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Public communication of natural sciences in Singapore by young scientists—motivations and barriers

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Abstract. Scientists are increasingly involved in public engagement activities because of the potential societal benefits of public engagement in science, such as progressing research and reinforcing science-based decision-making processes. With the current generation of young scientists being regarded as the change-makers of the future, they are also expected to actively participate in public engagement activities to keep their research relevant and connect with the society to cope with changing environments. However, published literature on young scientists' involvement in and opinions on public engagement remain limited and are largely lacking in the Asian context. This study aims to examine the perceptions, motivations and challenges of communicating natural sciences to the public by young scientists in Singapore. Through the interviews, young scientists revealed that their continued involvements in public engagement were mainly motivated by varying intrinsic and extrinsic factors such as being able to provide accurate science knowledge to the public and to raise awareness of their research areas respectively. The participants also reported structural and psychological barriers that could have hindered their active involvement in public engagement. Based on the participants' experiences in public engagement, we have identified recommendations that could help to improve structural support and provide more outreach opportunities so that young scientists can be more inclined to communicate nature sciences and actively drive outreach efforts to conserve our environment and wildlife in light of impending threats such as climate change and destructive human activities.

Key words. science communication, public engagement, outreach, challenges, nature

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INTRODUCTION

Over the past decade, there has been a growing interest for the scientific community to encourage public engagement in science because of the potential societal benefits in augmenting policy-making processes and advancing research (Royal Society, 2006; Golumbic et al., 2017; Safford & Brown, 2019). In more recent years, public engagement outcomes are also increasingly being requested to be incorporated into research deliverables by funding bodies to promote knowledge sharing with the public (Pearson, 2001; Hundey et al., 2016; Chen, 2019). As such, scientists who can formulate and execute public outreach strategies well can further increase their chances of success in research funding and collaboration.

Several studies have examined scientists' motivations and the barriers that would affect their willingness to participate in public engagement. Public engagement, defined as the methods of communicating scientific knowledge to the non-specialist audience (Bauer & Jensen, 2011; von Roten et al., 2011), can be delivered through various forms such as public lectures, media interviews, disseminating information using social media and developing programmes with organisations. By participating in such activities, scientists believed that the transfer of scientific knowledge to the public could help to garner support for scientific endeavours, improve science literacy and assist the public in making informed decisions related to their everyday lives (Greenwood & Riordan, 2001; Pace et al., 2010; Kuehne et al., 2014; Ho et al., 2015; Besley et al., 2018). Some scientists also expressed a sense of enjoyment when participating in public engagement activities (Andrews et al., 2005; Poliakoff & Webb, 2007). Through public engagement, some scientists expressed that they could gain public trust in their research and reach out to potential project collaborators and funders (Dunwoody & Ryan, 1985; Pace et al., 2010). On the other hand, scientists commented that the lack of time because of work commitments, such as administrative work, research and teaching, limited their involvement in public engagement activities (Royal Society, 2006; Merino & Navarro, 2019; Valinciute, 2020). Many scientists were also discouraged from participating in public engagement because these efforts were largely not recognised as official activities or being valued as merits by their institutions (Brownell et al., 2013). Some scientists also felt that those who actively contribute their

research through scientific publications and conferences were regarded as more capable academically than those who were more involved in public engagement activities (Dunwoody & Ryan, 1985; Royal Society, 2006). Overall, these studies have provided policy makers and academics some evidence to review current approaches in public engagement to promote more active science communication among young scientists.

Compared to older and more experienced scientists, studies across many countries (e.g., Argentina, France and Spain) have also shown that young scientists were less likely to participate in public engagement activities (Bentley & Kyvik, 2011; Torres-Albero et al., 2011; Valinciute, 2020). However, to cope with the increasing demand for scientists to participate in public engagement events, young scientists can be tapped as valuable resources to advance communication of scientific knowledge. Young scientists, including graduate students and early career scientists, are suitable as they are active drivers of many frontier research topics and are often charismatic enough to front as leaders of scientific endeavours (Kompella et al., 2020).

However, recent studies have highlighted the barriers that young scientists face when they consider participating in public engagement. The lack of support and infrastructure in science communication are often thought to hinder young scientists' active participation in public engagement activities (Bankston & McDowell, 2018; McCartney et al., 2018). Young scientists also revealed that they were often pressured to generate publications and secure project grants that were regarded as more beneficial for their career advancement (Leshner, 2007; Merino & Navarro, 2019). In addition, young scientists in the tenure track or enrolled in Ph.D. studies had to teach modules that could take up more time on top of their research work. In comparison to junior scientists, senior scientists were also given more opportunities to interact with the media which could boost their visibility and success in research funding (Dunwoody & Ryan, 1985).

Youth are regarded as the change-makers of the future. Hence, young scientists are also expected to actively participate in public engagement activities to ensure that their research remains relevant to society and able to encourage positive changes especially in this era of rapid environmental changes (Kuehne et al., 2014; Pace et al., 2010). However, there is a paucity in available literature on young scientists' involvement and opinions on public engagement and this necessitated a further understanding of young scientists in these aspects (Bauer & Jensen, 2011). The insights and experiences from many international academics and organisations on public engagement may be valuable only as case studies because of the lack of Asian context (Ho et al., 2020). The differences in Western and Asian cultures, values and perspectives may present different approaches in formulating science communication strategies in the Asian environment. The objectives of this study are to understand the motivations of young scientists who are currently active in public engagement in natural sciences, and the barriers that they face. The data collected from this research will represent the voices of young scientists, especially in Singapore's culture and environment, and provide valuable insights to create strategies to promote active public engagement among young scientists.

