learning events, incorporating applied activities, both within and outside of school and institutional contexts. Additionally, efforts have also begun to nurture effective science communicators, including not only teachers, but also students of science, scientists and professional science communicators.

5.1. Communicating science

The Science Centre's role as a hub for getting school children and the public to engage with science and technology informally was extended in the late 1990s. On the 20th anniversary of Science Centre Singapore, in 1997, the centre underwent a major revamping exercise. For this, it received S$34.7 million from the Ministry of Education to improve its facilities for school programs. This saw 95 per cent of Singapore schools signing up as institutional members to participate in the centre's science enrichment programs. The centre was consequently recognised as playing a key role in providing mass-based science education (Lim, 2017). During that time, the Science Centre Singapore also became a full member of the Asia Pacific Network of Science and Technology Centres (ASPAC), an organisation connecting science and technology centres in the region.

Apart from having a role in educating the public, the Science Centre has held regular workshops for educators to learn or upgrade their skills in science communication (Dairianathan and Lim, 2014). The workshops have been conducted to propagate the teaching of science using exhibition galleries and science show tricks. The teacher-participants learn and are encouraged to share creative strategies of communicating and teaching science, demystifying specific and challenging topics, and correcting common misconceptions.

In 2002, the Physics Demonstration Laboratory, located at the National University of Singapore's Faculty of Science (NUS FoS), was started by Professor Sow Chong Haur as another platform for science outreach. The laboratory, targeting students, aimed to demonstrate interesting phenomena through hands-on activities. In its initial stages, the Physics Demonstration Laboratory relied on using commercially available apparatus for demonstrations. It subsequently moved on to designing and building its own science demonstrations. Over the years, the laboratory presentations have evolved from standard 'show and tell' demonstrations to more 'engaging' participative demonstrations where audiences are asked to predict or explain the observed phenomena. This mode of science communication through participative demonstration has been adopted to increase student engagement, deepen learning and to allow common student misconceptions to surface and to be discussed. In 2008, the laboratory was renamed the NUS Science Demonstration Laboratory to include activities from the other science disciplines (NUS FoS, 2018a; Teng, 2016).

Communicating science in formal and informal educational contexts in Singapore during the 1990s up to 2010s, therefore, incorporated a variety of strategies that aimed to nurture curiosity, nimble-mindedness and a positive attitude towards science.

5.2. Nurturing science communicators

In comparison to the preoccupations surrounding the teaching and learning of science, Professor Tan (2011, p. 15), upon reflecting on the development of science communication in Singapore since 1965, noted that what was overlooked for some time was the nurturing of professional science communicators to work in the 'main-stream media, government agencies responsible for science-related matters, and the education service'. Despite the availability of overseas scholarships to pursue an MSc in science communication, offered in the 1980s by the National Science and Technology Board (now the Agency for Science, Technology and Research or A*STAR), Tan observed that 'both the media and educators did not think that was a priority' (p. 16).

This changed in January 2009 when the joint MSc degree program in science communication was introduced by the National University of Singapore (NUS) in collaboration with the Centre for the Public Awareness of Science (CPAS) at The Australian National University (ANU) (NUS FoS, 2018b). CPAS was responsible for developing one of the first specialised degree programs for science communication in 1987 (McKinnon and Bryant, 2017). Leveraging this expertise and combining the unique and complementary strengths of both ANU and NUS, the program at NUS targets both educators who wish to upgrade their skills in education as well as those working in areas of science policy, journalism and scientific writing. The program aims to achieve this through using a curriculum that focuses on communication skills and scientific content. Graduate students who enrol in the program are introduced to theories of communication, learn creative and innovative ways to display science and explore in-depth controversial and emerging science communication issues. They are also given opportunities to apply their learning to develop strategies to communicate science effectively to the public. Since its inception in 2009, the program has successfully trained 97 graduate students, with a yearly intake of 15–20 students.

While an MSc degree program in science communication is available, Singapore's tertiary institutions do not offer an undergraduate degree program. To promote public communication of science amongst undergraduates, Professor Sow, working in collaboration with the Ministry of Education, commenced the Young Educator in Science (YES) program in 2011. This program gives undergraduates opportunities to engage in activities to promote science to the general public and to younger students (NUS FoS, 2018c). YES members are often involved in conducting science demonstration workshops, holiday camps and public exhibitions to develop relevant skills in science communication. Since its inception in 2011, over 250 undergraduates have been trained under

the YES program. The program has been very well received by the participants who get to develop and practice science communication skills while increasing their depth of knowledge about the subject matter at hand.

