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In a state of superposition: exploring (in)effective public communication about quantum technology

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Conclusion

6.1 Introduction

This dissertation focused on investigating the public communication around quantum science and technology that may affect public engagement. To this end, we conducted a series of studies. First, we analysed the occurrence of potential popularisation issues surrounding quantum science and technology in English TEDx talks and Dutch newspaper articles. Second, we tested the effect of these potential popularisation issues on people's engagement with quantum technology. Finally, we explored whether metaphors make key quantum phenomena more comprehensible and whether this, in turn, influences attitudes towards quantum technology.

This chapter gives a brief summary of the main findings of each study, presents the implications for research and practice, and describes limitations and future research avenues. It concludes with four recommendations for science communication researchers and four recommendations for science communicators based on the implications of this dissertation's findings.

6.2 Summary of the insights of this dissertation

6.2.1 Occurrence of four potential popularisation issues

In the scientific literature, it is argued that potential popularisation issues surrounding quantum science and technology occur in public communication. These issues are:

1. framing quantum science and technology as something enigmatic (Coenen et al., 2022; Vermaas, 2017);
2. skipping the underlying quantum phenomena when explaining what quantum technology entails (Grinbaum, 2017);

3. using a narrow instead of a wider public good frame (Roberson et al., 2021);
4. focusing on the domain of quantum computing at the expense of the other two quantum technology domains (i.e., quantum communication and quantum sensing & metrology; Roberson et al., 2021).

No empirical research had investigated whether these potential issues actually occur in public communication about quantum science and technology. Therefore, **Chapter 2** and **Chapter 3** set out to address this question. Using a quantitative content analysis, Chapter 2 analysed the occurrence of the four potential issues in 501 English-language TEDx talks, and Chapter 3 analysed these issues in 385 Dutch-language newspaper articles.

The results demonstrated that the four potential issues occur very similarly in English TEDx talks and Dutch newspaper articles.¹ First, *the spooky and enigmatic frame* occurred in almost a quarter of both datasets (23% in TEDx talks and 24% in newspaper articles). The frame was therefore found to be apparent, but did not appear in the majority of the TEDx talks and the newspaper articles.

Second, we analysed the occurrence of *explanations for three quantum phenomena*: superposition, entanglement and contextuality. In line with Grinbaum's (2017) concern, we analysed how often a quantum phenomenon explanation was present when quantum technology itself was mentioned. We found that around half of the analysed materials with a reference to quantum technology contained at least one explanation for one of the key quantum phenomena (54% for English TEDx talks and 51% for Dutch newspaper articles). While this occurrence was more common than expected based on Grinbaum's (2017) concern, still a substantial amount of the TEDx talks and the newspaper articles do not provide an underlying explanation of these three key phenomena.

Third, we analysed whether the uses and implications of quantum technology in and on society were reflected upon in a *wider sense or a more narrow sense*. Reference to how quantum technology can solve problems or improve people's lives (the social progress frame, which is considered a wider public good frame) was hardly found in both datasets (7% in English TEDx talks and 3% in Dutch newspaper articles). However, there was also hardly any reference to how quantum technology can realise economic development or lead to competition (the economic development/competitiveness frame, which is considered a narrow public good frame; 5% in English TEDx talks and 9% in Dutch newspaper articles). The concern of Roberson et al. (2021) was additionally analysed by examining the occurrence

¹Percentages depicted in this section are rounded to whole numbers.

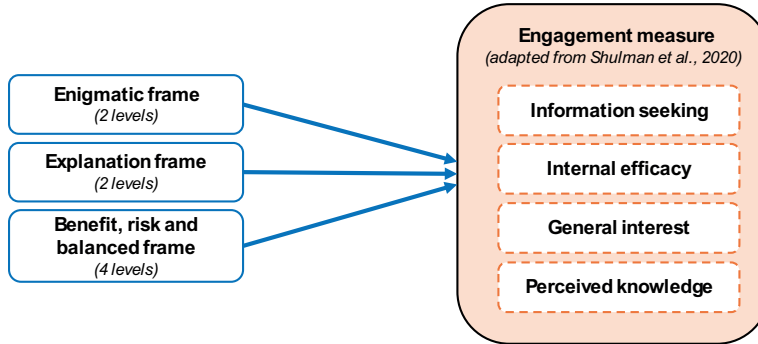
of the benefit frame versus the risk frame divide, where a wider public good frame constitutes a reflection on both benefits and risks. Results demonstrated that benefits were emphasized approximately six times more often than risks (benefits were mentioned in 34% of English TEDx talks and 33% of Dutch newspaper articles, while risks appeared in only 5% and 6%, respectively). This demonstrated that, as a wider sense of how quantum technology can cause harm is lacking, the wider public good frame does not really seem to exist in both datasets.

