OFFICE OF THE PRIME MINISTER'S CHIEF SCIENCE ADVISOR

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A Commentary on Digital Futures and Education

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The following paper outlines our understanding of the digital futures faced by children and adolescents, especially as these relate to their education. It examines established trends, the impact these might have on development and learning, and how we might design education to optimise valued outcomes. We identify a set of potential benefits and risks, and propose principles for how, as a nation, we could capitalise on those benefits and mitigate the risks.

1. Living and working digitally: trends

1.1 Across the world, children and adolescents have increasingly ubiquitous access to and use of online devices, smart tools, and technologies. In education, this will mean digital environments universally available in schools, changing the nature of learning and teaching. Artificial Intelligence and machine learning (technologies that learn, model, and predict: AI), smart tools, and automated technologies are changing the nature of schooling and daily life in general.

1.2 The trends are very clear. In 2016, 43% of the world's population had access to the internet (up from 6.5% in 2000), with 3.2 billion people online.[1] In the US, 84% of children and teenagers have internet access, 75% of 12 – 17 year olds have their own cell phones (up from 45% in 2004), and nearly all teenagers use text messaging, some with high frequency (a third more than 100 per day).[2] 93% of all UK classrooms contain an interactive whiteboard and, worldwide in 2016, these were predicted to reach one in eight classrooms (estimated at 34 million teaching spaces)[3]. In 2012, 96% of 15-year-olds in OECD countries had a computer at home and 72% used a desktop computer, laptop, or tablet at school.[4] The average 8-to-10 year old in the US spends nearly 8 hours a day with a variety of different media and older teenagers spend >11 hour per day.

1.3 The data are similar for New Zealand. An overall estimate for accessing any form of social media was 2.8 million in a month in 2014 and, in 2015, the usage of Facebook was estimated to be 2M+ per day (33% for news, 79% to stay connected with friends and family); Nielsen, in 2016, estimated 81% of the population of 10 year olds owned mobile devices and 88% of this age group used the internet across a week.[5] We have increasing digital connectedness: in 2015, 72 % of adults owned or accessed a laptop or notebook for private use (up from 66 percent in 2013); the exponential growth in smart phones will reach a ceiling shortly – currently 70% across all ages, but 91% for 18 year olds. New generations of personal devices with increased functionality will allow even greater personalised access to, and choice of, what is available through social networks and the internet; in New Zealand, the range of uses includes information, news, and social contact.[6]

1.4 As with many other educational innovations, there is a risk of differential access, whereby richer or more privileged groups get access to innovation and resources and those less rich and less privileged groups get less, with compounding effects on educational achievement gaps (known as 'Matthew Effects').[7] Between countries, the differences in access to, and use of, computers are associated with national wealth and within countries, they are associated with individual Socio Economic Status (SES).[8]

1.5 There is evidence from 2014 for a similar 'digital divide' in New Zealand.[9] Whereas over 90% of schools reported online learning occurring at school, the pattern was markedly different at home, with substantially higher proportions of students in more affluent (higher decile) schools than of students in low-decile schools reporting internet access at home . These differences appear to be exacerbated in Māori medium settings.

1.6 This first digital divide is still an issue in New Zealand. Access to broadband, wireless and the infrastructure of digital technology may be becoming more fully national, but the overall costs of access are still high in international terms, internet speeds are relatively low in international terms, and there are regional and household differences in both access and costs.[10] A 2015 survey indicated age and household income, ethnicity and regional location, remained significant factors in differential internet usage.[11]

1.7 In addition, a second 'digital divide', reported internationally and also in New Zealand, can occur whereby there is less complex and less educationally relevant usage patterns by students from poorer and less privileged communities[12]

2. Work trends

2.1 Four trends are apparent in work places in developed countries, including New Zealand. One is for workplaces to increasingly require a minimum level of digital skills. This trend is accompanied by a second: adults with higher levels of problem-solving skills using digital tools

have higher employment rates and receive higher wages. A third trend is an increasing rate of job automation consequent upon the use of AI and digital tools and resulting in a reduction or change in workforce needs. Most vulnerable are jobs have been routine, but the capabilities of machine learning now extend beyond routine work, even to aspects of 'judgment' and 'creativity'. [13] Fourthly, the labour market increasingly rewards social skills, especially those relating to teamwork, collaboration, and oral-communication skills.[14] Labour-force participation among adults with the highest levels of skills in solving problems using digital devices is 6 percentage points higher than that among adults with the lowest level of proficiency in those skills, and 15 points higher than those with no skills; this last group suffer a serious wage penalty (earning 6% per hour less than those with the lowest proficiency).[15]

3. Living in the digital world: benefits and risks in four areas

Like any tool being adopted by a society, increased access to, and use of, digital technology will inevitably impact on aspects of children's development. There is evidence currently for both benefits and risks in four areas of development. Caution is needed when discussing these risks and benefits because, in some areas, there is only limited evidence for the claims.

