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COMPUTATIONAL THINKING CURRICULA IN AUSTRALIA AND NEW ZEALAND

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INTRODUCTION

Australia and New Zealand (NZ) are neighboring countries that have independent education systems, but both have introduced the subject of "digital technologies" over a similar period, and the process has been in political and cultural contexts that have a lot in common. Both countries have the subject situated within a curriculum area that covers technology in general, which has a focus on design, innovation, and end-users.

This chapter explores similarities and differences through the lens of categories based on the Darmstadt Model, a framework that provides a category system for comparing and contrasting computer science (CS) education across regional or national boundaries (Hubwieser et al. 2011). We have selected aspects that are particularly relevant to understanding how the curricula have evolved in these two countries.

EDUCATIONAL SYSTEM

New Zealand and Australia have independent education systems, and in fact within Australia states and territories can determine how education is run. Consequently, the countries (and states/territories) are not exactly the same in their approach to education although there are considerable commonalities. In both countries, the new learning area in the curriculum that correlates to computing is called "digital technologies" (DT). In these curricula, DT includes substantial elements relating to both computer science (or computational thinking) and using digital devices as a tool. An extensive comparison of the curricula of the two countries has been published by ACARA (2019).

NEW ZEALAND

The New Zealand pre-tertiary school system generally has thirteen years of schooling, referred to as "year 1" to "year 13." Children typically start at year 1 in primary school on their fifth birthday. High school usually starts at year 9, and from years 11 to 13 students sit for school-leaving assessments, with the "National Certificate of Educational Achievement" (NCEA) being the most common national qualification that covers those three years (New Zealand Qualifications Authority 2021).

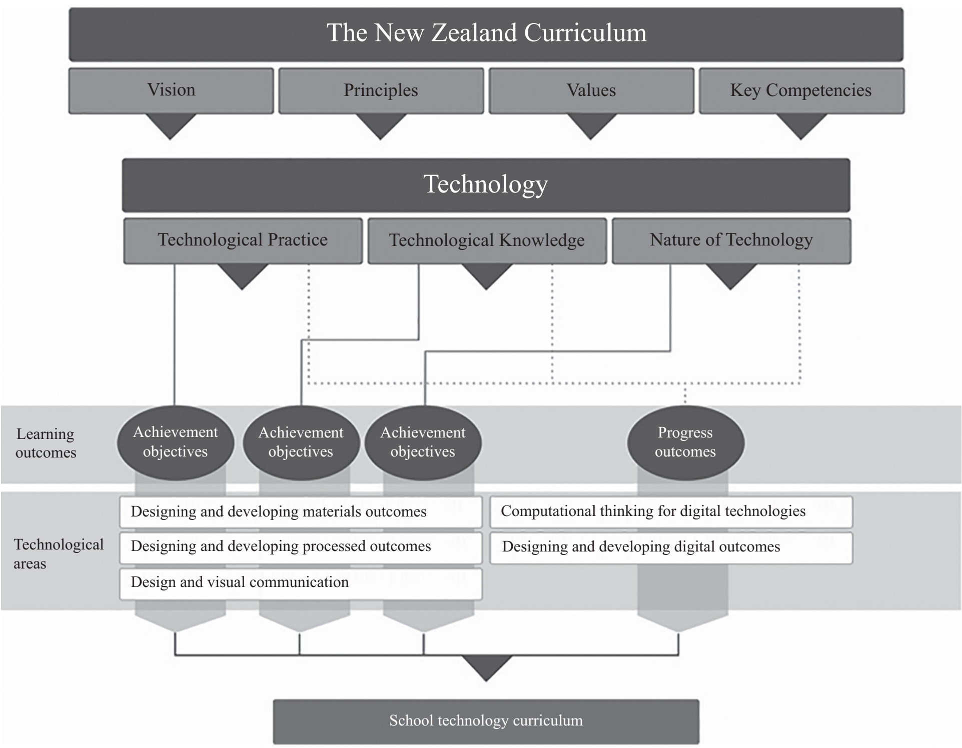
New Zealand is a bicultural country, and the New Zealand school system operates under two main curricula: the "New Zealand Curriculum" (NZC) for English medium instruction and Te Marautanga o Aotearoa (TMoA) for Māori medium instruction (New Zealand Ministry of Education 2021a). These curricula are not simply translations of each other but organize knowledge differently with different emphasis. Nevertheless, computing falls under the area of "technology" in the NZC, and under "hangarau" (which can be translated as "technology") in the TMoA. Within these areas, they are slightly different but have a lot in common; a key difference is the context in which they are taught. In this chapter, we will focus on the English-medium New Zealand curriculum.