Finally, both datasets showed *a focus on the domain of quantum computing & simulation*, as it was referred to more often than the other two quantum technology domains. The quantum computing & simulation domain appeared in 24% of the English TEDx talks and 40% of the Dutch newspaper articles. This was followed in both datasets by the quantum communication domain with a 6% mention in English TEDx talks and 9% mention in Dutch newspaper articles. Finally, the domain of quantum sensing & metrology hardly occurred as it was referenced in only 2% of the English TEDx talks and 1% of Dutch newspaper articles. This is surprising given that the latter technologies are expected to reach commercial applications much earlier than quantum computers (C. L. Degen et al., 2017, but Chapman et al., 2024 argue this low focus on quantum sensors is because quantum sensors do not promise new capabilities, while the domains of quantum computing & simulation and quantum communications do).

When analysing the English TEDx talks, an additional potential issue appeared that we had not found in the scientific literature at the time of the study (but see Bondani et al., 2024): 15% of the talks were found to contain a mystical viewpoint, i.e., a pseudoscientific, inaccurate picture that can potentially result in misconceptions about quantum technology's applications. This was surprising given that the TEDx guidelines explicitly discourage speakers to present such viewpoints ('TEDx Content Guidelines', n.d.). Due to its frequency in the TEDx talks, this potential issue was added to the analysis of Chapter 3, but only 3% of the newspaper articles were found to make reference to a mystical viewpoint. This showed that, perhaps, most journalists want to ensure that the ideas they present about quantum science and technology fit inside widely accepted scientific paradigms, thereby aligning their coverage with views from the scientific community (see Bennett's 'indexing' theory; Bennett, 2016).

Figure 6.1

Conceptual model of the between-subjects experiment in Chapter 4.



6.2.2 Effect of frames on people's engagement with quantum technology

The second aim of this dissertation was to investigate the effect of the potential popularisation issues, which were quantified in Chapters 2 and 3, on public engagement with quantum technology. Therefore, **Chapter 4** presented an experiment to investigate this second aim.

To measure engagement, we adapted the scientific engagement scale from Shulman et al. (2020) for the context of quantum technology. This measure included four variables: 1) participants' intention to seek additional information on quantum technology (information seeking); 2) their belief about their own ability to understand and engage with quantum technology information (internal efficacy); 3) their general interest in quantum technology (general interest); and 4) their confidence in their knowledge of quantum technology (perceived knowledge). Figure 6.1 provides an overview of the conceptual model of the study.

A linear multiple regression analysis showed:

1. no significant effect of the enigmatic frame on any of the engagement variables;
2. a significant positive effect of explaining a quantum phenomenon on general interest in quantum technology;
3. a significant positive effect of the benefit frame on participants' belief about their own ability to understand and engage with quantum technology information;

4. and a significant negative effect of the balanced frame on people's confidence in their own quantum technology knowledge.

These findings yielded important new insights into whether the potential issues are actual issues with respect to self-reported engagement. They showed that explaining quantum phenomena and emphasizing the benefits of quantum technology may be helpful for engaging people with quantum technology, while the enigmatic frame seemed to neither increase nor harm engagement. In addition, the balanced frame reduced people's confidence in their quantum technology knowledge. This revealed an interesting tension, as Roberson et al. (2021) argued that for the greatest public benefit, it is important to reflect broadly on both the benefits and risks. In our view, this ethical consideration is more important to consider in public communication about quantum technology than its potential drawbacks.