MATERIAL & METHODS

Data collection. A semi-structured interview consisting of four segments and 10 leading questions (Table 1) was adopted for this study. The participants were provided with the interview information sheet prior to their sessions. For the online interviews, more open-ended questions were added and tailored according to participants' respective backgrounds and experiences as the sessions progressed. The key discussion points included understanding participants' (1) interest in science communication and (2) motivations and challenges towards public engagement activities, (3) experiences in science communication training and (4) desired opportunities, training and support for future public engagement activities. Ethical approval was obtained for this study from the National University of Singapore Institutional Review Board (NUS-IRB Reference Code: NUS-IRB-2020-174). For this study, we defined "young scientists" as individuals between the ages of 18 and 35, based on the criteria of the National Youth Council of Singapore (National Youth Council, n.d.), who are holding either Science, Technology, Engineering and Mathematics (STEM) positions in universities, research institutes and organisations, or are current postgraduate students (M.Sc. and Ph.D.) enrolled in a STEM programme. Participants should also have been involved in more than one public engagement activity (see Table 2) in the past one year. The online interview sessions were conducted via an online communication platform (Zoom Video Communications, Version 5.0.2.) and recorded digitally with the consent of the participants. For one participant, the interview was conducted through email because of comfort preference.

Table 1. Themes and research questions used for this study.

Question Theme	Research Question	Leading Question
Interest in science communication and public engagement	What motivates young scientists to actively participate in public engagement activities?	How was your interest in science communication and public engagement activities developed? What are some of the public engagement activities that you enjoy the most? Why?
	What kind of public engagement activities do young scientists organise or participate in?	What kind of public engagement activities do you organise or participate in?
Challenges faced in public engagement	What are some of the challenges do young scientists face when you participate in public engagement activities?	What are some of the challenges you face when you participate in public engagement activities? Why?
Experiences in science communication	Are young scientists in Singapore adequately supported or trained for public engagement activities?	Did you have any form of science communication trainings? If yes, where did you have the training? Please elaborate on the focus of the training. Are there any aspects of science communication trainings that helped you substantially in public engagement? Are there any aspects of science communication trainings that contributed substantially to your professional development?
Opportunities, trainings and support in science communication and public engagement	Are young scientists in Singapore adequately supported or trained for public engagement activities?	What can your direct supervisors and institution administration do more of to support science communication training and public engagement activities?
	How can young scientists be encouraged to participate in public engagement activities?	Do you have any suggestions on policies/programmes that can encourage young scientists to participate more in public engagement? How would you advise other young scientists who are interested in science communication and public engagement activities?

Table 2. Types of public engagement activities that scientists participated in.

Type of Activities	Examples
Collaboration with science centres/museums	Video contents for museum exhibitions Video contents documentaries
Contributed articles and books for the public	Biodiversity database Newsletters Petition papers
Institutional open day	University open house
Organising events	Conferences Guided walks Podcasts Public talks
Public lecture	Public talks Seminars Webinars
Radio interview	Radio interviews
Science festivals	Booth engagements Stage events
Taken part in a public panel or debate	Panel discussions
Television interview	News interviews Television programmes
Used social media to disseminate science knowledge	Sharing on personal Facebook, Instagram, Twitter and blogs Sharing on research groups' Facebook, Instagram, Twitter and blogs
Engagement with non-governmental organisations (NGOs), associations or interest groups as advisors or activists	Advisory role Citizen science programme Stakeholders' engagement Programme collaborations Volunteering as advocates Volunteer training
Engagement with policymakers	Government agencies meeting Stakeholders' training
Worked with teachers/schools (including writing educational materials and school presentations)	Career guidance School assembly talks Teacher training Webinars

Data analysis. All the interviews were transcribed verbatim with notation when necessary (Table 3). All identifiers were removed and replaced with alphabet code or general keywords to safeguard the participants' confidentiality. To further protect the participants' identities, their personal pronouns were also replaced with neutral pronouns, i.e., 'they', 'their' or 'them'. The transcripts were then analysed using grounded theory which allows for themes that portrayed the experiences and sentiments shared by the participants to emerge from the interviews (Strauss & Corbin, 1998). The responses were coded manually to identify dominant themes and sub-themes. Similar themes were subsequently grouped into broad categories and sorted into respective research questions.

Table 3. Transcript notation used in transcripts.

Notation used	Meaning
( )	Inserted by the researcher for more clarity or replaced with general terms to maintain anonymity
…	Significant pause
[sound]	Language not captured by text

RESULTS

In total, 17 semi-structured interviews were completed between 11 August 2020 to 12 October 2020. The majority of the participants were males (52.9%) (Fig. 1A) and included researchers, postgraduate students and faculty staff (Fig. 1B) from universities (88.2%) and conservation organisations (11.8%) (Fig. 1C). Most of the participants' research interests were in Biology (35.3%) and Marine Science (35.3%) and also spanned across disciplines such as Environmental Law, Environmental Science and Natural Science (Fig. 1D). All participants are involved in ecology and conservation related projects. The online interviews averaged 48.4 ± 30.6 minutes.