The "front end" of the NZC includes values and key competencies that are expected to be developed and promoted through schools' delivery of the curriculum. The key competencies are thinking; relating to others; using language, symbols, and texts; managing self; and participating and contributing. There are clear opportunities to practice these in many aspects of computing.

The subject content of the NZC is articulated through eight "learning areas." One of these learning areas is "technology" (New Zealand Ministry of Education 2021b), the other seven being typical curriculum areas such as "mathematics and statistics," "the arts," and "science." Within the technology learning area, two out of its five "technological areas" (figure 5.1) are grouped as "digital technologies" (DT); these are "computational thinking for digital technologies" (CTDT) and "designing and developing digital outcomes" (DDDO).

Each of CTDT and DDDO has a series of "progress outcomes" (New Zealand Ministry of Education 2021b) that show the stages a student should go through as they progress in these areas. The progress outcomes essentially define the curriculum, and so they indicate the level of detail that is provided to schools on what they should teach and assess. These are described in more detail in the "Intentions" section later in this chapter.

Supporting documentation including exemplars is provided, although the New Zealand education system has a strong emphasis on "local



5.1 Structure of the technology learning area in the New Zealand curriculum (from nzcurriculum.tki.org.nz) (New Zealand Ministry of Education 2021i).

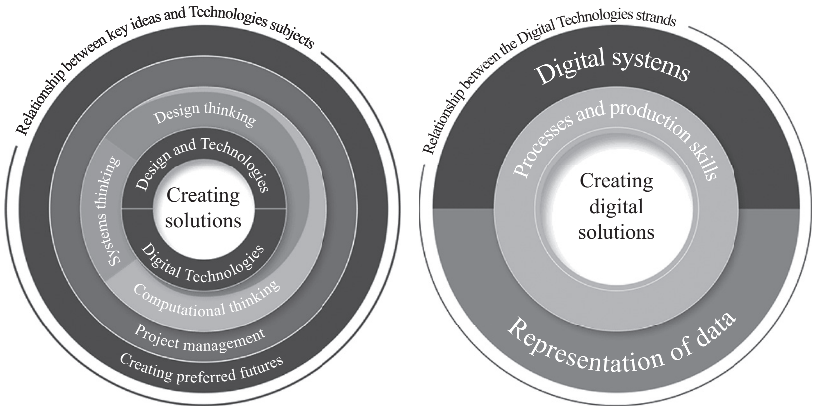
curriculum" (New Zealand Ministry of Education 2021j), where schools work out how to deliver the material in the most appropriate way for their community. Thus, the NZC is not highly specified like some curricula, and a lot of autonomy is given to schools and teachers to choose when it is delivered, what textbooks or resources are used, and how it is integrated with other learning areas.

AUSTRALIA

Similar to New Zealand, the Australian pre-tertiary school system also typically has thirteen years of schooling, with a preliminary year, referred to in this chapter as "foundation," to align to the Australian Curriculum (states vary in their naming of the initial year), followed by "year 1" through "year 12" (ACARA 2021a). Children typically begin their first year of primary school at five or six years of age. Secondary school (or high school) usually starts in year 7 or 8 (depending on the state). While a curriculum has been developed up until year 10, years 9 to 10 are elective subjects. In senior secondary years 11 to 12 students sit for school-leaving assessments, with the Australian Curriculum, Assessment and Certification Authority (ACACA agency) in each state or territory being responsible for their assessment and reporting for the Senior Secondary Certificate for that state or territory. The Australian Curriculum (AC) currently has only four learning areas covering years 11–12, with no curriculum available for DT in years 11–12, resulting in states/territories deciding on implementation at those levels.

The AC consists of eight learning areas that happen to have almost the same titles as the learning areas in the NZC (ACARA 2019, table 1). The foundation (F) to year 10 (F–10) technologies learning area contains two distinct but related subjects: *digital technologies (DT)* and *design and technologies (D&T)* (ACARA 2021a).