Also at the undergraduate level, since the mid-2000s, credit-bearing science communication courses have been embedded in the science degrees offered at both NUS and the Nanyang Technological University (NTU), two of six public universities in Singapore with the highest levels of undergraduate intake (Ministry of Education, 2017). For example, for all first-year undergraduates enrolled in the Faculty of Science in NUS, the SP1541 'Exploring Science Communication through Popular Science' is a compulsory module. The course aims to equip students with relevant knowledge and skills to communicate complex scientific content in ways that are comprehensible and accessible to non-experts, with a focus on audience-centric communication competencies (written and oral) (NUS FoS, 2018d). One unique feature of this course is the use of popular science texts as a teaching tool to highlight the techniques used to communicate effectively to a non-scientific audience.

Similarly, at NTU, undergraduates from different schools within the College of Science are required to take scientific communication courses (Bolton et al., 2018a, 2018b), which aim to develop students' academic and professional communication competencies. These courses emphasise the importance of designing written and spoken communicative events that are not only delivered appropriately to, but also received successfully by, the intended audience who may comprise students' scientific colleagues and members of the public. In the higher-level course, undergraduates learn about the structure, elements and language features of scientific texts and undertake a group research project, which takes them through the processes of proposing, designing and conducting research. They subsequently present their projects as a written scientific report and as an oral presentation targeted at a non-specialist academic audience.

In summary, the developmental efforts taking place within science communication in Singapore, up to the 2010s, include concerted efforts to develop a local pool of competent science communicators (professionally credentialed and non-credentialed in the subject) for both the private and public sectors.

6. Science communication branching out (2010–present)

Since 2010, science communication in Singapore has become more visible and has established a firmer footing, extending into previously unchartered spheres to meet the changing needs and demands of the times. The reach of science communication has now expanded so that it has become a viable career option to consider in Singapore and an area of growing importance in academic research. Efforts in communicating science to the public have brought science to different informal spaces and to a wider range of audiences. The growing influence and importance of science communication has been, perhaps, most evident from Singapore's role in hosting the inaugural Asia-Pacific Science Communication Conference 2018 and the recent establishment of a commercial entity to provide professional science communication services to private and public organisations.

6.1. Science communication as a career in Singapore

The increased interest in nurturing science communicators has opened up more avenues to work as a science communicator in Singapore. Graduates from the science communication program or science students with interests in communication can nowadays undertake specific roles in a variety of areas. These include, but are not limited to, roles in these four areas: (1) as corporate science communicators who work directly with researchers to translate the impact of an institute's scientific work to the public and the media, to train scientists to engage with the media and to manage media communications (e.g. responding to media inquiries, public relations, developing the corporate image); (2) as informal science educators who work in informal learning spaces such as nature parks, zoos, science centres and museums, and who develop and execute programs (e.g. walks, exhibition content, educational activities, the tour of exhibits etc.) to enhance interactions with the public; (3) as science and media communicators who create communication resources (e.g. publications in print, broadcast, electronic media) for science journalists, authors or documentary makers; and (4) as formal science educators such as teachers who communicate science content in a formal educational setting.

6.2. Science communication research in Singapore

Also gaining ground, though still in its infancy compared to other developed countries, has been interest in science communication research. Before 2000, studies on science educational pedagogy and informal science learning were loosely deemed as 'science communication' research. In Singapore, such

investigations have been undertaken by practitioners involved in science literacy in education, or those involved in science educational and pedagogical research. Their findings have been published in peer-reviewed journals or archived in the digital repository of the National Institute of Education, Singapore (e.g. Lee, Hwang, Kim, and Wolff-Michael, 2009).

More recently, however, the number of academic research documents reporting on science communication in Singapore has been increasing. This may be attributed to the presence of the joint ANU–NUS master's of science in science communication program and the science communication research actively undertaken by academics such as Associate Professor Shirley Ho Soo Yee and her colleagues from NTU's Wee Kim Wee School of Communication and Information. To date, graduate students enrolled in the joint ANU–NUS master's program have been adding their research projects to a slowly expanding pool of locally based research into science communication. These graduate students must undertake a research project as part of their course requirements. The focus of research, in these projects, spans areas such as science pedagogy, public engagement and science literacy, science in the media and science on social media.