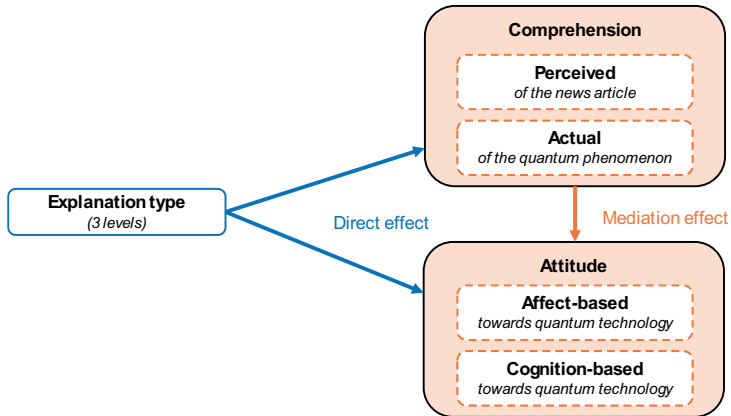
6.2.3 Effect of metaphors on comprehensibility of quantum phenomena, and their (subsequent) effect on attitudes

While Chapter 4 already examined how an explanation of a counterintuitive quantum phenomenon influences dimensions of engagement, **Chapter 5** explored the potential issue raised by Grinbaum (2017) in more detail: that, without a comprehension of quantum technology's underlying quantum phenomena, public attitudes toward quantum technology become more negative. Grinbaum (2017) suggested the use of metaphors to overcome this issue. To investigate this, Chapter 5 tested to what extent metaphors make quantum phenomena more comprehensible, and whether that consequently influences people's attitudes towards quantum technology.

Chapter 5 used an experiment, preceded by a small-scale study among Dutch quantum experts to design accurate stimulus material. The small-scale study aimed to identify the most accurate metaphors for communicating key quantum phenomena, specifically superposition and entanglement, to non-experts. To achieve this, $n = 22$ native Dutch-speaking quantum experts evaluated five metaphors about superposition or entanglement on accuracy and validity in a survey. The metaphors were generated by ChatGPT 3.5, a widely adopted and accessible large language model, to respond to calls within the science communication research community to evaluate the accuracy of AI-generated scientific explanations (Schäfer, 2023). The metaphor for superposition that was rated most accurate compared it to a coin spinning in the air, which is heads and tails at the same time until the coin hits the table. The metaphor for entanglement compared it to rolling a pair of dice, where if one die is rolled, the outcome of the other die is predetermined, even if it is on the other side of the gambling table. Because these two metaphors were considered the

Figure 6.2

Conceptual model of the between-subjects experiment in Chapter 5.



most accurate by quantum experts, they were used in the main experiment.

The experiment in Chapter 5 used 1 factor (explanation type: metaphorical, non-metaphorical, no explanation) and 2 items (quantum phenomenon: superposition, entanglement). A total of $n = 1,167$ participants representative of the Dutch adult population were asked to read a fictitious news article that either included a metaphorical, non-metaphorical, or no explanation at all about superposition or entanglement. Afterwards, we measured four variables: 1) participants' beliefs about their understanding of the news article (perceived comprehension); 2) their actual understanding of the quantum phenomenon (actual comprehension); 3) their emotions and feelings towards quantum technology (affect-based attitude); and 4) their thoughts and beliefs about quantum technology (cognition-based attitude). Figure 6.2 provides an overview of the conceptual model of the experiment.

Results demonstrated that, regardless of whether an explanation of a quantum phenomenon was metaphorical or non-metaphorical:

1. the explanation led to significantly lower scores on participants' perceived comprehension of the news article;
2. participants' actual comprehension of the quantum phenomenon was significantly higher;
3. no differences were found between the three conditions (metaphorical, non-metaphorical, no explanation) on attitudes.

Since previous research suggests that there is a relationship between comprehension and attitude (Akin et al., 2021; Wyer Jr & Shrum, 2015), we examined whether this relationship also applies in the context of our study. Results of the mediation analyses demonstrated statistically significant, but very small effects. They showed that, regardless of whether an explanation was metaphorical or non-metaphorical:

1. the explanation lowered participants' feelings of understanding the news article, which led to a decrease in their affect-based and cognition-based attitudes;
2. the explanation increased participants' actual understanding of the quantum phenomenon, which led to an increase in their affect-based and cognition-based attitudes, but this was counteracted by a direct negative effect.

