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RESEARCH ARTICLE

Assessing the journey of technology hype in the field of quantum technology

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Abstract • The 'second quantum revolution' promises new technologies enabled by quantum physics and has been the subject of substantial hype. We show that while creating expectations has helped secure support for quantum research, their iterative effects can come to affect the field in concrete ways. These iterative impacts for quantum include emerging discussions about ethics and the delivery of promised outcomes. Such contestations could open up alternative quantum futures, but this will depend on how the 'hype helix' of iterative expectations unfolds.

Bewertung der Entwicklung des Technologie-Hypes im Bereich der Quantentechnologie

Zusammenfassung • *Die ‚zweite Quantenrevolution' verspricht neue, durch Quantenphysik ermöglichte Technologien und hat einen großen Hype ausgelöst. Die durch diesen Hype geweckten Erwartungen haben zu erheblichen Spekulationen und Investitionen von Nationalstaaten und Unternehmen geführt. Wir zeigen, dass das Schüren von Erwartungen zwar die Forschung im Bereich der Quantenphysik vorangebracht hat, ihre iterativen Auswirkungen jedoch auf unerwartete Weise nachwirken können. Es tauchen auch umfassendere Fragen zu Quanten auf, die sich mit Ethik, Energie-Fußabdrücken und unmöglichen Versprechen befassen. Diese Auseinandersetzungen könnten im Prinzip alternative Quantenzukünfte eröffnen, dies wird allerdings davon abhängen, wie sich die ‚Hype-Helix' der iterativen Erwartungen entfaltet.*

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Introduction

Hype – or the use of exaggerated, sensational language to create narratives about the future impact of science and technology – has been central to building social and material support for the field of quantum technology. Quantum technologies draw on quantum science to build a range of applications around the world (Gibney 2019). The technologies – including quantum computers, quantum sensors, and quantum key distribution – are the subject of much hype (Roberson 2021). Similar to artificial intelligence, quantum technology is considered a critical technology by several nations due to the potential technical capability – a 'step change' – and the potential for vast economic gain.

We draw on published empirical research to examine how quantum hype is shaped by the interaction between scientific promises and national-strategic visions. We contribute to the wider field of enquiry around hype in proposing that the process of hype in research is not so much one-way as it cyclical – providing feedback to the actors who spark these conversations in new and sometimes unanticipated ways. This new model is described as a 'hype helix'. We use this model as we consider how the language used by physicists to describe the 'second quantum revolution' is shifting through the introduction of uncertainty (pessimism) and incorporation of new concerns and issues. Furthermore, we review how quantum hype discourse prompts iterative effects, including international conversations on the societal impacts of quantum technologies led by forums that include the World Economic Forum. Our research points to the fact that, while hype is an effective mechanism for scientists to achieve support for their research, hyped promises can be adopted by government and returned to scientists in the form of expectations that scientists must attempt to fulfil.

The management of expectations and hype

Hype consists of promises of new benefits or outcomes from science and innovation, which are articulated in present-day research agendas (Birch et al. 2012; McCray 2013). This language and the resulting work that researchers do to manage stakeholder expectations is integral to the creation and evolution of science and technology fields. Schyfter and Calvert (2015) explore the interplay of hype and inflated expectations in their work on synthetic biology – a field shaped by promised-laden rhetoric on the delivery of biotechnology and the creation of a new industry. These promises towards synthetic biology, in turn, influenced stakeholder expectations and forcefully directed research into narrow, now pre-determined, focus areas.

Use of hype is complicated by side-effects that scientists cannot control, e.g. how the expectations they create will be received by other audiences. Public communication on benefits or results of scientific research and/or technological developments invite response from stakeholders in the field and wider audiences (Ettenhuber 2008). These responses to hype are influenced by societal contexts people exist within; a critical concern in a digitally-connected world (Davis and Jurgenson 2014; Marwick and Boyd 2011). This necessitates careful management and moderation of hype. Examples of expectations management relevant to this area include the method of 'recalibration' in biomedical innovation (Gardner et al. 2015), which seeks to contain the hope and despair experienced by patients seeking cures (Petersen et al. 2017), and the deliberate use of pessimism by biotech firms looking to counterbalance optimism (Tutton 2011). The case of quantum technologies in this paper is another example of how overpromising is moderated and managed by multiple stakeholders.

Tracking the modulation of the quantum hype

Current models for hype in science and innovation describe the journey of hype in relation to science popularisation models by charting how a topic moves from specialised to non-specialised audiences. These models – including the industry-focused 'gartner hype cycle', which depicts how exaggerate expectations and claims surrounding emerging technology rise and fall – assume that the cycle or wave of hype occurs once (n.a. 2015). They do not explicitly account for the iterative effect of expectations or the way an audience might respond to exaggeration. Nor do they generally incorporate a mechanism for the recalibration or moderation of expectations. Konrad and Alvial Palavicino (2017) do, however, implicitly allude to the need to modulate expectations while charting the evolution of hype for graphene. To build on and improve these models, we propose the hype helix (figure 1).