Research into the Singapore public's perceptions of science and technology, especially in controversial areas such as nanotechnology and nuclear power in Singapore have also been carried out by a range of Singapore-based researchers (Ho et al., 2018; Chuah et al., 2018; Lee et al., 2016; Ho et al., 2015b; Liang et al., 2015; George et al., 2014; Chua et al., 2008, Subrahmanyan and Cheng, 2000). A fairly recent and important contribution, by Associate Professor Shirley Ho and her colleagues, is a pathbreaking study on Singaporean attitudes towards science and technology and how these might shape the conversations of policymakers and communicators when discussing science and technology in the Singapore context (Ho et al., 2015a).

This survey of the general attitudes Singaporeans have towards science and technology finds that they believe that advancements in science and technology have improved their lives and have helped to sustain Singapore's economic competitiveness. The respondents also perceived that these benefits outweighed any harmful effects encountered. Their findings indicate that Singaporeans have a keen interest in scientific and technological knowledge and want to engage with policymakers about policies pertaining to these areas. The findings also highlight the fact that the Singaporean public does not have extreme attitudes (either positive or negative) towards science and technology issues. Other studies have noted that Singaporeans tend to adopt a 'perceived benefit and risk' viewpoint when assessing emerging issues (Chuah et al.,

2018; George et al., 2014) indicating that they are generally receptive to scientific and technological innovations so long as they are given sufficient information to make their own informed decisions about costs and benefits.

While the branching out of science communication within formal higher education contexts has seen important and promising developments in the training of professional science communicators and in science communication research, its extension within the public sphere has increasingly seen science being communicated to a broad spectrum of audiences through informal learning channels such as science shows, social media, public events and open days.

6.3. Science Centre Singapore

An important part of the Science Centre's mission under Professor Lim Tit Meng, the centre's CEO since 2010, has been to provide opportunities for all members of the public, regardless of age or educational background, to access science and to transition the centre's focus on science and technology to include engineering and mathematics as well.

Under Professor Lim's leadership, KidsSTOP—a specially dedicated space for pre-schoolers and early primary children under the age of eight to learn, explore and experience science—was opened in June 2014 (Science Centre Singapore, 2014a). KidSTOP comprises interactive physical exhibits that expose children to all-things-science in their formative years of development. The STEM Inc. program, an applied STEM learning program offered in collaboration with the Ministry of Education (Science Centre Singapore, 2014b), has also been introduced with the goal of working directly with schools to show students that STEM knowledge can be used to solve real-world challenges. Lessons and hands-on activities in the applied STEM learning program focus on bridging conceptual understanding in school curricula to applications in real-world scenarios, showing students the relevance of STEM in today's world and providing opportunities for them to apply their creativity and scientific knowledge to design and develop useful products.

Together with its partners, the Science Centre has also reached out to audiences who may not frequent its premises. This is done through the Singapore Science Festival, an annual festival that celebrates the best of science, technology and innovation in Singapore. Unlike other festivals typically set up in one central location, the Singapore Science Festival comprises multiple satellite events held over a period of three weeks in a variety of locations, such as shopping districts, heartland malls and even hawker centres. Such initiatives bring the Science Centre's activities to locals from all walks of life.

Beyond such show-and-tell initiatives involving science, another avenue for the general public to learn and keep up-to-date about innovations in science and technology is through experimenting for themselves. There are now co-creation spaces in the Science Centre in the form of a tinkering studio, the Einstein Room and the Eco-garden, which the public can access for a small fee to engage in hands-on activities, interact with objects and gain a deeper understanding of science. Tapping into the worldwide Makers Movement, which started in the USA in 2005, in 2012 the Science Centre hosted the first Mini Maker Faire in Singapore. In 2015, within a short span of three years, the Singapore Maker Faire was elevated to full Maker Faire status, giving agency to students and the local community to transform their science and technical knowledge into action.

6.4. Science communication in public spaces

Apart from the Maker Faire, science communication, over the years, has also taken place in public spaces such as the Housing Development Board (or public housing) heartland areas, community centres and shopping malls. These locations provide excellent spaces to communicate science to audiences who may not have had much exposure to, a strong interest in or inclination towards science. The events provide opportunities to those in this demographic to engage in activities and to interact with science exhibits. Examples of communication activities hosted in public spaces include The Pint of Science Festival, the Festival of Biodiversity and the Science Buskers Festival.

Other organisations have also participated in bringing the public to science. For a whole weekend in September, for example, as part of the One North Festival, the public is invited to experience research at major scientific hubs in Singapore such as the Biopolis and Fusionopolis. Organised by A*STAR and its partners, the festival is a celebration of research, innovation, creativity and enterprise. During this festival, members of the public are invited to attend talks by scientists, observe public science demonstrations and tour the research facilities. All the science communication activities at this event are helmed and hosted by A*STAR staff and their supporting partners.