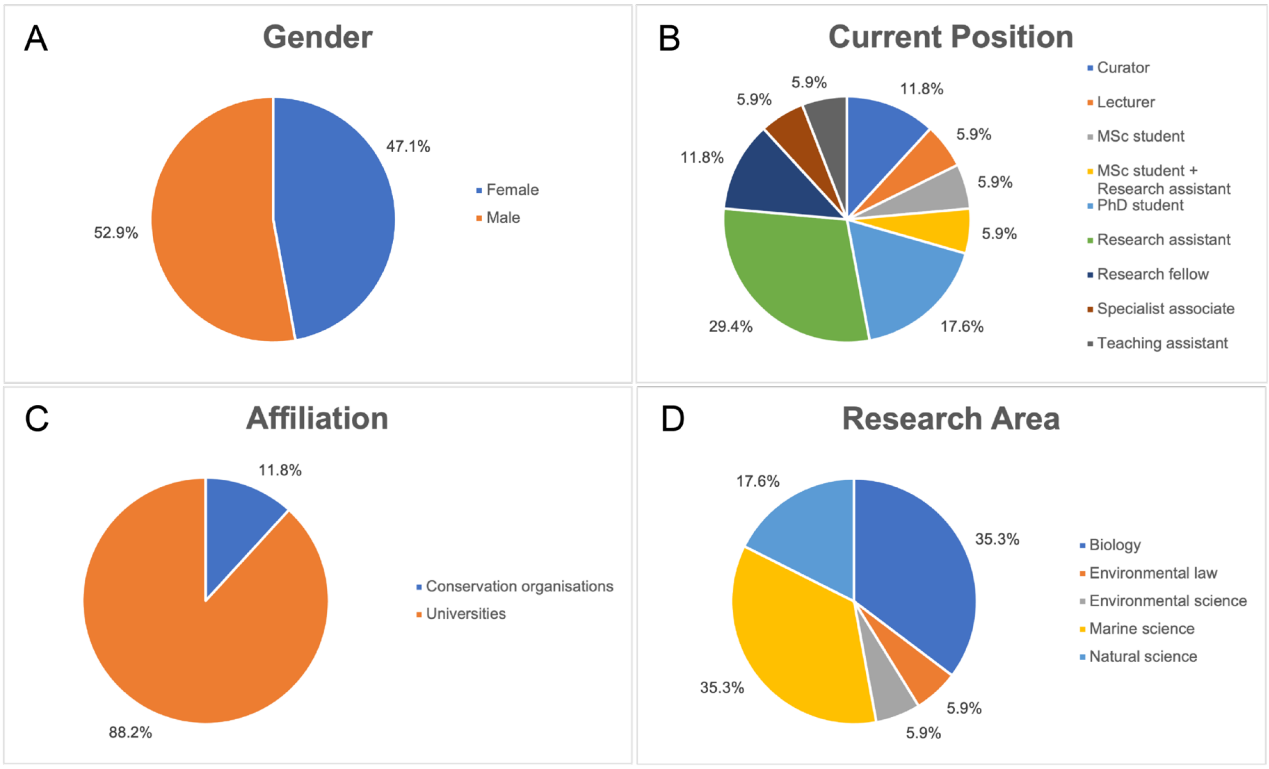

Fig. 1. Participants' profile (%) in terms of gender (A), current position (B), affiliation (C), and research area (D).

1. Young scientists' entry into public engagement activities in Singapore. Overall, many participants (41.2%) indicated that their interest in conducting public engagement activities started when they began working in their full-time jobs in academia, non-governmental organizations (NGOs) or government agencies. Most participants (47.1%) were introduced to public engagement activities (e.g., blog writing, public speaking, guided walks) during their secondary, pre-university and undergraduate studies as part of assignments or modules. Only one participant was exposed to public engagement activities when they had to organise such activities (e.g., exhibitions, guided walks and public talks) to showcase their research groups' research work. Participants (35.3%) also shared that their volunteering experiences with nature interest groups (e.g., the NUS Toddycats, Naked Hermit Crabs, Team Seagrass) and wildlife-related attractions (e.g., Lee Kong Chian Natural History Museum, Singapore Zoo) contributed to their sustained interests in public engagement. Through conducting outreach activities (e.g., guided walks, roadshows or public lectures) with these organisations, positive encouragement and responses from members of the public have also further motivated participants to participate in more public engagement events.

As participants became more involved in public engagement, they progressed from activities with a small audience group (e.g., guided walks, laboratory tours) to large-scale events such as public talks and science festivals. They also conducted school programmes to share their research or general science knowledge that are usually not taught in the school's curriculum (e.g., climate change, marine science, local biodiversity). Participants who were more experienced in public engagement were more involved in working groups with various stakeholders (e.g., industry leaders, interest groups) established by government agencies to provide their scientific expertise to assist in policy planning processes.

2. Motivations for active participation in public engagement. From the transcript analysis, participants highlighted different motivations that led to their active involvement in public engagement.