The findings reported in Chapter 5 suggest that when a news article aims to increase people's feeling of having understood its content, science communicators better skip explaining counterintuitive quantum phenomena of quantum technology. However, when the goal is to increase people's actual comprehension of the quantum phenomena that underlie quantum technology, explanations do help. Metaphorical explanations seem to have no additional benefit over non-metaphorical explanations in this context, in contrast to what Grinbaum (2017) suggested.

6.3 Implications of the insights of this dissertation

The studies presented in this dissertation connected multiple disciplines, and are among the first to explore the emerging field of research at the intersection of quantum technology and society. In this section, we examine both the implications of our findings for the science communication research field and its practical implications for science communicators.

6.3.1 Implications for the science communication research field

First of all, the studies in this dissertation showed that claims made about potential issues in science communication should be examined empirically. While researchers might intuitively assume that a particular frame is used very frequently, only empirical data can offer true insight into whether that is actually the case. For example, this dissertation revealed that - contrary to concerns in the literature (Roberson et al., 2021; Seskir et al., 2023) - the focus on a quantum race between countries is rarely mentioned in English TEDx talks and Dutch newspaper articles, and therefore is likely having less of an effect on people's perceptions. This

dissertation thus demonstrated that empirical investigations on the frequency of certain “issues” in materials aimed at non-expert audiences truly clarifies which concerns may represent genuine problems and which rarely occur and therefore may not pose as major obstacles as expected.

Secondly, the content-analytical studies in this dissertation focused on two formats: English TEDx talks (Chapter 2) and Dutch newspaper articles (Chapter 3). These two formats differ in several ways, for example in the type (presentations vs. news articles), the language (English vs. Dutch), the creator of the content (non-expert or expert speaker vs. journalist), and the audience (local communities and internet users watching the talk on YouTube vs. readers of Dutch newspapers). Also the word length differs, as transcripts of the TEDx talks averaged around 2,400 words, while the newspaper articles in our sample averaged only 956 words. In this dissertation, we have thus been able to gain insight into the occurrence of the potential popularisation issues from literature in two very different types of communication. Our results showed that the occurrences in these two communication types are very comparable, potentially suggesting a trend in public communication about quantum technology. The reason why we were able to discover these similarities and differences between the two types of communication is that we carefully developed a reliable codebook for the identification of potential popularisation issues surrounding quantum science and technology. To develop this codebook, we formulated concrete definitions and clear coding instructions. Through elaborate discussions between multiple coders and the execution of subsequent intercoder reliability tests, we were able to determine the reliability of the codebook, which - as we have shown - can be applied to identify the potential popularisation issues across different communication forms. To allow the further use of this codebook and in light of open science, the materials in this dissertation have been deliberately shared openly in the journals in which the works are published and on the Open Science Framework (OSF).

Furthermore, quantum technology is still in an early stage of development, has not (yet) had a large-scale societal impact, and remains largely unfamiliar to the public (Chapter 5). This dissertation demonstrated that even for topics about which people know very little, the type of information provided can already shape their views of the topic (see also Druckman and Bolsen, 2011 and Van Giesen et al., 2015, amongst others). Even brief, one-time exposures, such as a few sentences (Chapter 4) or a short news article (Chapter 5), can lead to significant differences in outcomes such as interest or comprehension. In the context of emergent technologies, of which the public is still largely unaware (Cobb & Macoubrie, 2004; Scheufele & Lewenstein, 2005) but which can have major societal consequences, communication choices

thus seem to matter for its public engagement (see also Reincke et al., 2020).

Finally, as Retzbach and Maier (2015) also noted, studies examining the effect of frames on various aspects of public engagement with science remain sparse. In the context of new technology, most studies focus on the effect of frames on public support (see e.g., Achterberg, 2014; Cobb, 2005; Druckman & Bolsen, 2011; Palm et al., 2025). While support is indeed an important variable to study, given that it is one of the goals of public engagement (Van Dam et al., 2020), there are also other important reasons to engage the public with a new technology. For instance, public engagement may also lead to more socially robust solutions (Roberson et al., 2021) and is in line with a democratic perspective (Van Dam et al., 2020). This dissertation demonstrated that measuring the effects of frames on variables that are not directly about public support can provide important insights into engagement (Chapter 4).

6.3.2 Practical implications for science communicators

Besides research-related implications, the results in this dissertation also have implications for researchers, journalists, communication officers and other actors who wish to communicate about quantum technology to a broader audience (we will refer to these actors as science communicators in the remainder of this chapter).