Figure 31.1: A photograph at the local heartland showing Singapore science communicators demonstrating the power of lemon to produce electricity to interested members of the public. This was one of our recent science busking events organised by science communication students in the joint ANU–NUS master's degree program.

Source: NUS, Faculty of Science, Dr Lim Zhihan (used with permission).

A notable aspect of these events is that the impetus for the outreach is not always top-down. While a fair share of events such as Singapore Science Festival are organised by the country's leading institutions in research, ground-level initiatives such as Science Café SG exemplify events held for the common public by the people. Here, citizen groups arrange for scientists to present their work to interested members of the public. Table 31.1 highlights a sample of events where research carried out by scientists, scientific and technological advancements and educational campaigns are communicated in informal settings. The list is not exhaustive, but the events are representative of local, informal and public gatherings held to foster interest in science and technology, to enable scientists to interface with the general public to communicate their work and, perhaps most importantly, for members of the public to communicate their interest in science to others in interactive and entertaining ways.

Table 31.1: Science communication events in public spaces.

Public science communication events (year started)	Frequency	Description	Organised by
Omni Theatre (1985)	Daily	The general public can view movies and live shows related to science and technology.	Science Centre Singapore (SCS)
Science Centre Observatory (1989)	Weekly	The general public can participate in a variety of astronomy-themed events.	SCS
Buskers Festival (Part of Singapore Science Festival or SSF) (2008)	Annually	Participants use everyday tools and items to demonstrate scientific concepts in a show-and-tell competition.	SCS and A*STAR
Bucket Science Symposium (2009)	Annually	A thematic science show where performers use everyday tools and items to demonstrate scientific concepts.	NUS, Faculty of Science and SCS
NUS Science Demonstration Laboratory (2009)	Ad hoc	An experiential learning lab where students participate in guided demonstrations and hands-on experiments.	NUS, Faculty of Science
Science communication and STEM workshops / talks (2011)	Ad hoc	Informal/casual gatherings where scientists speak about their work to the general public.	*Asian Scientist* magazine
Festival of Biodiversity (2012)	Annually	This festival, organised by the National Parks Board in collaboration with the Biodiversity Roundtable, conducts workshops and exhibitions to promote conservation and create awareness about Singapore's biodiversity.	NParks with Biodiversity roundtable
Star Lecture (Part of SSF) (2012)	Annually	Informal/casual gatherings where scientists speak about their work to the general public. Conducted by Speakers from the Royal Institute of Science, London.	SCS and A*STAR
Science Café SG (2013)	Monthly	Informal/casual gatherings where scientists speak about their work to the general public.	Singapore Skeptics, Ground-Up Citizen group

Public science communication events (year started)	Frequency	Description	Organised by
Maker FAIRE SINGAPORE (Part of SSF) (2015)	Annually	Do-it-yourself technological event featuring hands-on activities, projects and tools that introduce the public to science, technology, engineering, art and maths.	SCS, A*STAR, and Defense Science Organisation
One-North Festival (Part of SSF) (2016)	Annually	A festival for the general public to engage in the latest science and technology–related activities in Singapore. The Xperiment science carnival, formerly a three-day event held in conjunction with the science festival in 2009, has now been incorporated into the One-North Festival.	SCS, A*STAR, and JTC Corporation
Tech Terik (2015)	Ad hoc	Casual gathering where the public can discuss up-and-coming science and technology innovations with a technology expert.	Ground Up Innovation Labs for Development
Pint of Science (Singapore edition) Festival (2018)	Annually	A festival where the general public can engage in the latest science and technology themed talks in Singapore.	A*STAR and SCS
Citizen Science Programs	Annually, biannually, or depending on group schedules	Public can participate in organised research efforts to collect data about particular research subjects.	NParks with various citizen groups
Science in the Café	Ad hoc	Informal/casual gathering where presenters and the public can discuss and share ideas on issues in STEM.	SCS
Show Us Your Science – Passion and Knowledge Exchange	Ad hoc	Opportunity to communicate with those passionate in science in SCS's exhibition gallery.	SCS

6.5. Building science communication networks in Asia Pacific

In 2018, NUS faculty, in conjunction with the 10th anniversary of the joint ANU–NUS master's of science in science communication, organised and hosted the inaugural Asia-Pacific Science Communication Conference. The conference aimed to establish connections with science communicators worldwide, especially those from the Asia-Pacific region, to share knowledge, experiences, techniques and innovations.