3.1. Citizenship

- Digital media (including social media) provide increasingly immediate and direct access to networks, commentary, information, and ideas, with a consequent amplification of contacts, social influence, and the shaping of ideas and beliefs. There are potential benefits of greater connectedness, notably an increasingly well informed and critically aware citizenry, with amplified social cohesion.
- Social media can enhance access to valuable support networks, providing positive effects for those with health needs and fostering social inclusion and community membership for marginalised or excluded groups, such as LGBTI youth.[16] The significance of not being connected is illustrated by the relationship between usage and mental and physical health outcomes which, for adolescents, is not linear. Negative outcomes have been found at both extremes of low/no Internet usage and heavy usage (>2 hours/day).[17]
- The risks to citizenship come from how opinions can be manipulated with the rapid and extensive access to information and with the use of smart social-media platforms. Self-perpetuating and reinforcing systems of knowledge can be created whereby misinformation, inaccuracies or untruths are taken as truths through the repetition and support within the network.[18] The potential consequence is the uncritical adoption of positions on political and other issues, and uninformed resistance to alternative views.

An example of how the digital environment can exacerbate risks, is computational propaganda: algorithms, automation, and human curation designed to purposefully distribute misleading information over social-media networks.[19] Use of this tool is increasingly influencing popular decision making, including in democratic elections. Judgments about health matters and complex science issues are increasingly susceptible to these influences. Prevalence and impact on individuals appear to be particularly high in social platforms, rather than in digital forms of traditional media.[20]

3.2. Well-being

- Of particular concern is how the tools can impact on social and emotional skills and, more generally, on the psychological well-being of children and young people. The concern here is for the generalised impact on these social and emotional skills, not just in the digital contexts but. Given the significance of intra-personal skills (e.g., self-control) and inter-personal (e.g. prosocial) skills to individual and societal well-being, an important finding is that digital technology can have positive effects. There is widespread evidence that the use of digital tools in classrooms is associated with increased engagement (less distractibility, persistence, and independence) and increased agency or self-efficacy.[21] Similarly, adding well designed digital games to business as usual in the classroom is associated with increases in various social and emotional skills.[22]
- However, consistently producing benefits for social and emotional skills is dependent on a number of specific conditions that include: the complexity of the activities accessed through the digital devices; how well matched they are with current skill levels of students; the degree to which teachers add instructional support – for example, in the form of feedback; and whether there is a whole-school approach to the promotion of the skills.[23] These conditions also determine whether the increases in these skills are generalised across aspects of functioning and academic achievement of children and young persons.
- There are risks to social-emotional skills. High use of digital devices by younger children has been associated with increased distractibility and, by older children, with addiction-like behaviours or pathological engagement.[24] An increase from 2007 in the UK in young women aged 16-24 years with Common Mental Disorders was linked with increased time on the internet or using social media.[25] As noted above, negative outcomes for aspects of mental health have been found for heavy Internet use (>2 hours/day).[26] Also, an online 'disinhibition effect' has been identified.[27] This describes how users of the internet and social media tend to be less inhibited and have reduced capacity to judge the appropriateness of their own behaviour.

- Social media, coupled with personal devices, potentially change patterns of types of bullying behaviour.[28] Cyber-bullying (also called cyber-victimisation) where actions through digital means are intended to harm peers, has been associated with the same negative consequences that face-to-face bullying has, including anxiety and lower academic achievement, suicidal ideation, self-harm and sometimes suicide. Prevalence rates of cyber-bullying vary markedly among countries. Overall, prevalence may be lower than traditional bullying but is comorbid with traditional forms. Exposure patterns are different from face-to-face bullying: cyber incidents are less avoidable given ubiquitous access and use and are less able to be detected by others who could provide guidance such as parents and teachers. Further, the cyber world is less amenable to third-party prevention or interruption; thus, large ripple effects are possible across online communities. Some groups are more vulnerable than others (e.g., LGBTQI youth or those diagnosed with Autism Spectrum Disorder).[29] The lack of personal and social control in cyber-bullying suggests that there is a risk that it has a greater impact than in-person bullying. More research is needed on this point but current evidence suggests that the range of negative consequences is the same (i.e., social, academic, and health), but cyberbullying may have greater effects on suicidal ideation than face-to-face bullying.
- Current usage in schools shows how digital tools can be used to increase other areas related to well-being such as self-expression, creativity and entrepreneurial activity.[30] There is potential to increase opportunities for development in these areas, although the evidence base for how best to optimise is limited. Much more research is needed in this area. Educational programmes focused on using digital tools for creativity and self-expression, indicate that careful educational design is needed to ensure positive outcomes.