Underpinning both technologies subjects are key ideas of design thinking, systems thinking, and computational thinking. Figure 5.2 depicts a key difference between D&T and DT, which shows a greater emphasis on design thinking and computational thinking, respectively. D&T is concerned with contexts related to engineering, food and fibre, food specializations, and materials and technologies specializations. DT is the subject area that includes computing content and is the focus of this chapter.



(a) AC: Technologies key ideas (b) AC: DT strands

5.2 AC: DT key ideas and strands (from ACARA 2021c).

The AC: DT subject includes two related strands (figure 5.2b): "knowledge and understanding," which is "the information system components of data, and digital systems (hardware, software and networks)," and "processes and production skills," which involve "using digital systems to create ideas and information, and to define, design and implement digital solutions, and evaluate these solutions and existing information systems against specified criteria."

The Australian government is committed to "closing the gap" and empowering Aboriginal and Torres Strait Islander students to reach their potential (Education Services Australia 2019). Unlike New Zealands's Te Marautanga o Aotearoa for Māori medium instruction, Australia does not have an explicit curriculum for Aboriginal and Torres Strait Islander education. Australia has taken the approach to include "Aboriginal and Torres Strait Islander Histories and Cultures" as one of the three identified cross-curriculum priorities that aims to highlight opportunities across the curriculum for all students to deepen their knowledge with a framework of First Nations Peoples, Culture and Country/Place (see figure 5.3). The cross-curriculum priorities are presented as guiding elaborations, embedded within learning areas alongside some content descriptors. As an example, in years 5–6 an elaboration suggests: "comparing past and present information systems in terms of economic, environmental and social sustainability, including those of Aboriginal and Torres Strait Islander Peoples."

5.3 Aboriginal and Torres Strait Islander Histories and Cultures cross-curriculum priority framework (ACARA 2021d).

The implementation of the F–10 AC is the responsibility of state and territory school and curriculum authorities (ACARA 2021e), who decide how and when the AC is implemented in their jurisdiction, including if they will develop their own version. All states or territories have either chosen to use this curriculum or a very similar version, except New South Wales (NSW) where they have developed their own syllabus based on the AC, featuring "digital technologies" within the years F–6 science and technology and years 7–10 information and software technology syllabuses (NSW Education Standards Authority 2021). The Australian Curriculum was being reviewed in 2020–2021, and version nine of the AC was published on a new website in early 2022.

SOCIOCULTURAL AND POLICY FACTORS

The development of digital technologies in both countries has come from a mixture of grassroots concerns from educators frustrated about the place of computing in the curriculum, and a push from industry to grow the diversity and number of qualified people to address the lack of talent available. As has been the case in most countries, this has been set against the typical issues of decision makers not understanding the difference between *using* and *creating* digital technologies, the difficulty of finding space in an already full curriculum for new topics, and the capacity to support teachers to deliver this new material.

NEW ZEALAND

The current NZC was developed in the 1990s, and at the time included the "technology" learning area. However, this had a broad focus—technology is defined in the curriculum as "intervention by design," and the curriculum noted that "technological areas include structural, control, food, and information and communications technology and biotechnology. Relevant contexts can be as varied as computer game software, food products, worm farming, security systems, costumes and stage props, signage, and taonga [prized objects]." The curriculum emphasized general principles rather than particular types of technology, and the key elements were (and remain) three "strands": technological practice, technological knowledge, and nature of technology.

In 2008, concerns were expressed (particularly from industry and universities) about the lack of visibility of computing as a discipline and the confusion around teaching *with* digital devices rather than teaching *about* digital devices.

This led to a review that initially resulted in new standards being introduced to the NCEA assessments, which are typically used by students in their last three years of high school. Prior to this change, the only computing assessments that these students had access to were more focused on *using* computers and were "unit standards." These weren't useful for qualifications such as university entrance, so they were not attractive to students who might be interested in studying computer science in the future. A number of new "achievement standards" were added to the NCEA from 2011, and many students used these to engage with programming and other computer science topics (Bell, Andreae, and Robins 2014).

In 2014, the New Zealand government announced a project called "A Nation of Curious Minds—He Whenua Hihiri i te Mahara," which included the goal of "more science and technology-competent learners, and more choosing science, technology, engineering and mathematics (STEM)-related career pathways." One result of this was to develop new curriculum content that “will be available for all students from Year 1 to Year 13.” The timeline was to publish the content at the end of 2017 for use from 2018, and “in term 1 2020, it will be expected that schools will be teaching the new content” (Curious Minds 2021).