2.1. Intrinsic motivations. The intrinsic motivations, that are driven by one's natural interest or enjoyment in activities without wanting to reap external rewards (Ryan & Deci, 2000), mentioned by the young scientists throughout the interviews included providing up-to-date relevant scientific information to the public, having a sense of self-fulfilment, self-learning of science knowledge and viewing public engagement as an innate duty of a scientist. Understanding intrinsic motivations are important as most of the public engagement events that the young scientists carried out are voluntary and not required for their day jobs.

2.1.1. Providing up-to-date relevant scientific information to the public. Most participants (64.7%) highlighted that they enjoyed sharing basic scientific knowledge and novel research findings of their research area with members of the public. They regarded such public engagement activities as opportunities to provide information, to encourage discussions and self-directed learning among the public. For instance, one participant gained knowledge on wildlife that was not taught in school during past experiences in guided tours conducted in the Singapore Zoo and was motivated to participate in public engagement in order to provide similar learning experiences to the public.

Some participants (29.4%) also indicated that it is essential to get buy-in and support from stakeholders for nature conservation-related matters. By highlighting current issues and scientific content on various platforms, young scientists can engage and advocate both the public and policy makers on the importance of nature conservation. Some participants (47.1%) have used science-based evidence to inform and assist policy makers in formulating strategies in managing issues such as wildlife conservation and environmental protection. Two participants also started their own initiatives or participated as advocates in interest groups and used their scientific expertise to educate the public through various activities. One participant created a science-based online platform and invited local experts across different science topics to share their work to the public. Another participant also co-founded an interest group to share about local wildlife through guided walks, podcasts and social media posts.

> "I love talking and especially getting people to learn a little bit, be a little bit more interested. A little [thing] that you say to people can really affect them and change their mind about a topic and get them really interested and get them thinking. Because the only thing you want them to do to get them thinking just a little bit. You know you just plant the seed and you just let like let it go and carry on."

2.1.2. Having a sense of self-fulfilment. Being able to share relevant scientific information and getting the public excited about their research areas also provided some of the participants (41.2%) with a sense of self-fulfilment. Through participants' experiences in public talks, addressing misconceptions on their research areas provided them "gratification at the time to pass on lesser-known facts". Some participants (41.2%) also enjoyed conducting guided walks and field programmes that provided experiential learning for the public. One participant also commented that it was fulfilling to see that the public showed curiosity in their research area. Through these interactions and understanding the positive receptivity of the public to their research work, one participant felt "quite proud" of their work.

2.1.3. Self-learning of science knowledge. Five participants (29.4%) also highlighted that they enjoyed learning new knowledge through interacting with the audience during their public engagement activities. By consolidating information from various sources and translating them into more accessible and relatable content, participants also indicated that they were able to gain new scientific information and better understanding of scientific concepts through the process.

2.1.4. Regarded public engagement as an innate duty of a scientist. Some participants (35.3%) also felt that engaging with the public to provide them with accurate science information is a moral duty of a scientist. For instance, because of the changing climate and increasing concerns on environmental sustainability, one participant highlighted that people are becoming more aware of such issues and correct scientific knowledge can benefit the public in making better choices that could affect their ways of living. One participant also stressed the importance of taking the active role to convey the right messages.

> "I feel like as young scientists, we are given this power of science, power of knowledge and we should use it wisely by actually standing up against fake news, misinformation [and] poorly conveyed ideas [to further educate the public]."

2.2. Extrinsic motivations. The extrinsic motivations, that resulted from behaviours that are driven by external rewards such as fame and academic success (Ryan & Deci, 2020), as highlighted in the transcripts, included raising awareness about the research field, understanding the public's perception towards their research area and incorporating public engagement efforts into research work.

2.2.1. Raising awareness about the research field. The primary extrinsic motivation for most of the participants (70.6%) to be involved in public engagement was to raise public awareness about their research fields to gain support for their

research. Participants also mentioned that by taking part in public engagement activities, research outcomes can be amplified to reach diverse groups of people (e.g., government agencies, general public, industries) which in turn can lead to more support for their research. For participants with research fields that are considered less well known in Singapore (e.g., wildlife conservation, marine science), there is a need to promote the research area to garner more public interest and funding opportunities. For instance, participants (41.2%) who were working on native wildlife that are not well known or popular with the public felt that it was essential to share their research with the public so that their study subjects (in terms of specific species) or sites can be better understood and protected.

> "(Science communication) is a necessity, especially for scientists like me who are not working on very accessible, very sexy topics like Covid-19 or health sciences …"

> "I needed to communicate to people that there is this (study species) in Singapore and in Malaysia. It's part of our natural heritage and it's important that people learn about, appreciate them and then maybe help to conserve them."

As such, some participants (35.3%) leveraged on the wide audience reach through media interviews and documentary productions to raise more awareness on their research areas. One participant also mentioned that their involvement in documentary series by an international television network has provided them more opportunities to interact with potential funders and collaborators to support their wildlife conservation research projects.

Furthermore, public access to scientific discoveries is limited as many of these research findings are published in scientific journals and subscription-based newspapers that are behind paywalls. As such, two participants (11.8%) felt that it is important to translate their research findings into content that can be easily shared through social media or public seminars that are more accessible for the public. Some participants (29.4%) also managed social media accounts for their research team or interest groups to share key project findings and relevant information on natural sciences.

