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Research Article

Ethical innovation of quantum computing in Europe: A policy intervention

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ABSTRACT

This intervention on European quantum technology policy shares key insights from a workshop that took place at TU Delft in September 2025, organised by the Delft Quantum Governance and Values Lab and funded by the Netherlands' Centre for Quantum and Society. The workshop brought together scientists, policymakers, industry actors, and Ethical, Legal, and Social Aspects (ELSA) scholars. Extended discussions between these experts identified five targeted interventions, intended especially for policymakers of the EU Member States and the European Commission, but also relevant for quantum researchers, ELSA researchers, and industry actors within and outside the EU. We believe implementation of these interventions will promote the development and uptake of quantum computing in the public interest and foster public trust in these emerging technologies and the institutions that make use of them.

Target audience

- Policymakers of the EU Member States and the European Commission;
- Quantum researchers, industry, and ELSA researchers within and outside the EU.

Executive summary

This intervention on European quantum technology policy shares key insights from a workshop that took place at TU Delft in September 2025, organised by the Delft Quantum Governance and Values Lab and funded by the Netherlands' Centre for Quantum and Society. The workshop brought together scientists, policymakers, industry actors, and Ethical, Legal, and Social Aspects (ELSA) scholars.[1] Extended discussions between these experts identified five targeted interventions, intended especially for policymakers of the EU Member States and the European Commission, but also relevant for quantum researchers, ELSA researchers, and industry actors within and outside the EU. We believe implementation of these interventions will promote the development and uptake of quantum computing in the public interest and foster public trust in these emerging technologies and the institutions that make use of them.

1. **Recognise and critically assess competing narratives driving policymaking on quantum computing by:**
   a. Employing ELSA expertise to scrutinise and make explicit the narratives that currently drive decision making and their sources.
   b. Ensuring that ELSA experts are represented on the High-Level Advisory Board proposed as part of the EU Quantum Act, in addition to quantum scientists and technology experts.
2. **Meaningfully operationalise high-level policy objectives for industry by:**
   a. Strengthening existing industry-government fora to translate European values and strategic aims into concrete, practicable guidelines for quantum companies of all sizes.
   b. Publishing clear, value-led EU guidelines for permissible non-strategic international collaboration in quantum computing R&D.
3. **Engage the public to co-shape Europe's quantum future by:**
   a. Commissioning a European Quantum Public Engagement Strategy.

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[1] A full list of attendees (who gave permission to be named) is provided in the appendix.

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4. **Foster accountability and mitigate misuse of quantum computing by:**
   a. Anticipating regulatory gaps prior to the future emergence of a market for quantum computing services.
   b. Establishing institutional incentives for responsible provision of quantum computing services.
   c. Educating the public early about the potential for misuse of quantum computing.
5. **Demand evidence of societal benefit from quantum computing applications by:**
   a. Developing a standardised Social Value Assessment framework for demonstrating the social value of quantum computing use-cases.
   b. Requiring periodic reassessment of the social value of funded research into quantum computing use-cases.

Introduction

Substantial global efforts to develop large, practical quantum computers are well underway. Governments, corporations, and research institutions around the world are investing heavily in quantum computing. With each incremental technical milestone comes heightened anticipation of the transformative impact these technologies will have for society, science, industry, and national security. Expectations are at an all-time high: coinciding with the 100th birthday of quantum mechanics, UNESCO named 2025 the International Year of Quantum Science and Technology,[2] and the 2022 and 2025 Nobel prizes in physics[3,4] honoured discoveries underpinning quantum computing. Yet, the parallel growing interest in the societal, legal and ethical implications of quantum computing (e.g., de Wolf, 2017; Coenen et al., 2022; Arrow et al., 2023; Possati, 2023; COMEST, 2025) – reflected, for example, by the inclusion of a dedicated Ethics part of the official opening ceremony of the International Year of Quantum[5] – has not adequately translated into policy action. Considering such issues early will help to steer the development of quantum computing and its applications in societally beneficial directions and foster public trust, thus supporting a swift, focused, and deliberate introduction of this technology into European society with ethics built in World Economic Forum (2022).