First of all, quantum experts most often framed quantum science and technology as something spooky and enigmatic in TEDx talks (Chapter 2). Our results showed that emphasizing the enigmatic nature of quantum science a single time in a text does not seem to influence people's self-reported engagement with quantum technology (Chapter 4). This suggests that in science communication about quantum science and technology, the spooky and enigmatic frame has no clear advantage or disadvantage in engaging the public.

Second, our results showed that whether or not to include explanations of counterintuitive quantum phenomena in communications to a broader audience depends on the goal of the communication. If the goal is to increase interest in quantum technology, and engagement with quantum technology in general, explaining a counterintuitive quantum phenomenon may help (Chapter 4). Furthermore, a short explanation may result in a (slight) increase in actual understanding of the quantum phenomenon in question (Chapter 5). However, if the goal is to make the audience feel that they have understood the communication itself about quantum technology, it may be better to avoid explanations of the underlying counterintuitive quantum phenomena (Chapter 5). Still, science communicators do not need to fear that explaining a quantum phenomenon in communication has a large negative effect on

public attitude. While our results did show that a quantum phenomenon explanation has a negative effect on attitudes towards quantum technology through a decrease in perceived comprehension of the news article, this effect is very small and probably practically negligible - especially given the generally positive attitudes toward quantum technology that were found throughout our sample (Chapter 5).

Metaphors do not appear to offer an additional advantage over non-metaphors in explaining counterintuitive quantum phenomena (Chapter 5). Although previous studies have advocated for the use of metaphors in public communication about quantum science and technology (e.g., Grinbaum, 2017; Hilkamo & Granqvist, 2022), our results showed no significant differences in participants' comprehension or attitudes when exposed to metaphorical versus non-metaphorical explanations of a quantum phenomenon in a news article. This suggests that effective communication about quantum science and technology is not necessarily dependent on the use of metaphor. However, our small-scale expert study suggested that some metaphors may be too complex or mysterious to convey, which could lead to a wider gap between what experts consider good science communication and what resonates with the general public.

Finally, we found that quantum computing was discussed much more than other quantum technologies, suggesting a narrow focus on the field (Chapters 2 and 3). Furthermore, we found a tendency among TEDx speakers and journalists to communicate the benefits of quantum technology but ignore the risks (Chapters 2 and 3). This may contribute to a too narrow reflection of the possible impact of the quantum technology field as a whole on society (see also Roberson et al., 2021). The results of our experiment suggest that such a focus on communicating the benefits of quantum technology can increase people's confidence in their own ability to understand and engage with information about quantum technology (Chapter 4). Yet, our results also showed that presenting both the benefits and risks may reduce people's confidence in their own knowledge about quantum technology (Chapter 4). It has been suggested, however, that a broad reflection on the potential benefits and risks of quantum technology is necessary in order to maximize its benefits while minimizing its risks (see Roberson et al., 2021). From this perspective, the decrease in people's perceived knowledge does not outweigh the importance of such a broader discussion.

6.4 Limitations and future research avenues

This dissertation is among one of the first works to connect the fields of science communication and quantum technology. Yet, many more questions remain on

how to establish a good connection between quantum and society. This section discusses the main limitations of this dissertation and provides suggestions for future research.

6.4.1 A focus on one-way communication

First, if we look critically at this dissertation, the focus has been more or less on one-way communication. While the first role of public engagement according to Reincke et al. (2020) is meaningful information sharing, and engagement has consistently underpinned the way in which the research was set up, actual quantum technology engagement and dialogue have not been examined. In order to ensure real mutual learning between quantum scientists and society, the two remaining roles proposed by Reincke et al. (2020) - listen to, and learn from, each other, and investing in relationships - should also be addressed.

Future research could explore the two remaining roles for experts and science communicators in achieving meaningful engagement with quantum technology (Reincke et al., 2020), for example, by setting up and evaluating quantum engagement initiatives (see Busby et al., 2017). In doing so, it is important to try to avoid the pitfalls that revert such a two-way communication initiative into a one-way model (Bauer & Bogner, 2020; Kurath & Gisler, 2009). Bauer and Bogner (2020), for instance, noted that engagement events on synthetic biology often remained academic and rational, dividing the scientists and the ‘illiterate’ public. Therefore, quantum engagement initiatives should create space for emotional responses and controversial positions (Bauer & Bogner, 2020). In addition, scientists should be encouraged to raise their own questions and concerns instead of merely answering the questions of others (Reincke et al., 2020): for example, how could criminal organizations exploit quantum technology (Vermaas et al., 2019) or how could quantum technology further widen the digital divide between regions (Ten Holter et al., 2022)?