> "The work that I published in journals, it's great for me. But at the same time, it's all behind paid walls. And it's not just behind paid walls for scientists who are interested in (study subject), but rather it is behind paid walls for anybody who is doing science, almost literally anybody doing science. So how can I break this wall in a way by being able to share [information with the public]. In that sense, I took an interest to write about papers and talk about my papers either on my blogs or social media platforms."

2.2.2. Understanding the public's perception towards their research area.
Some participants (52.9%) were motivated to participate in public engagement activities so that they can understand the public's attitudes on their research interests. This is especially relevant to those participants working controversial issues or study subjects that are commonly regarded as "pests" or "non-charismatic". By interacting with different demographics, participants can obtain diverse opinions towards their research areas that can help them to understand public perceptions so that they can clarify the misconceptions about their research areas and formulate better strategies to communicate with the public.

> "I also want to know why do people tend to get this fear or general negative feedback about these insects. So maybe it started from young, maybe learned from the parents or other adults. I think also because of social media also like pest exterminator they always show (study subject)."

2.2.3. Incorporating public engagement efforts into research work. Through public engagement activities, participants provide opportunities for members of the public who have strong interests to contribute to conservation and scientific projects as citizen scientists. Two participants (11.8%) also commented that citizen science, the involvement of non-scientists in research, can be a tool to expand their datasets, build relationships with the public and potentially lower project expenditures (Kruger & Shannon, 2000; Dickinson et al., 2010; dela Cruz et al., 2014). For example, participants who organised volunteer training for citizen science programmes mentioned that the data collected by the volunteers can be further analysed and be used for academic research. Such collaborative programmes can encourage more public interactions with researchers that can also help to increase the public's scientific literacy, generate greater awareness of nature conservation issues and instil interest in future conservation efforts (Conrad & Hilchey, 2011; Toh et al., 2017).

> "Another part of doing presentations is also kind of like citizen science work where you kind of train people on how to collect data and then they will go out to collect data. So, in that sense you see that being translated directly into work. … But citizen science is, after they were trained, the volunteers go out and collect data. They come back with the data and they ask you more questions."

3. Barriers to active participation in public engagement. Based on the analysis of our study, the barriers faced by young scientists to participate actively in public engagement activities can be divided into two main categories: structural challenges and psychological barriers.

3.1. Structural challenges. In this study, we defined structural challenges as issues that are related to infrastructure, resources and the participants' perceived science communication skill set.

3.1.1. Difficult to commit to public engagement activities because of research priorities. Many participants (52.9%) highlighted that it can be difficult to participate actively in public engagement activities because of commitments such as working full-time, doing postgraduate studies and having family obligations. While most supervisors and institutes are generally supportive of such efforts, some participants (23.5%) also expressed that taking part in public engagement events takes time away from their ongoing research work. For instance, one participant mentioned that even with supervisors' support, there is still a need to fulfil the scientist's expectation to publish scientific papers.

> "It really so happens that our supervisors are really supportive. There's also a good amount of trust. Because they trust that you can still publish papers and do this at the same time."

Similarly, those doing postgraduate studies prioritised completing their studies over public engagement. As most research projects have a short timeline, scientists also have to prioritise their research deliverables over public engagement activities.

> "Ever since I joined as faculty, my outreach has been very little because I have been really brought down by with my workload… We want specific deliverables to be met within the research side. So, the outreach side kind of takes a backseat unfortunately because the students only have like one year or less than a year, like 8 months to do the entire project."

3.1.2. Lack of institutional support and resources. Some participants (17.6%) also mentioned that their institutions or departments do not formally recognise their public engagement efforts as part of their official work portfolio and that these activities are usually not included in their performance review. One participant also highlighted that publishing research papers and patents remains a top priority for researchers in their institute.

> "So, for one as academics and full-time research staff, the deliverables that we have will always be very strongly grounded on the number of publications, and in the number of patents, depending on what research you do, as well as the administration work that you do, your service… That's why many of us ended up feeling more packed because we have to do so many things but actually a very small proportion is recognised as official efforts or officially in your appraisal."

Similarly, two participants (11.8%) also mentioned that they did not have full support from their departments and/or their colleagues when engaging in public engagement activities. For example, they may face pressure from their supervisors and peers to place their research work above other non-work-related activities.

> "Supervisors not really (supportive). PhD students, it's not really encouraged to do work outside of your own work unless our project involved public engagement as our Key Performance Indicators (KPIs)."

Participants also mentioned that they are challenged by the lack of resources within their institutions (23.5%) to facilitate outreach activities. It can be difficult for projects without public engagement activities as a listed research output to have additional budget that could cover the extra costs and manhours required to organise or participate in such activities.

3.1.3. Lack of public engagement opportunities to the broader scientific community. Despite expressing their interest in public engagement, two participants (11.8%) were unable to find the right opportunities because of the lack of experience or recognition in their research field. As mentioned by participants (23.5%), some of these outreach opportunities are limited to certain groups of people in the community or that one is required to "know the correct people or you need to find out about the event yourself". One participant also highlighted that most public engagement opportunities are mainly directed to the supervisors or senior scientists, as such rendering them fewer opportunities to participate in such activities.

> "I observed that usually the invited speakers, or people who give talks are usually when they become lecturers or professors. (Young scientists) do not usually have the opportunity to present. In terms of training maybe the supervisor can seek opportunities for the junior researchers."