This work resulted in the technology learning area being revised. This appeared as an addendum to the curriculum (New Zealand Ministry of Education 2021d) in which five “technological areas” are defined: designing and developing material outcomes, designing and developing processed outcomes, design and visual communication, designing and developing digital outcomes, and computational thinking for digital technologies; the latter two are grouped as “digital technologies.”

Although all schools were “expected” to offer the new content by 2020, its introduction was hindered by factors described next that made it challenging to engage teachers with the new content.

A more detailed history of these changes can be found in Bell, Andreae, and Lambert (2010); Thompson and Bell (2013); Thompson, Bell, Andreae, and Robins (2013); Bell (2014); Bell, Andreae, and Robins (2014); Fox-Turnbull (2019); and Falloon (2020).

AUSTRALIA

On the fourteenth of October 2014, the Australian government released the Industry Innovation and Competitiveness Agenda (Australian Government 2014) that aimed to strengthen Australia’s competitiveness, with a major announcement being the introduction of the “coding across the curriculum program” to enhance computer programming skills across the curriculum. Until this point, the teaching of computing as a discipline was largely left to tertiary study, with school curricula focused on the use of digital tools for learning and teaching. The AC: DT subject has introduced computing as a specific discipline area, with the effective use of technologies being captured as one of the seven general capabilities across the curriculum within the information and communication technology (ICT) capability (ACARA 2021f). The AC highlights opportunities where ICT capabilities can be used across subjects/learning areas, including for DT. There have been challenges in supporting teachers to understand the distinction between ICT capability and DT, which required targeted messaging in professional learning and resources. Consultation for the ICT capability opened in late April–July 2021 and includes a review of all aspects of the curriculum, including the proposed renaming of the general capability to digital literacy and revision of the learning continuum.

The ACARA is an independent national authority responsible for advice and delivery of the national curriculum, assessment, and reporting for all Australian education ministers, including development of the AC. The development of the AC was inspired by the 2008 Melbourne Declaration of Educational Goals for Young Australians (Ministerial Council on Education, Employment, Training, and Youth Affairs 2008), in which all Australian governments committed to building equity and excellence and for all young Australians to become successful learners, confident and creative individuals, and active and informed citizens. The declaration also called for the need for students to develop ICT skills in response to evolving technologies in society. In 2019, the new Alice Springs (Mparntwe) Education Declaration was approved by ministers of education, highlighting the STEM learning areas that are a key national focus for school education in Australia (Education Services Australia 2019).

The initial "shape of the F–12 AC" was first approved by the Australian Council of Commonwealth and state and territory education ministers in 2009 (ACARA 2021g). The paper reflected the position of the 2008 Melbourne Declaration. The conceptualization and development of the AC: technologies commenced in 2010 and underwent a rigorous consultation and writing process, with the curriculum being endorsed and published in December 2015. Final implementation of the AC: DT was to the responsibility of states and territories, with the support of ACARA.

Following five years of implementation, in 2020, education ministers agreed that it was timely to review the F–10 Australian Curriculum (ACARA 2021h), including broad stakeholder consultation, feedback from state and territory jurisdictions, and research benchmark comparisons against selected international curricula of Singapore, Finland, British Columbia and New Zealand. The review was completed in 2021This brings a critical point for the future of the AC: DT and the direction Australia will take moving forward—whether it be to remain the same or adapt.

TEACHER QUALIFICATION

Teacher capability is a key bottleneck that needs to be addressed to effectively introduce digital technologies as a subject. In New Zealand and Australia, programming and related knowledge were not a part of many teachers' education since it was not in the school curriculum and relatively few teachers had computing degrees.

NEW ZEALAND

In New Zealand, teachers aren't required to have a specific qualification to teach digital technologies and may have come into the subject from a variety of pathways. The traditional "technology" subject in schools grew out of subjects such as woodwork and cooking, which were replaced by areas with names such as "materials technology" and "food technology." This also included "information and communication technology," but ICT teachers often came from a background in teaching typing, and later on office software, so they were more focused on using the computer as a tool.