6.4.2 Predefined set of frames

Chapters 2 and 3 used a predefined set of frames to analyse the occurrence of four potential popularisation issues found in the scientific literature. However, this method also introduces a limitation, as we may have overlooked potentially interesting frames for public engagement, such as those discussed in papers published after our research was conducted (e.g., the incomprehensibility frame; Seskir et al., 2023).

Future research could therefore use a top-down approach to explore additional

potential popularisation issues that were published after our study was conducted. This approach could be combined with an “open category” format, to identify potentially new frames that are frequently encountered in quantum communication and have not (yet) been mentioned in the literature (see Pöhlmann et al., 2024 for a first bottom-up study in this direction). The effect of the frames that appear most frequently in public communication about quantum technology should then be tested on outcome variables such as engagement.

6.4.3 Experimental limitations

The experiments in Chapters 4 and 5 relied on self-reported measures, such as participants’ stated intentions. While this is an easy way to obtain information about participants’ intentions and attitudes, these measures may not accurately reflect real-world behaviour. People may give answers based on what they assume is socially desirable, such as claiming that they will seek further information about quantum technology because they believe it is expected of them (see e.g., Neuberger, 2016 who found that participants overreport on their information seeking behaviour). To assess real-world behaviour such as actual information seeking, future research could, for instance, include an option at the end of a survey allowing participants to request for more information about quantum technology.

The experiments in Chapters 4 and 5 furthermore made use of a single text that presented the condition under study once. This provides a good indication of the effect a one-time presentation of particular information has on participants. For example, Chapter 4 showed that a brief, single presentation of the spooky and enigmatic frame had no significant effect on participants’ self-reported engagement. A limitation of this approach is, however, that it does not reveal how repeated exposure to a frame might influence participants, whilst, for example, the spooky and enigmatic frame may be emphasized more often in communication about quantum science and technology. A first step toward understanding the effects of repeated exposure would be to conduct a study in which different groups are exposed to a different number of repetitions of the condition, or to conduct a longitudinal study in which participants are exposed to a certain condition multiple times over a specific period (see e.g., Retzbach & Maier, 2015).

In addition, the experiments in Chapters 4 and 5 focused on the effect of message characteristics on a representative sample of the Dutch adult population. While this provides a good overview of the effects of certain communication features on the Dutch public in general, it does not explore the impact on specific groups within society that may differ in individual characteristics. Such characteristics, like trust

in science (Achterberg, 2014) or individuals open to new or inconsistent information (Retzbach & Maier, 2015), can influence the effect of frames. Future research could explore this in more depth by identifying how individual characteristics influence the effect of certain frames.

Finally, the experiments presented in Chapters 4 and 5 in this dissertation made use of online panel services. An advantage of these services is that they allow for the relatively fast recruitment of a sample that is broadly representative in terms of age, gender, and education level. However, there are also limitations to using online panel services (see e.g., Kleijngeld et al., 2004). One of the criticisms is that participants may be less engaged with the research when they are primarily motivated by financial rewards (note that this concern does not apply to KiesKompas, which does not offer such rewards). Moreover, online panels are not fully representative of the Dutch population, as certain groups are systematically excluded such as individuals with limited digital skills. A study by Kleijngeld et al. (2004) demonstrated good consistency and reliability of the data of PanelClix, but with developments such as ChatGPT it remains an open question whether those findings still hold (Meem et al., 2024). To address these limitations, future research should address the research questions in this dissertation using other approaches than online panel services, such as offline surveys in lab settings, in-depth interviews, or focus groups.

6.4.4 A quantum technology hype

A key insight from this dissertation is that the potential benefits of quantum technology are mentioned about six times more often than its potential risks in English TEDx talks (Chapter 2) and Dutch newspaper articles (Chapter 3) – suggesting skewed communication. Such a strong focus on potential benefits of a new technology may possibly indicate hype, where hype is defined as that potential benefits are exaggerated and its risks understated (Caulfield & Condit, 2012; Roberson, 2020).