For participants working with less popular or lesser-known research areas (e.g., non-charismatic animals, native biodiversity) (23.5%), they mentioned that they are challenged by social stigma and negative connotations of their study subjects or areas, thus limiting their audience reach because of existing perceptions. One participant mentioned that

working with non-charismatic animals also resulted in them not having enough opportunities for public engagement as the public may not be inclined to participate in talks with a subject that they are less inclined to know more about.

> "I'm already talking about an animal where people already have their own mindset about this animal before I open my mouth. So, mine is like I have to go many steps back before I even arrive to the stage where we have to protect their homes, we have to keep them around."

> "People don't get that point, they are a lot. … it's still very hard to garner empathy for snakes. … People already have the pre-conceived notion about, the snakes are bad, snakes are evil and I think there's also the bias you know. If it's an otter, I'm willing to empathise with this animal. But if it's a snake, it doesn't deserve respect, it doesn't deserve the same kind of treatment."

3.1.4. Lack of science communication skills. Some participants (47.1%) highlighted their lack of science communication skills as a barrier to enhance their engagement with the public. Overall, participants found it difficult to convey science in a less technical way which included the use of jargon, simplifying and framing key messages. One of the participants also mentioned that because of the norm of speaking and using scientific terms with peers in academia, they required some adjustments to speak with the general public. Participants (29.4%) also found it challenging to balance between oversimplifying science concepts and providing too much information. Some participants (35.3%) also faced difficulty in framing their intended messages in different situations.

3.2. Psychological challenges. Participants also highlighted some psychological challenges as a barrier for them to actively participate in public engagement activities.

3.2.1. Imposter syndrome. Some participants (17.6%) mentioned that imposter syndrome, a psychological condition where an individual attributes his or her accomplishments to luck rather than having actual skills (Bothello and Roulet 2019), was a barrier that made them feel inadequate and less credible when they were being asked to conduct public engagement activity. This was fairly evident in young scientists as they may not have been in the research field long enough to have a deep understanding of the science. Such feelings included a sense of being unjust to their research fields and that they have not done a good job in sharing their work because of their relative lack of experience. In addition, one participant was resistant towards public engagement activities because there is "always someone who is better qualified, better equipped and just generally more credible" than them to address the audience.

> "For me, I tend to have a bit of imposter syndrome. If I'm not certain about certain things, I find it hard to. I can't bring myself to communicate it to other people. So, like, I feel like really have to know the subject before in case I spread something bad."

3.2.2. Mental exhaustion. Some participants (17.6%) also felt that participation in public engagement activities can result in burnout and exhaustion. For instance, one participant felt the need to portray themselves as having high energy levels so that they can get enough attention and excitement from the crowd to participate actively in the sessions. Furthermore, it can be difficult for people who are shy in nature. One participant also indicated that one of their biggest challenges is public speaking as they have to cope with stage fright that could compromise their sharing with the audience.

DISCUSSION

Though this study, we showed that young scientists in Singapore have relatively balanced intrinsic and extrinsic motivations towards public engagement in the field of nature-based science. This, on the other hand, differed from the observations by Ho et al., (2020) where Singapore-based scientists indicated that extrinsic factors largely drove them to conduct public outreach activities to gain recognition and attract potential project funders and collaborators. The intrinsic motivations highlighted by young scientists in this study were to provide accurate and current scientific information to the public, having a sense of self-fulfilment and to gain more scientific knowledge through contributing their expertise. Like previous studies examining scientists' motivations in communicate science, participants in this study also regarded the dissemination of scientific knowledge as a duty of a scientist (Martín-Sempere et al., 2008; Brownell et al., 2013; Dudo & Besley, 2016). Participants also regarded some of their public outreach activities, such as social media interactions, as a data source for their research. Through such interactions, scientists can raise awareness about their research and also build relationships with the public that could benefit future engagements (Golumbic et al., 2017). In addition to their intrinsic and extrinsic motivations, some indicated that they received funding and resources support from their grant agencies and home institutions to conduct public engagement activities. Some participants mentioned that their supervisors are actively involved in public engagement activities and constantly providing outreach opportunities and trainings for the participants. Participants also highlighted the importance of rallying family members, friends and colleagues to form support groups for one's endeavours in public engagement. As such, establishing a conducive environment to foster positive attitudes towards public engagement can further motivate young scientists to participate in public engagement.

One major barrier that hindered young scientists' active participation in public engagement was the lack of time because of work, studies and personal commitments. This finding was consistent with other studies where most researchers tend to prioritise work duties that can help them to advance in their academic career (Gascoigne & Metcalfe, 1997; Royal Society, 2006; Merino & Navarro, 2019; Ho et al., 2020). More external support from the institutions' in-house public relations and outreach departments in terms of logistical and administration assistance would help to ease young scientists' responsibilities and lower the barriers for participation in public engagement. By actively seeking opportunities and providing platforms for young scientists to share their research, these specialised departments in institutions can help to boost visibility and garner more public support for both the scientists and institutions. Participants also hoped to seek some form of remuneration for their efforts in public engagement activities even though science communication may not be formally recognised by their institutes. As such, institutions can consider acknowledging some of the public communication efforts by providing incentives or recognition that would encourage young scientists to include such activities in their curriculum vitae, as well as acknowledging that such activities could also contribute to their professional development (Jensen & Croissant, 2007; Mizumachi et al., 2011; Bankston & McDowell, 2018). Young scientists can also document their public engagement efforts in academic publications (see Toh et al., 2017 or public websites (see One°15 Marina, n.d.) to generate more valuable outputs that would be recognised by their institutions.