3.3. Cognitive development

- Cognitive benefits, via enhanced visual and perceptual skills and knowledge acquisition, have been found for multitasking and for digital environments generally, including games[xxxi]. The benefits accrue: when tasks are sufficiently complex and developmentally appropriate; when there is greater self-regulation and engagement; and, in educational settings, when there is substantial teacher guidance[xxxii]. An example is the use of interactive books with preschoolers.[xxxiii] If interactive books are designed well – and this means the interactive features are closely connected with the meaning of what is being read in ways that highlight aspects of the narrative – an added value for understanding and vocabulary can occur. In addition, adding high-quality interactions can increase the effectiveness of these books.
- However, there are potential costs for cognitive and brain development in terms of efficiency and accuracy of performance, especially for younger children whose attention systems and executive functions are immature.[xxxiv] Early use of digital media with large cumulative hours of use, together with content that is not of high quality, predict deficits in the ability to understand others' thoughts and feelings (cognitive empathy), as well as poorer self-control.[xxxv]
- There is little evidence that, by itself, the provision of digital devices consistently increases the learning of academic subjects and raises achievement levels. Recent comparisons across countries show that heavy investment in digital technology has had little or no impact on 15 year olds' achievement in reading, science, and math.[xxxvi] However, within countries, experimental studies show that implementation of digital environments can have positive effects. Increased learner control over the pace, sequence and content of learning, is consistently found to increase behavioural engagement.[xxxvii]
- However, studies generally show no generalised positive effects of this increased agency, for example on achievement, without other conditions being in place.[xxxviii] These conditions include: increased time on higher-order tasks (such as editing and synthesising in writing); increased teacher-student interactions, either face-to-face or online; supportive home-school relationships; and enhanced aspects of guidance and feedback[xxxix].With these in place positive effects on academic outcomes have been found including on ill-structured problems in STEM subjects. [xl]

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3.4. Socialisation

- What children and adolescents experience in family settings influences their learning in educational settings. Similarly, what happens in classrooms affects patterns of learning and development in families. This means a major goal in many educational systems is to promote parental engagement. In terms of effects on learning and development, engagement is most effective where information flow is high and mutually supportive activities take place (such as support for reading at home which complements reading at school).[xli] Because of these reciprocal relationships, developments in digital education are likely to impact families and communities and, in turn, this will impact learning at school.
- Positive effects of digital tools have been found on family socialisation. Each of the benefits noted above can add value to the way in which parents rear children and interact with adolescents. For example, parents may enhance aspects of cognitive and language development in their children through their selection and use of digital tools such as educational apps and interactive storybooks. These effects have flow-on effects in preparation for schooling and beyond. With careful design – which includes, for younger children, periods of pausing for parents to interact – apps can have benefits on learning, including in mathematics.[xlii] However, despite the bourgeoning market in digital devices for parenting, very few of the digital tools that are marketed as educational have been experimentally tested.
- As noted above, there are positive effects of the use of social media and digital platforms for communicating with others and establishing social networks. This means increased connectivity with family members, including caregivers, is possible. We know, for example, that transgender adolescents who feel supported by their parents have lower rates of depression and anxiety.[xliii]
- There are risks to effective socialisation, which follow from those outlined above. Some digital tools can have unintended negative effects on language interactions because of their design, by misdirecting attention away from more complex learning.[xliv] However, there are additional risks through overuse of digital devices. For under two's, overuse reduces time spent in parenting practices known to be effective in socialisation such as face-to-face interaction. [xlv] Heavy parent use of mobile devices is associated with fewer verbal and nonverbal interactions between parents and children and may be associated with more parent–child conflict.[xlvi] As yet, there are no population-based data for New

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Zealand to show whether, or to what degree, these unwanted effects might be occurring here.

- Similar negative effects on family relationships have been found for adolescents.[xlvii] Up to half of adolescents in the US report being addicted to their smart phones. But poorer family functioning and lower rates of parent-child interactions occur with high screen use. Parent usage also can be a problem. High rates of screen time by parents and heavy usage of mobile devices have been associated with lower parent-child interactions and increased conflict.
- Risks are likely to be exaggerated where there is limited sharing of expectations and activities between schools and families / whānau. There is little local evidence about the degrees of consistency and mutual understanding of expectations and practices that currently exist between parents and teachers.