This policy perspective paper seeks to contribute meaningfully to the emerging policy approach to the development of quantum computing in Europe by outlining an agenda of issues that merit closer – scholarly and public – attention. It draws on insights from an interdisciplinary workshop in Delft, September 2025, organised by the Delft Quantum Governance and Values Lab[6] and funded by the Netherlands' Centre for Quantum and Society.[7] This workshop brought together a group of ELSA scholars working on issues in the development and implementation of quantum computing in Europe; our interventions express the perspective of this group, as it emerged over the course of the workshop. We address our interventions to policymakers of the EU Member States and the European Commission. The interventions we advocate, however, are highly relevant to quantum researchers, ELSA researchers, and industry actors both within and outside the EU.

The discussion is structured around five targeted interventions in European quantum computing policy, concerning: (1) competing narratives, (2) regulation and geopolitics, (3) the role of the public, (4) accountability and vigilance, and (5) the "Quantum for Good" narrative.

1. Competing narratives of the development of quantum computers

A number of features make it difficult to apply traditional approaches of technology assessment[8] to quantum computing. First, the development of quantum is still in a prototype phase, and its trajectory remains highly uncertain. Paradoxically, early predictions can prematurely narrow the range of designs and applications considered viable by decision-makers (Grunwald, 2016). This paradoxical situation is not unique to quantum, having already been instantiated in the development of nanotechnologies (Mehnert & Grunwald, 2024, p. 281). Second, a small number of states and corporate actors currently dominate the development landscape, limiting the diversity of voices steering the development of quantum computers (Qureca, 2025). Third, the technical opacity of quantum computing and its perceived distance from everyday life impede informed public debate (Vermaas, 2017). Finally, breakdown of global multilateralism, politicisation of international trade and research cooperation, and rising supply chain dependencies and vulnerabilities (QDNL, 2023a, b) exacerbate the uncertainty surrounding the future trajectory of quantum computing.

Given that technology assessment is unreliable under these circumstances, decisionmakers must rely on other sources. In particular, they draw on established narratives surrounding the innovation of quantum computing to make their policy choices. For example, quantum computing has been framed as a "critical technology" (European Commission, 2023a; US National Science & Technology Council, 2024) leading to an uncooperative "quantum race" between geopolitically competing countries (Roberson et al., 2021); as posing a "threat" in the hands of "bad actors" (Mehnert, 2025); as a "disruptive technology" (European Research Council, 2025) leading to efforts to create a lucrative "Quantum Valley" modelled on Silicon Valley (European Union, 2023; Quantum Flagship, 2024); and as a "techno-solution" driving a search for socially beneficial use cases (World Economic Forum, 2024a; Open Quantum Institute, 2025a). These narratives are put forward by very different actors within quantum computing ecosystem with very different aims and interests and are not always mutually compatible. For example, narratives surrounding the impact of quantum computing for the European economy oscillate between a doomsday threat (e.g., Mosca, 2018) and an essential "growth engine" (European Commission, 2025).

Policymakers have little choice but to draw on such narratives.

[2] https://www.unesco.org/en/years/quantum-science-technology
[3] https://www.nobelprize.org/prizes/physics/2022/summary/
[4] https://www.nobelprize.org/prizes/physics/2025/summary/
[5] https://www.unesco.org/en/articles/opening-ceremony-international-year-quantum-science-and-technology
[6] https://www.tudelft.nl/en/tpm/research/tpm-labs/quantum-governance-and-values-lab/
[7] https://qdnl.nl/centre-for-quantum-and-society

[8] Technology Assessment (TA) (with capitals), in our understanding, is a democratically legitimised and institutionalised form of assessing technologies, gauging their impact on society and evaluating its impacts, with the aim of reducing risks and harmful impacts of those technologies. Other academic branches, such as medical or bioethics, where biotechnologies are also assessed, share many features and might be said to be engaging in "technology assessments" – without capitals. The methods of *institutionalized* TA have always been varied and interdisciplinary and changed over time (Bogner, 2021). While at the beginning, TA was understood also as a tool to make suitable economic and technological investment decisions, the impetus to reduce societal risks (and not merely increase shareholder value) came increasingly to the fore, as well as the involvement of stakeholders for epistemic and normative reasons. For a long time, a key methodological problem of TA has been "its consequentialist focus" - the ambition to predict a technology's impact on society and identify some ethical problems accompanying that impact. A recently proposed hermeneutic extension of TA seems particularly well fitted for technologies that are only just emerging and whose full realisation lies in the far future. Here, epistemic uncertainty warrants a different approach, namely an understanding of the plurality of ways in which the future of those technologies already persists, how and why they are envisioned in the way they are. While one might conceptually distinguish them clearly, we will in the following not sharply uphold that distinction. We believe that both intertwine inseparably epistemic/descriptive (anticipation and more advanced insights on the present) and evaluative (the accompanying ethical problems) elements (see also Sand, 2023).