Figure 31.2: A group photograph of the speakers and participants of the inaugural Asia-Pacific Science Communication Conference 2018.
Source: NUS, Faculty of Science, Science Communication program committee (used with permission).

6.6. Science communication services by Wildtype Media Group

A milestone in the development of science communication in Singapore since the 2010s is the entry it has now made into the commercial sector. Within this sector, Wildtype Media Group Private Limited—headed by Adjunct Assistant Professor Juliana Chan, an award-winning, multi-talented biomedical scientist—has emerged as the first STEM-focused media company in Singapore that provides professional science communication services to government agencies, industry and academia in Singapore as well as the broader Asian region. Having a strong desire to communicate, and make

more prominent, the valuable scientific research being conducted in Asia to the wider international lay and academic audience, Chan began the *Asian Scientist* magazine as a blog in 2011 (Chan, 2018). Two years later, Chan, as the founder and editor-in-chief of the magazine, launched and circulated a print version of the magazine. Its popularity has grown exponentially since then. The magazine continues to be very well received by scientists, students and the general public and, in May 2018, Asian Scientist Publishing expanded as Wildtype Media Group Private Limited, extending its marketing and communication services to the science, technological and medical sectors that want to make their work more accessible to the general public through the use of print, digital and social media campaigns. The media company has also contributed as a media partner in the One North Festival (Rohaidi, 2016) and has organised science public outreach programs such as a talk with Nobel laureate Sir Richard Roberts and a pre-med seminar (Chan, 2018).

7. Conclusion

The different developmental phases of science communication outlined in this chapter mark, very broadly, the various ways in which science and technology have been deployed and communicated, either intentionally or unintentionally, to support Singapore's national development. During Singapore's early years following independence, science communication comprised government-led discourses emphasising the importance of science and technology in securing Singapore's future as a nation. This communication was undertaken to garner public support and has ostensibly contributed to shaping the relatively high regard that Singaporean homes have for STEM (cf. Marginson et al., 2013, p. 56). Science communication from 1980 to 2000 broadened considerably and emerged from multiple sources—the government, formal and informal public institutions like schools and the Science Centre Singapore, the media and key individuals. The discourses during this period included examples of science being communicated in a manner that shaped and tapped public knowledge about science and its processes, as was seen in the case of NEWater. More recent developments have come to focus on developing a local pool of professional science communicators for different sectors in Singapore. Efforts have also been made to encourage the general public to participate in informal science communication sessions with professional scientists and with other members of the public.

These developments collectively highlight the firm foothold that science communication has in the political, educational, commercial and social spheres of life in Singapore. Singaporeans, thus far, have shown a keen

interest in being informed about developments in science and technology. They have also expressed their desire for local policymakers to engage them when making decisions about policies pertaining to science and technology that will invariably affect their lives and the lives of future generations of Singaporeans (Ho et al., 2015a).

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Timeline

Event	Name	Date	Comment
First interactive science centre established.	Science Centre Singapore	December 1977	The idea for a science centre was first conceived in 1967 and it took 10 years to build
First national (or large regional) science festival.	National: Singapore Science Festival	2001	2000, Singapore hosted the Asia Pacific Economic Corporation (APEC) Youth Science Festival
First university courses to train science communicators.	Currently no formal undergraduate degree for science communication	–	Aspects of science communication may be covered in communication degrees. In addition, science faculties in Singapore universities mandate compulsory science communication modules for science undergraduates
First master's students in science communication graduate.	ANU–NUS joint master's degree of Science in Science Communication	July 2011	The first student was enrolled in January 2009
First PhD students in science communication graduate.	Currently no formal PhD program for science communication	–	Aspects of science communication may be covered in doctoral degrees in communication

Event	Name	Date	Comment
First national conference in science communication.	Inaugural Asia-Pacific Science Communication Conference 2018	November 2018	Aimed to allow experts and students to share knowledge, and held in conjunction with ANU–NUS master's of science communication
National Science Week founded.	No dedicated National Science Week	2001	But the Singapore Science Festival has a week of events before the satellite events happen
A journal completely or substantially devoted to science communication established.	Currently no academic journal has been established	–	The Science Centre has published a magazine targeted at schoolchildren known as *Singapore Scientist*
First significant TV programs on science.	The Science and Industry Quiz	1972	2004: The National Science Challenge is a televised competition for school students
Other significant events.	Lee Kong Chian Natural History Museum	April 2015	First natural history museum in Singapore. The collection has been inherited from predecessor museums that date back to 1878. 1976: Singapore Association for Advancement of Science was set up to promote public engagement of science and technology

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