Young scientists also highlighted the need for proper training to gain science communication skills that can help them to engage with the public more effectively, which was consistent with other international studies (Pearson, 2001; Besley et al., 2015; Holliman & Warren, 2017; Cerrato et al., 2018). The interviews revealed that participants were interested in courses that could help them improve audience engagement, content creation, framing techniques and using social media to disseminate scientific knowledge. In this digital age, social media platforms (e.g., Facebook, Twitter and Instagram) are increasingly being used as a tool to disseminate scientific information to the public, connect to other academics, and potentially crowdsource research project tasks (Sidlauskas et al., 2011; Dudo, 2015). To equip young scientists with relevant skills to keep up with advancements in new media, science communication workshops on content creation for different social media platforms and digital technologies can be initiated by institutions. In addition, training on the visualization of data using various programmes and creative storytelling techniques (e.g., comics, poetry) can help scientists create attractive graphics and content to encourage more interactions with the public (Lin et al., 2015; Illingworth, 2020).

By understanding the motivations of young scientists in Singapore and the barriers that they face through their experiences in communicating natural science to the public, we can formulate strategies that can equip our current and future scientists with relevant skills and opportunities that will increase their involvements in public engagement. Future studies can also incorporate the opinions of young scientists across more research disciplines, institutes and experiences to optimise approaches in public engagement across the nation to cultivate an emerging generation of young scientists who not only excel in science but also in engaging society with science.

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LITERATURE CITED

Andrews E, Weaver A, Hanley D, Shamatha J & Melton G (2005) Scientists and public outreach: Participation, motivations, and impediments. Journal of Geoscience Education, 53: 281–293.

Bankston A & McDowell GS (2018) Changing the culture of science communication training for junior scientists. Journal of Microbiology & Biology Education, 19: 19.1.43

Bauer MW & Jensen P (2011) The mobilization of scientists for public engagement. Public Understanding of Science, 20: 3–11.

Bentley P & Kyvik S (2011) Academic staff and public communication: a survey of popular science publishing across 13 countries. Public Understanding of Science, 20: 48–63.

Besley JC, Dudo A & Storksdieck M (2015) Scientists' views about communication training. Journal of Research in Science Teaching, 52, 199–220.

Besley JC, Dudo A, Yuan S & Lawrence F (2018) Understanding scientists' willingness to engage. Science Communication, 40: 559–590.

Bothello J & Roulet TJ (2019) The imposter syndrome, or the misrepresentation of self in academic life. Journal of Management Studies, 56: 854–861.

Brownell SE, Price JV & Steinman L (2013) Science communication to the general public: why we need to teach undergraduate and graduate students this skill as part of their formal scientific training. Journal of Undergraduate Neuroscience Education, 12: E6.

Cerrato S, Daelli V, Pertot H & Puccioni O (2018) The public-engaged scientists: Motivations, enablers and barriers. Research for All, 2: 313–322.

Chen C (2019) Forum: Research findings communicated in various ways. The Straits Times, 28 December 2019. https://www.straitstimes.com/forum/letters-in-print/research-findings-communicated-in-various-ways (Accessed 20 November 2020)

Conrad CC & Hilchey KG (2011) A review of citizen science and community-based environmental monitoring: issues and opportunities. Environmental Monitoring and Assessment, 176: 273–291.

dela Cruz DW, Villanueva RD & Baria MVB (2014) Community-based, low-tech method of restoring a lost thicket of *Acropora* corals. ICES Journal of Marine Science, 71: 1866–1875.

Dickinson JL, Zuckerberg B & Bonter DN (2010) Citizen science as an ecological research tool: challenges and benefits. Annual Review of Ecology, Evolution, and Systematics, 41: 149–172.

Dudo A (2015) Scientists, the media, and the public communication of science. Sociology Compass, 9: 761–775.

Dudo A & Besley JC (2016) Scientists' prioritization of communication objectives for public engagement. PloS One, 11: e0148867.

Dunwoody S & Ryan M (1985) Scientific barriers to the popularization of science in the mass media. Journal of Communication, 35: 26–42.

Gascoigne T & Metcalfe J (1997) Incentives and impediments to scientists communicating through the media. Science Communication, 18: 265–282.

Golumbic YN, Orr D, Baram-Tsabari A & Fishbain, B (2017) Between vision and reality: A study of scientists' views on citizen science. Citizen Science: Theory and Practice, 2: 6

Greenwood MRC & Riordan DG (2001) Civic scientist/civic duty. Science Communication, 23: 28–40.

Ho SS, Yang X, Liao Y, Turner D, Tan R & Chan JM (2015) A survey of public views and attitudes towards science and technology issues in Singapore. Asian Scientist. https://www.asianscientist.com/sgsciencesurvey/ (Accessed 17 October 2021)

Ho SS, Looi J & Goh TJ (2020) Scientists as public communicators: individual–and institutional-level motivations and barriers for public communication in Singapore. Asian Journal of Communication, 30: 155–178.