However, given that these narratives are not socially and politically neutral, policymakers must be aware of this non-neutrality and make fully explicit the framings, perceived trajectories, and tacit assumptions driving their choices. This includes identifying *whose* visions of the future currently guide policy debates, how the language of policymakers and researchers shapes societal expectations, and whether certain attention-grabbing "buzzwords" (such as "Q-Day") obscure broader ethical concerns, including the emerging "quantum divide" (Ten Holter, 2022; Gercek & Seskir, 2025) and the lack of representation of large parts of the population in those developments (Sand, 2019; Lane, 2026).

Explicitly acknowledging the narratives upon which policymakers draw is not sufficient by itself to assess the societal desirability of quantum computing or the societal changes it will bring. Rather, such acknowledgement provides an important input into such ethical, legal, and societal reflection. Moreover, hermeneutic questions, while descriptive, are typically motivated by normative concerns. The impetus to uncover dominant narratives of quantum computing stems from an inclination that the uncertainty surrounding the emergence of this technology brings societal risks that these narratives may obscure or distort (Sand, 2023). For this reason, we propose complementing existing ELSA efforts within the EU Quantum Flagship (such as the working group for EDI[9]) with a working group for assessing quantum narratives. By integrating such self-scrutiny directly into the Quantum Flagship itself, Europe stands to replicate the success of similar initiatives taken by its Member States as part of their national quantum strategies, such as the Netherlands' Centre for Quantum and Society within QDNL.[10]

We believe that such reflexive and reflective work can have a positive impact not only on the choices of policymakers but also on the design choice made in the development of the technology. For this to happen, the value of such reflection must be made clear to scientists and engineers, many of whom remain sceptical of societal, ethical, and legal reflection, viewing it as either abstract critique or external constraint. Yet attention to bias, blind spots, and representational gaps can improve the quality and utility of technology itself. For example, avoidance of unfair bias and broad inclusion at all phases of development are explicitly identified as essential for "developing AI systems that will be employed in the real world" (European Commission, 2019) by ensuring that these systems are fit for the purpose of serving the needs and interests of the widest possible userbase. Similar attention to the bias, blind spots, and representational gaps inherent in the narratives and assumptions underlying design choices in quantum research can support more robust, trustworthy, and societally meaningful development and commercialisation of quantum computing.

In this sense, quantum scientists and engineers *working together* with ELSA scholars will lead to the innovation of better quantum computers – both ethical and technologically. We therefore propose that ELSA scholars are represented on the High-Level Advisory Board proposed as part of the EU Quantum Act, in addition to quantum scientists and technology experts.[11] The presence of such expertise will enable the High-Level Advisory Board to reproduce and go beyond the success of High-Level Expert Group on AI, for which the ethical principles driving European AI development continue to be a central concern (High Level Expert Group on Artificial Intelligence, 2019).

2. Regulation and geopolitics of quantum computers

National and supranational governments increasingly view jurisdiction over next-generation technologies, the firms that develop them, and the resources they require as key sources of strategic advantage (e.g., UK Ministry of Defence, 2023) and geopolitical influence. Law and regulation play a central role in shaping this landscape by directing research funding, supporting industrial uptake, and ensuring fair and competitive markets (Mittal, 2025). Within this context, Europe faces the recognised challenge of fostering innovation that is both globally competitive and aligned with its values.