4. Two foci for optimising benefits and mitigating risks

4.1. *Critical thinking and critical literacies:* The development of critical thinking and critical literacy skills through education can help optimise the benefits and reduce risks. These skills include: areas of strategic problem solving; being able to recognise when information is needed; and locating, evaluating, and using the needed information effectively. They entail being aware of authority and bias in order to make judgements about the reliability and usefulness of information. They are especially required in the new digital environments[xlviii] and are identified in recent statements about science literacy and the need for a citizenry who can navigate around, and be able to critically engage with, the knowledge and information that impinge on everyday lives.[xlix]

4.2. These forms of critical thinking and literacy can be taught.[l] Content-specific approaches that are based on authentic (real world) problems and that use critical discussion plus individualised feedback and guidance are effective approaches across age levels and content areas.

4.3. Studies of how to promote a range of cognitive skills with digital tools are beginning. To date, the focus has been mostly on games and acquiring knowledge and learning strategies rather than the skills of critical thinking and critical literacy.

4.4. *Self-control and social skills:* Social and emotional skills are critically important for high-quality educational trajectories, post-school outcomes, and a range of individual and collective benefits. Together, these skills are associated with educational achievement (such that, by

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middle secondary school, the impact is as great as cognitive skills measured by prior achievement) and, later, with long-term, economic and social benefits.[li] Arguably, these are increasingly significant for resilience and well-being given the risks from digital tools outlined above (such as cyberbullying) and as noted earlier.

4.5. Just as the cognitive and literacy skills, self-control and social skills can be taught – and from an early age.[lii] School-based programmes usually create a context of caring teacher and student relationships, safe and orderly environments, and adult norms of high expectations and academic success. Those with additional specific features (step-by-step training, active forms of learning, sufficient time on skill development, and explicit learning goals), are especially effective at improving a range of skills, attitudes and academic achievement.[liii]

4.6. Demonstrations of how the use of digital tools can promote these skills are becoming available. Adding games that have a deliberate focus on the social skills can impact these skills, especially those of self-control (such as conscientiousness and accurate self-evaluation), but there is very little evidence of the effects of games on the range of inter-personal outcomes (teamwork, collaboration, and leadership) and these report mixed effects on achievement. [liv] Very recent experimental studies have used mobile devices to support collaborative learning in classrooms and have shown increased positive effects on peer interaction relative to individual- or group-learning conditions; again only when the instruction is deliberately designed to promote collaboration.[lv]

5. Teaching and learning digitally: new design skills are needed

5.1. Schools are in rapid transition to fully digital environments, with innovative use of online devices, tools, and technologies. In these, students have 1:1 devices (one laptop, netbook, tablet computer, or other mobile-computing device for every student), 24 / 7 access to digital technologies with these personal devices, and archival cloud-based systems linked with a real-time dashboard enabling synchronous interaction.

5.2. With ubiquitous adoption, more effective and possibly different forms of teaching and learning will emerge for valued student outcomes. [lvi] It is assumed that digital tools have properties, among other things, to enable greatly increased learner agency, with more and varied forms of collaborative, networked or 'lateral' learning; and the relationships between teaching and learning are less hierarchical, more synchronous, more distributed in time and place, and more personalised. These properties come from the use of personal devices for learners with super-fast access to learning networks and smart tools for instructional

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resources to both teach and learn in ways not confined to the physical properties of classrooms if, indeed, the unit of a bounded classroom is applicable at all.

5.3. Although this picture suggest the digital tools are in and of themselves sufficient to produce qualitative changes in learning and teaching, the evidence presented above presents a more complex and nuanced picture. This is illustrated with international and local studies which show impressive positive benefits to writing with fully digital environments. The gains have been found when usage involves higher order writing activities (editing, synthesising from texts, topic based on line research); where there is increased engagement in and volumes of writing, with increased personalised instruction; and with increased rich teacher student interactions, either face to face or through digital exchanges.[lvii] [lviii]

5.4. In summary, deliberate design by the teacher is needed to guarantee the learning of specific skills. This teacher augmentation of what digital tools provide means that learning can be both more efficient and effective, as well as having new qualities that are distinctly different from non-digital contexts for learning. Teaching also can be both more efficient and effective, and have new qualities that are distinctly different from non-digital contexts for teaching (e.g., in how to design and provide feedback).