We, nor other empirical research, have (yet) examined whether there is a widespread quantum technology hype. Still, some have argued that there is, such as scientists who state that no one has yet come close to building a quantum device capable of solving practical problems (Greene, 2022), and that many of the promises made about the impact of quantum technology are either very long-term or “really far-fetched” (Ezratty, 2022, p 8). Also teachers have stated that media hype surrounding quantum technology is influencing their teaching both in terms of attracting students who arrive with preconceptions and of shaping the content of their course (Meyer et al., 2023). However, other scientists have argued that there is an anti-hype; for example, one physicist wrote on X that “quantum computing is simultaneously

overhyped and underhyped. Schrödinger’s hype, if you will” (Fitzsimons, 2022). Future research should examine the amount of quantum technology hype by evaluating inaccuracies about methods or result interpretations, similar to Bubela and Caulfield (2004) analysis of hype in media coverage of genetic research.

6.4.5 Perspectives from the Global South

The studies in this dissertation mainly focused on the Global North (Chapter 2), and specifically on the Netherlands (Chapters 3-5). The Global North, and the Netherlands in particular, are interesting to study, as many countries in this region are investing heavily in quantum technology, and the Netherlands has emerged as one of the key players in the field (Gaida et al., 2023). In addition, the Dutch National Quantum Agenda, published in 2019, explicitly mentions the objective to research the societal impact of quantum technology at an early stage to ensure a good connection between quantum technology and society (Stichting Quantumdelta NL, 2020). However, by studying this group, we also touch upon a broader limitation in science communication research, where perspectives from the Global South are consistently underrepresented (Guenther & Joubert, 2017; Massarani, 2015). In the intersection of quantum technology and science communication, it is especially important to broaden the geographical scope of the research as quantum technology may deepen existing global inequalities when populations are denied access to the benefits that the technology can offer (Ten Holter et al., 2022).

It is thus important that the field of science communication and quantum technology is also understood from the perspective of the Global South, which future research should consequently focus on. For example, future research could, as a first step, determine whether and how national newspapers in Africa, Latin America and Asia are currently communicating about quantum science and technology to their readers.

6.5 Connecting quantum technology and society

A core motivation for conducting the research reported in this dissertation was to contribute to a better understanding of how information that is shared with non-expert audiences may contribute to creating a good connection between quantum technology and society. Based on the implications of this dissertation (section 6.3.1), we offer four recommendations for science communication researchers and four recommendations for science communicators:

Recommendations for science communication researchers

1. Empirically examine claims about potential issues, as only then true insight is gained into whether such potential issues are frequently presented to non-expert audiences.
2. Investigate the way potential issues appear across different types of public communication about quantum technology, such as books (Dihal, 2017), documentary films (Gaunkar et al., 2022), and games (Seskir et al., 2022), to determine whether the patterns in English TEDx talks and Dutch newspaper are a general trend.
3. Continue investigating how certain communication decisions about largely unfamiliar topics shape outcomes, in order to better understand which type of information influences which type of dependent variable for which audience segment(s) in the context of emergent technologies.
4. Extend framing studies beyond support to include other dimensions of engagement, in order to develop a deeper understanding of how communication influences public perceptions of emergent technologies.

Recommendations for science communicators

1. Decide for yourself whether or not to present quantum science as something spooky or enigmatic, as a brief, single mention seems to have no advantage or disadvantage to engagement.
2. Choose whether to explain counterintuitive quantum phenomena depending on your communication goal:
 - (a) Explain a quantum phenomenon if your goal is to increase interest in, and engagement with, quantum technology, or if your goal is to (slightly) increase your audience's actual understanding of the phenomenon.
 - (b) Do not explain a quantum phenomenon if your goal is to make your audience feel that they have understood your communication itself.
3. Decide for yourself whether to explain counterintuitive quantum phenomena using metaphors, as these do not seem to offer any additional advantage over non-metaphors. However, when using metaphors, be careful to ensure that they are not too complex or mysterious to convey, as otherwise they may lead to resistance from experts.

6. Conclusion

4. Pay attention to a broader range of quantum technologies and emphasize their potential benefits *and* risks, to ensure a balanced perspective.