First, Europe should resist calls for deregulation as a means of strengthening its quantum sector. The Draghi Report highlights the persistent difficulty of scaling European start-ups into world-leading firms (European Commission, 2024). Similarly, the European Quantum Industry Consortium (QuIC)[12] has identified features of Europe's current regulatory and governance landscape that impede the translation of its strengths in quantum research and start-ups into industrial leadership (QuIC, 2025a, b). A tempting response is to pursue competitiveness through deregulation, reflecting the aspiration for Europe to become the world's "Quantum Valley", expressed in the European Union's Declaration on Quantum Technologies and the Quantum Flagship's Strategic Research and Industry Agenda 2030. We believe this would be a mistake. At the current stage of quantum technological development, the priority is not deregulation but dedicated, coordinated, and value-led government support that enables responsible growth of European quantum computing companies while preserving public trust and promoting European values beyond the economic.

Second, Europe should complement its strategic objectives with more transdisciplinary engagement across government, industry, academia, and civil society. High-level aims, such as strengthening European competitiveness while upholding core European values, require translation into concrete and practicable guidance for firms operating across the quantum ecosystem. This should be achieved through regular industry-government fora involving organisations of different scales, facilitated by the Quantum Flagship's existing Quantum Community Network (QCN)[13] and QuIC, while also incorporating expertise from the social sciences, humanities, and civil society. Such transdisciplinary engagement would help identify sector-specific bottlenecks to responsible growth, anticipate ethical and societal challenges, and ensure that Europe's strategic, economic, and societal ambitions are enacted coherently "on the ground", rather than defaulting to the Silicon Valley model of "moving fast and breaking things."

Third, Europe should develop clear guidelines for value-led international collaboration in quantum computing. European values extend beyond the European continent, encompassing solidarity and mutual respect, the eradication of poverty, and the protection of human rights. Yet the increasing "securitisation" of quantum technologies (Smith, 2020) makes it more difficult for Europe to realise these commitments. Major powers increasingly frame quantum development as a "winner-takes-all" competition, restricting the movement of talent, resources, and expertise to strategically aligned partners (European Commission, 2023b). Export-control regimes, such as the United States' three-tier system (Congressional Research Service, 2025), shape international access to quantum hardware and place pressure on allies to adopt similar restrictions (Quantum Strategy Institute, 2025). Although meaningful regulation remains essential, these hegemonic and polarising dynamics constrain Europe's capacity to regulate independently and undermine its ability to engage in globally uplifting international scientific collaboration. This is especially concerning because quantum technologies, and quantum computing in particular, will have global consequences (AWO, 2024; QDNL, 2024). In line with the previous section, we therefore recommend that Europe demonstrate ethical leadership by challenging the narratives underpinning securitisation

[9] https://qt.eu/working-groups/equity-diversity-and-inclusion
[10] https://qdnl.nl/
[11] Here, as above, we are not conflating ELSA scholars with experts in (institutionalised) Technology Assessment but rather referring to ELSA scholars as a broad group of humanities and social science scholars investigating and critiquing the societal needs and dominant (moral) norms, and the relations therebetween, implicated in the development of new technologies – technology assessment, in the uncapitalised sense.
[12] https://www.euroquic.org/
[13] https://qt.eu/structure-governance/quantum-community-network

and pursuing regional sovereignty and security through global solidarity and openness in the development of quantum computing (European Policy Centre, 2025; Vermaas et al., 2025). This should be supported by clear, value-led EU guidelines defining permissible forms of non-strategic international collaboration in quantum computing research and development, enabling openness for global benefit while safeguarding security and competitiveness in strategically sensitive areas.

3. The role of the public in driving quantum innovation

Due to quantum computers' unique and esoteric attributes, and their development being driven by investments by the private sector, the role of the public in driving their innovation remains unclear. Unlike the digital computer, quantum computers are unlikely to become part of everyday life for many citizens. Furthermore, despite high expectations, quantum computing may not produce the sweeping social transformations often promised due to its inherent limitations: post-quantum cryptography and quantum encryption will likely neutralise many of the perceived risks of quantum decryption algorithms (de Wolf, 2017), and efficiency advantages for search or simulation applications are likely to be limited (Aaronson, 2008).