In the hype helix, expectations rise ('high expectations') and fall ('low expectations') as they travel through time, and between creator and audience. Incorporating the fluctuations proposed by other literature on hype, the spiral of the helix depicts highs and lows of attention and exaggerated expectations, and then reflects on how expectations return to their creators. The helix also depicts how expectations shift in form and function as they progress between different actors and audiences within various contexts.

In figure 1 (below), we exemplify how this model might work in various cases of science and innovation by labelling the stages of high and low expectations which transpired within our research. In this edition of the hype helix, we focus on the quantum hype. We represent two stages of hype through time for quantum technology. The first loop begins with the coining of the 'second quantum revolution' and reflects on how promises for quantum technologies rose in the early 2000s. The second loop begins with the experimental breakthrough in 2014, which created a launchpad for new, heightened expectations for the field. This process of contestation and expectation management for quantum by scientists, government, and industry is explored in this paper, after the methods section.

Method

As advocates for a new technological field, quantum scientists and engineers have rhetorically managed the uncertainty related to timelines and outcomes by using statements focused on significant benefits for audiences in science policy, politics, and industry. We consider the dynamics of hype surrounding quantum and the technologies the field aims to produce ('quantum technologies'), using on rhetorical analysis to deconstruct the core arguments presented in national strategies for quantum science. This allows us to explore the way this policy discourse was co-created by scientists, politicians, and industry (Ploeger 2009).

We draw on empirical data from a study we published in 2021 (Roberson et al. 2021) and data collected during the first author's doctoral research (Roberson 2020). The data included public documents published during the formation and finalisation of three national strategies for quantum science in the UK, USA, and Canada along with interviews with four physicists who were involved in the creation of one or more national strategies. These interviews provided additional depth to the situated rhetorical analysis of the strategy documents, including specific insight into the development of the strategies and the role hype played.

Following the Helix model: creation and moderation of expectations by physicists

Close reading of the quantum national strategy documents revealed that the rhetoric of economic gain and competition was routinely emphasised. This is in line with broader trends in re-

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search policy (Felt 2014) and previous work on high-energy physics (Ploeger 2009). This style of rhetoric matters because it influences the development of the research field and the evolution of distinct future trajectories. Competition-focused rhetoric frames science as a game or race between groups and drives preoccupation with whether a researcher/research team is winning or losing (Roberson 2020). Media coverage focused on the development of useful quantum computing provides an example of this rhetoric. Meanwhile, economic-focused rhetoric argues that a core value of basic research is its capacity to enable economic growth, leading to a focus on market benefits and risks. Through this rhetoric, a technoscientific future marked by geopolitical rivalry and market-based economics comes to be produced and reinforced, at least so long as it goes unchallenged.

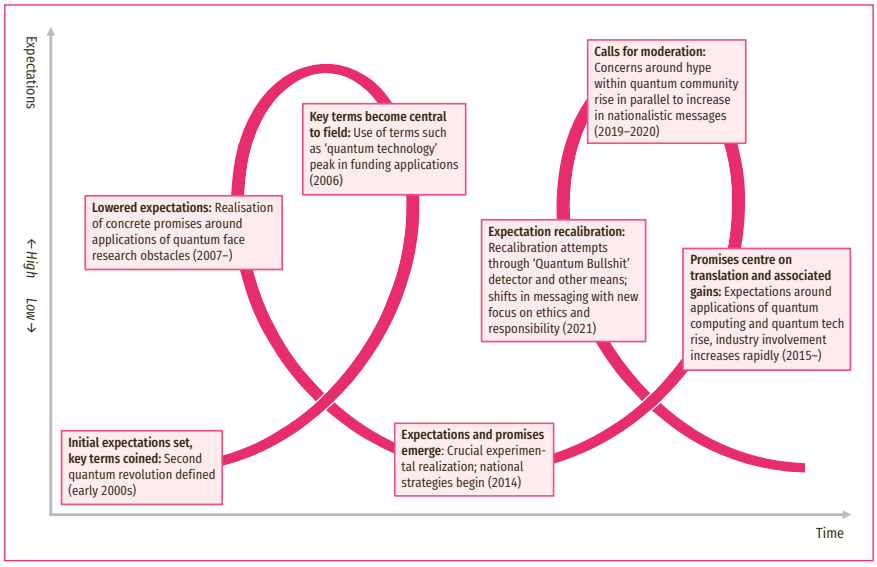

Fig. 1: Hype helix with stages mapped to public communication of quantum technologies.
Source: authors' own compilation

Documents produced during the development of national strategies for quantum show how expectations for quantum technologies originated within research and industry communities before they were adopted by governments. For example, a key meeting at Chicheley Hall in the United Kingdom led by the UK Defence Science and Technology Laboratory produced a researcher-led report (Pritchard and Till 2014) and subsequent government-issued policy documents on the value of quantum technology for the nation.