Holliman R & Warren CJ (2017) Supporting future scholars of engaged research. Research for All, 1: 168–184.

Hundey EJ, Olker JH, Carreira C, Daigle RM, Elgin AK, Finiguerra M, Gownaris NJ, Hayes N, Heffner L, Razavi NR, Shirey PD, Tolar BB & Wood-Charlson EM (2016) A shifting tide: recommendations for incorporating science communication into graduate training. Limnology and Oceanography Bulletin, 25: 109–116.

Illingworth S (2020) Creative communication–using poetry and games to generate dialogue between scientists and nonscientists. FEBS Letters, 594: 2333–2338.

Jensen P & Croissant Y (2007) CNRS researchers' popularization activities: a progress report. Journal of Scientific Communication, 6: 1–13.

Kompella P, Gracia B, LeBlanc L, Engelman S, Kulkarni C, Desai N, June V, March S, Pattengale S, Rodriguez-Rivera G, Ryu SW, Strohkendl I, Mandke P & Clark G (2020) Interactive youth science workshops benefit student participants and graduate student mentors. PLoS Biology, 18: e3000668.

Kruger LE & Shannon MA (2000) Getting to know ourselves and our places through participation in civic social assessment. Society & Natural Resources, 13: 461–478.

Kuehne LM, Twardochleb LA, Fritschie KJ, Mims MC, Lawrence DJ, Gibson PP, Stewart-Koster B & Olden, JD (2014) Practical science communication strategies for graduate students. Conservation Biology, 28: 1225–1235.

Leshner AI (2007) Outreach training needed. Science. 315: 161.

Lin SF, Lin HS, Lee L & Yore LD (2015) Are science comics a good medium for science communication? The case for public learning of nanotechnology. International Journal of Science Education, Part B, 5: 276–294.

Martín-Sempere MJ, Garzón-García B & Rey-Rocha J (2008) Scientists' motivation to communicate science and technology to the public: surveying participants at the Madrid Science Fair. Public Understanding of Science, 17: 349–367.

McCartney M, Childers C, Baiduc RR & Barnicle K (2018) Annotated primary literature: A professional development opportunity in science communication for graduate students and postdocs. Journal of Microbiology & Biology Education, 19: 19.1.24.

Merino N & Navarro DHT (2019) Attitudes and perceptions of Conacyt researchers towards public communication of science and technology. Public Understanding of Science, 28: 85–100.

Mizumachi E, Matsuda K, Kano K, Kawakami M & Kato K (2011) Scientists' attitudes toward a dialogue with the public: a study using" science cafes". Journal of Science Communication, 10: A02.

National Youth Council. (n.d.) Frequently Asked Questions. https://www.nyc.gov.sg/en/faqs/. (Accessed 21 November 2020)

One° 15 Marina. (n.d.) Pledge to Protect: One° 15 Marina Coral Garden Updates. https://one15marina.com/news-post/eco-updates/coral-garden-updates/ (Accessed 22 November 2020)

Pace ML, Hampton SE, Limburg KE, Bennett EM, Cook EM, Davis AE, Grove M, Kaneshiro KY, LaDeau SL, Likens GE, McKnight DM, Richardson DC & Strayer DL (2010) Communicating with the public: opportunities and rewards for individual ecologists. Frontiers in Ecology and the Environment, 8: 292–298.

Pearson G (2001) The participation of scientists in public understanding of science activities: The policy and practice of the UK Research Councils. Public Understanding of Science, 10: 121–137.

Poliakoff E & Webb TL (2007) What factors predict scientists' intentions to participate in public engagement of science activities? Science Communication, 29: 242–263.

Royal Society (2006) Science Communication: Excellence in Science. Survey of factors affecting science communication by scientists and engineers. London: Royal Society. https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2006/1111111395.pdf. (Accessed 18 November 2020)

Ryan RM & Deci EL (2000) Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology, 25: 54–67.

Ryan RM & Deci EL (2020) Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. Contemporary Educational Psychology, 61: 101860.

Safford H & Brown A (2019) Communicating science to policymakers: six strategies for success. Nature, 572: 681–683.

Sidlauskas B, Bernard C, Bloom D, Bronaugh W, Clementson M & Vari RP (2011) Ichthyologists hooked on Facebook. Science, 332: 537.

Strauss A & Corbin J (1998) Basics of Qualitative Research: Technique and Procedures for Developing Grounded Theory. Sage Publications, Thousand Oaks, 312 pp.

Toh TC, Ng CSL, Loke HX, Taira D, Toh KB, Afiq-Rosli L, Poquita DRC, Cabaitan P, Sam SQ, Kikuzawa YP, Chou LM & Song TC (2017) A cost-effective approach to enhance scleractinian diversity on artificial shorelines. Ecological Engineering, 99: 349–357.

Torres-Albero C, Fernández-Esquinas M, Rey-Rocha J & Martín-Sempere MJ (2011) Dissemination practices in the Spanish research system: scientists trapped in a golden cage. Public Understanding of Science, 20: 12–25.

Valinciute A (2020) Lithuanian scientists' behaviour and views on science communication. Public Understanding of Science, 29: 353–362.

von Roten FC (2011) Gender differences in scientists' public outreach and engagement activities. Science Communication, 33: 52–75.