For these reasons, the impact of quantum computing is likely to be incremental and narrow as opposed to radical and broad, at least in the medium term. Researchers and policymakers should, therefore, be measured in how they present the potential impact of quantum computers to the public and realistic about the role the public ought to play in steering their development. Four broad models for approaching public engagement are available to policymakers, which can be implemented jointly or separately:

- Open access – providing public or academic access to emerging quantum computing resources through shared infrastructure (Seskir et al., 2023).
- Participatory priority-setting – involving citizens, civil society, and non-expert stakeholders in shaping research agendas and prioritising applications (ibid.).
- Understanding and education – ensuring that the broader public can participate in discourse about the development of quantum computing in an informed and reasoned way. Several innovative approaches to promoting relevant public understanding of quantum computing, such as "quantum games" and "quantum art", are already being developed (Seskir et al., 2022; Piispanen, 2023; Chiofalo et al., 2024).
- Design for Values – bringing the public directly into the development process itself, working together with scientists and engineers to build their knowledge, values, and needs into Europe's future quantum computers (van der Velden & Mörtberg, 2015).

The appropriate (combination of) model(s) must reflect a realistic assessment of the interest the public has in quantum computing; this may change over time as the technology advances and new applications emerge. Policy must therefore be designed to be adaptable to such changes.

Realism about the level of public interest in quantum computers is not the same as dismissiveness of the public's ability to contribute to their development. Public consultation over quantum computing should move beyond the "deficit model" (Gross, 1994) of public ignorance and expert wisdom. Instead, engagement with the public should be genuinely dialogical, treating citizens as partners in reflection rather than passive recipients of information. At the same time, it must be recognised that science communication competes in a crowded information environment in which entertainment, marketing, and misinformation often dominate. Public engagement must therefore be targeted and strategic, avoiding hype, and focusing on tangible examples of what quantum computers can do and how this will affect people, as opposed to esoteric and distracting technical details.

With this in mind, we recommend the commissioning of a European Quantum Public Engagement Strategy, grounded in an evidence-based understanding of public interest and concerns, drawing appropriately on existing, well-defined models of public engagement, and aimed at empowering European citizens to engage meaningfully in the development of European quantum computing. This aligns with the EU's commitments as expressed in the European Declaration on Digital Rights and Principles (European Commission, 2022).

4. Fostering accountability and public vigilance against misuse of quantum computers

While the beneficial applications of quantum computers are often prominent in the narratives put forward by researchers and advocates, it is equally important to consider malicious or harmful uses of quantum computers. State and corporate interests will inevitably (and, often, understandably) seek to exploit quantum capabilities for strategic advantage – whether utilising Shor's algorithm to "store now, decrypt later" (Olsson & Öhman, 2025) or Grover's algorithm to guess passwords and access private data (Europol, 2023). Historical precedents show that even unlikely scenarios can materialise when technological means align with institutional incentives. Public vigilance may erode as malicious uses become normalised or hidden behind technical complexity. Just as many citizens have grown resigned to digital surveillance as a fact of online life, so too might they accept quantum-enabled intrusions as the cost of progress.

Such resignation must be resisted, and policymakers should make use of a variety of mechanisms to ensure users and providers of quantum computing services remain accountable:

- Policymakers must look to markets that have emerged around other advanced technology services to prepare for the emergence of a market for quantum computing services and anticipate potential regulatory gaps for this dual use technology.
- Policymakers must think about the infrastructural underpinnings of quantum computing services to regulate easy availability of this technology and ensure private service providers put in place appropriate guardrails.
- Policy choices about the development of quantum computing should be accompanied by substantial efforts to meaningfully inform the public about the potential risks of quantum computing.

By intelligently combining these approaches, policymakers can maintain public trust in quantum computing and mitigate against its potential misuse. While this task may seem overwhelming, such efforts in the domain of quantum computing would not be without precedent; similar balancing acts have arisen in the context of other rapidly developing new technologies, such as AI (Perboli, Simionato & Pratali, 2025). Complementing the recommendations of Section 1, ELSA researchers can contribute their relevant expertise to the effectiveness of public communication about quantum computing.