However, as these expectations circulated through different social groups worldwide, quantum hype met opposition with the views of the quantum physics research community (Das Sarma 2022). This echoes the findings of Schyfter and Calvert (2015) in terms of the iterative relationship between hype created by researchers and subsequent expectations of key stakeholders, in this case government and industry. Around 2014, initial hype fostered an atmosphere of urgency around quantum technologies. This provoked interest amongst policymakers and parliamentarians and prompted national investment and coordination efforts. In recent years (2019 onwards), however, expectations have returned to researchers in the form of questions around the dangers posed by the 'quantum arms race' and a need for more detail around the implications of using quantum technologies in society (Inglesant et al. 2021).

Interviews with physicists involved in the creation of national strategies for quantum science provide some additional context on the iterative evolution of quantum hype and expectations. The nationalist focus found in the documents analysed was largely absent in the responses of interviewees, although one (senior quantum physicist) said "the element of competition was a strong focus for the United States and United Kingdom" (Roberson 2020, p. 110). Physicists preferred discussion on the need to grow a critical mass with regards to enabling the presence of skilled workers and production of research, which would help produce crucial early-stage prototypes and, eventually, commercially viable machines while nurturing the emerging sector.

Reflecting on the hype which accompanied greater investment and interest in quantum commercial outcomes, scientists tended to highlight the uncertainty of future predictions for quantum technology. While some academic questions for quantum science may have been achieved, the physicists were quick to highlight the potential obstacles on the road ahead. They highlighted "continuing high levels of uncertainty around the eventual applications of quantum physics" (Roberson 2020, p. 110).

Alternately fearful and hopeful expectations generated around quantum technologies are likely to play some part in how public narratives evolved (Borup et al. 2006; Schyfter and Calvert 2015). The statements provided by physicists through research interviews in 2018–2019 may be part of conscious attempts to intervene in relation to extreme expectations with the intention of preventing potential disappointment (Eames et al. 2006). In this research article, we develop upon this perspective by presenting a new model of how hype occurs in communication on science and technology.

Expectations crafted by quantum scientists iteratively returned to impact on the field. The original audiences of the expectations – including, government, private companies, and other professional bodies – are taking seriously the chance that quantum computing – and quantum technology more broadly – may negatively impact society. An example of this altered state is visible in World Economic Forum discussions and a subsequent report on the quantum computing ethics (WEF 2021). This is despite some physicists' fears that it is too early yet to

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seriously review the societal impacts of quantum technology. The influence of geopolitical tension is also visible in government policies focused, perhaps pre-emptively, on export control of quantum technologies and enforcement of sovereignty (Williams 2021).

Concerns over the impact of hype on academia and quantum start-ups has also been rising and physicists have responded with attempts to moderate language used in the field. In 2019, an article in Nature tracked the scale of private investment in quantum technology start-up companies (Gibney 2019). They found that in 2017 and 2018 alone companies received at least 450 million US dollars in private funding, mostly from venture capitalists. Looking forward a few years and in 2021 quantum computing company PsiQuantum raised another million US dollars again, a sum of money which brings its total valuation up to 3.15 billion US dollars. Researchers interviewed for the Nature article worried about the hype, saying "there's a lot of hype in the field, a lot of promises that on the face of it look a little ridiculous, and some of that gets funded" (Gibney 2019, p. 24). In response to similar concerns over hype, some researchers began an anonymous Twitter account called the 'Quantum Bullshit Detector', which aims to dispel high expectations by retweeting hyped claims and marking them 'bullshit' (Chen 2019).

Conclusion

As new developments have emerged in the field of quantum technology, the journey of hype for the field has included framing, and then re-framing of developments and promised outcomes within stories of potential success (Borup et al. 2006). The hype helix we present in this article builds upon key literature, including Schyfter and Calvert's (2015) observation that promises for science and technology futures build iteratively, affecting first the organisations lobbied by researchers and then the researchers themselves in turn. By proposing the hype helix, we suggest a different way of conceptualising and modelling the role of hype in technoscientific work. Further investigation and testing of the model are needed to review how well it charts technoscientific hype in other fields.

This research article portrayed the process how expectations of quantum are taken up by nations. These expectations in turn have generated discomfort amongst researchers and tensions between national visions and academic research. We have charted how high and low expectations emerged in different stages of public communication about the quantum field. As represented in the hype helix, expectations rose upwards initially in the early- to mid-2000s. This hype has informed a long-running narrative designed to deliver increased support for quantum.

We note that efforts and intervention to modulate initial promises are undertaken by scientists, and, as a consequence, lowered expectations are introduced into the discursive field of quantum. Meanwhile, an atmosphere of competition may have had broader implications than just affecting the ability of quantum scientists to collaborate. Pressure to be first to market and media might also conflict with calls for public dialogue and discussion on the societal aspects and impacts of emerging quantum technologies.

Undeniably, the hyped-up narrative for quantum has produced a desirable result for quantum scientists in the form of national coordination and funding in multiple countries, so ensuring the continuing momentum of the field. However, the risk remains that by using hype physicists might jeopardize stakeholders' trust in quantum science and technology by creating unrealistic expectations. So, the importance of moderating and managing hype remains.

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