6. Smart analytics and Artificial Intelligence: new resources are needed

6.1. Artificial Intelligence is advancing in many fields; reduction or elimination of some types of work and changes to the nature of others are taking place as a consequence. A case in point is health workers.[lix] Very smart AI tools are already creating more efficient and accurate forms of diagnosis and higher quality and more reliable surgery. But AI may not replace the surgeon and the general practitioner; rather, it is likely to free them to concentrate on the very human aspects of their work, which involve empathy and other aspects of human interaction associated with making decisions about patient health and well-being. In a similar way, smart tools in agriculture are enabling greater precision in judgments and use of resources.

6.2. Precision teaching, like precision farming, should be under development right now. The archiving and analytic functions that are currently possible presage newer and smarter analytics for teachers and students.

6.3. We need a rapidly expanded research and development infrastructure to develop archiving systems linked with very smart analytics to enable exponentially increased precision teaching.

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7. Design skills, smart tools and the role of the teacher

7.1. The design skills and smart tools create conditions for teachers to focus on core properties of effective pedagogy. The role of the teacher, like that of the surgeon, may be able to concentrate even more on those aspects of human interaction known to be essential to effective learning for educational purposes. As noted earlier, these include close personalised interactions with positive affect; extended reciprocal interactions involving complex language uses; and acting on highly developed specialised knowledge of curriculum areas. The risk here is that reliance on digital tools for teaching could reduce the close relationships between teacher and student which are the basis for these aspects essential for learning.

8. **The role of computational thinking**.

8.1. Claims have been made that we could change a generation's way of thinking across many areas of knowledge by teaching them computational skills through programming.[lx] The claims overstate the generalisability of these skills. In our view, these are forms of critical thinking applied with digital tools to digital contexts and have a necessarily constrained range of impacts.

8.2. Nevertheless, as noted above, we do need students to develop critical digital literacy, in which they learn how to knowledgably appraise the design and function of programmes and apps and other yet to be invented forms of digital tools. They do need to understand the nature of digital algorithms sitting behind games so they can spot those that might promote gambling or other potential harms.

8.3. Despite this content specificity, the more we learn similar skills across different activities the more the skills are generalisable. This means that the goal should be to have curricula that enable critical-thinking skills to be generalised and that includes with, and in the context of, digital tools as computational thinking.

8.4. This concern for a generalised approach to promoting skills applies to the areas of self-control and social skills noted above. The issue for our educational system is to build a coherent within-and-across schools approach to the development of these skills.

9. Summary of Implications

9.1. A well-resourced research and e-development strategy is needed to deliver smart digital tools that reliably and effectively promote specific skills to optimise benefits in education. The tools are required both for students' learning and for teaching. The former are in the design of

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programmes, apps, and social-media platforms that are appropriate for current and evolving curricula. The latter entail access to smart analytics that enable teaching to be more data-based, contingent, flexible, and personalised.

9.2. Issues in equitable access to and use of digital technology for educational purposes need to be addressed.

9.3. A systematic focus for optimising benefits and mitigating risks through deliberate teaching is needed. This creates three immediate challenges:

- better evidence for how to develop the valued social and cognitive skills for all children and young people and at scale
- increased focus through initial teacher education and ongoing professional development on the expertise teachers need to promote these skills
- systematic monitoring of how well individuals are developing these skills across the early childhood and school years; which can be linked with other life course measures (for example in the Integrated Data Initiative) and used to judge system effectiveness

8.3 Teaching will need to be even more skillful. It will include expertise in designing instruction with digital tools to promote valued skills (the teacher acting as instructional designer); appropriate capability understand and use smart tools; and having requisite levels of the social and emotional, and cognitive skills which underpin effective pedagogy. The increased complexity of teaching in turn carries implications for the selection, training and ongoing professional development of teachers.

9.4. Our curriculum and assessments should focus on enabling students to learn these skills in the context of the preparation for employment after their schooling.

9.5. A systematic national approach for parents/ family / whānau education which:

- enables greater engagement between schools and parents/ family/whānau to support children's digital lives and learning outside of school.
- provides guidance for positive socialisation within digital environments.

9.6. A life course approach to promoting the valued skills is needed. In such an approach early childhood teaching and learning should develop skills which are built on through the primary and secondary years, which in turn prepare students for the immediate and future possible patterns of employment, which already recognise in many areas the significance of the critical cognitive skills and the social and emotional skills.

9.7. Each of the above directions should address the usual challenges in implementing educational change. Notably, guaranteeing the quality and consistency of the valued teaching and

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learning outcomes at scale. The benefits and risks are too great to assume local initiatives and implementation are sufficient to guarantee these valued outcomes nationally.

9.8. How to promote positive skills and the appropriate means to reduce the negative impacts of social media and digital tools requires extensive public discussion. That discussion will need to address issues of how to constrain inappropriate and damaging digital tools and social media.

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