5. Beyond "Quantum for Good"

A clear illustration of a narrative that drives the development of quantum computing is that of "Quantum for Good," which has become central to debates about the societal value of quantum technologies more broadly.[14] While it can encourage investment in beneficial applications, the phrase risks becoming an empty slogan if it is not accompanied by critical reflection on whose interests are being served and which values are guiding innovation (Shelley-Egan, 2025; de Jong & Shelley-Egan, 2026). For example, as noted, quantum computers are

[14] https://quantumforgood.eu/

emerging at a time when global multilateralism is breaking down, and technology increasingly functions as a lever for exerting geopolitical influence. Moreover, the value of a new technology is often subsumed under capitalist logics of competition and growth. We have good reason to question these value frameworks as suitable for orienting the ethical development of quantum computers. Policymakers must examine how the "Good" of quantum computing is negotiated – and by whom, including by those acting on a geopolitical level such as nation states (Open Quantum Institute, 2025b; World Economic Forum, 2024b). "Quantum for Good" should be a starting point, not a stopping point, for thinking about the value of quantum computers for society (de Jong & Shelley-Egan, 2026). It should be reinterpreted by policymakers and other influential actors as a demand for evidence-backed arguments for the social value of specific quantum computing use-cases.

For this reason, we recommend the development of a standardised Social Value Assessment framework for quantum application research, co-designed by quantum scientists and engineers and ELSA researchers, taking into account relevant factors like the maturity of the technology (de Jong, 2025), to ensure every application of quantum computing in Europe is demonstrably in the interest of European society (and beyond). Furthermore, as quantum computing technology develops in maturity, periodic reassessment of the social value of funded research into quantum computing applications should be required to ensure continuous, critical reflection on the evolving societal value, risks, and costs of specific quantum computing development pathways.

Conclusion

In summary, we advocate for the following policy interventions for the development and uptake of European quantum computing:

1. **Recognise and critically assess competing narratives driving policymaking on quantum computing by:**
   a. Employing ELSA expertise to scrutinise and make explicit the narratives that currently drive decision making and their sources.
   b. Ensuring that ELSA experts are represented on the High-Level Advisory Board proposed as part of the EU Quantum Act, in addition to quantum scientists and technology experts.
2. **Meaningfully operationalise high-level policy objectives for industry by:**
   a. Strengthening existing industry-government fora to translate European values and strategic aims into concrete, practicable guidelines for quantum companies of all sizes.
   b. Publishing clear, value-led EU guidelines for permissible non-strategic international collaboration in quantum computing R&D.
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4. **Foster accountability and mitigate misuse of quantum computing by:**
   a. Anticipating regulatory gaps prior to the future emergence of a market for quantum computing services.
   b. Establishing institutional incentives for responsible provision of quantum computing services.
   c. Educating the public early about the potential for misuse of quantum computing.
5. **Demand evidence of societal benefit from quantum computing applications by:**
   a. Developing a standardised Social Value Assessment framework for demonstrating the social value of quantum computing use-cases.
   b. Requiring periodic reassessment of the social value of funded research into quantum computing use-cases.

The window of opportunity for ensuring the ethical development of quantum computing remains open – for the time being. The course of their development will be shaped as much by the narratives we accept and the values we adopt now as by future technical breakthroughs. Ethical development of quantum computers means policymakers and researchers fostering critical self-scrutiny, prioritising adaptive governance, and pursuing meaningful public engagement – ensuring that future quantum computers advance not only corporate and geopolitical ambitions, but also serve the broader public.

CRediT authorship contribution statement

Benedict Lane: Writing – review & editing, Writing – original draft. **Christine Boshuijzen-Van Burken:** Conceptualization, Writing – original draft. **Eline de Jong:** Conceptualization, Writing – original draft. **Anushka Mittal:** Conceptualization, Writing – original draft. **Martin Sand:** Conceptualization, Writing – original draft, Writing – review & editing. **Zeki Seskir:** Conceptualization, Writing – original draft. **Clare Shelley-Egan:** Conceptualization, Writing – original draft. **Pieter Vermaas:** Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Benedict Lane

Appendix

This policy intervention is based on the outputs of a workshop that took place at TU Delft in September 2025, organised by the Delft Quantum Governance and Values Lab and funded by the Netherlands' Centre for Quantum and Society. The listed authors consist of the organisers (Benedict Lane and Pieter Vermaas) and several of the invited speakers (Christine Boshuijzen-Van Burken, Eline de Jong, Anushka Mittal, Martin Sand, Zeki Seskir, Clare Shelley-Egan), who contributed directly to the preparation of this paper. However, many of the results articulated in this paper are the joint achievement of all the participants of the workshop, both presenting and non-presenting. Below are listed the names of the participants (published with permission):

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