When DT was introduced to the NCEA qualification in 2011, sources of upskilling for teachers included a series of "CS4HS" (computer science for high school) workshops run by universities. CS4HS was supported by Google, Inc. and grew out of an outreach program in the US (Blum and Cortina 2007) that seeded many opportunities for teacher professional development in Australasia (Thompson and Bell 2013). Grassroots support arose quickly in the form of a professional teachers' association, originally called the "New Zealand Association of Digital, Information, Technology Teachers" (NZACDITT), which later changed its name to "Digital Technologies Teachers Aotearoa" (DTTA). Through this group, teachers supported each other to work with the new curriculum, and later this turned out to be valuable because it provided a voice and support for teachers when the DT curriculum content was being extended for more junior classes.

After the full (year 1 to 13) curriculum was introduced, the government announced a raft of initiatives to help teachers and schools grow their capacity in DT, including "$24 million of new money toward additional professional learning and development for teachers" (New Zealand Government 2017). A large initiative that this funded was the "Kia Takatū ā-Matihiko" (te reo Māori, which roughly translates to "Be Ready for Digital Technologies") project (New Zealand Ministry of Education 2021e), a three-year government-funded multiorganization project to provide a large range of professional development for teachers, including a self-review tool, an online community, curation of teaching resources, online training, and in-person meetups as well as programs supported by other organizations such as "Code Club for Teachers" (Code Club 2021) and events run through The Museum of New Zealand—Te Papa Tongarewa. The Kia Takatū ā-Matihiko program was bicultural, providing teacher support and resources in both English and te reo Māori, for both the digital technologies and hangarau matihiko curricula content. The government also funded related initiatives, including professional development providers to work in schools, which the schools could apply for, and a national competition called "123Tech" (ITP NZ 2021) for students. These initiatives reached many teachers, although a final analysis is yet to be reported.

Two factors interfered with these 2018 to 2020 initiatives. In 2019 there was considerable industrial action from teachers and then from principals, and because the initiatives often did not fund time out of school for teachers, it was difficult to expect them to participate fully. Then, in 2020, the Covid-19 pandemic meant that teachers were working under heavy workloads to implement distance teaching for their students, which again reduced their availability to participate. One positive effect of the pandemic was that professional development programs also went online, and this meant they could reach teachers in distant communities who may not have participated otherwise.

Starting from an indigenous framework enabled an equitable, accessible, and bicultural approach as the basis of the initiatives described previously, but two programs that specifically addressed equity issues during the rollout of the new curriculum were "Raranga Matihiko | Weaving Digital Futures" (Museum of New Zealand—Te Papa Tongarewa 2021) and "Digital Ignition | Māpura Matihiko" (Digital Ignition 2021), which were designed to be accessible for schools so that distance and resourcing issues could be overcome to enable students to engage with the new curriculum content. Raranga Matihiko ended up running a home-learning TV show when schools were closed due to Covid-19.

AUSTRALIA

There are 149,462 primary and 138,832 secondary full-time or equivalent teachers across 9,503 schools in Australia (ACARA 2021i). As in New Zealand, Australian primary school teachers are generalists, required to teach across all learning areas without subject qualifications; as a consequence, pre-service primary teacher programs are expected to cover all learning areas broadly. High school teachers do not need specialist qualifications to teach a subject, but some may have chosen to major in technologies (design and technologies and/or digital technologies). Some schools may have "specialist" teachers dedicated to that subject area and responsible for teaching that subject in all classes.

Most early efforts to introduce computing into schools prior to the launch of the AC: DT was via outreach efforts from universities and industry keen to engage more young people in computing study and career pathways. University outreach has been primarily led by CS departments, and like New Zealand, some of these efforts have also been supported through the CS4HS funding program offered by Google Australia, now called Educator PD grants (Google for Education 2021). Since 2011, Google's program has supported 188 grants to sixty-six organizations delivering CS PD to primary, secondary, and pre-service educators across Australia and New Zealand.

Coinciding with the AC: DT release, on 7 December 2015, the Australian government announced its National Innovation and Science Agenda (NISA), committing $1.1 billion over four years to twenty-four measures across research, innovation, and entrepreneurship, including $84 million toward inspiring Australian students in digital literacy and STEM from 2016–2019 (Australian Government Department of Industry, Science, Energy and Resources 2015) across fifteen initiatives. On 11 December 2015, the Australian Education Council endorsed the National STEM School Education Strategy 2016–2026, further bolstering this initiative. School initiatives from 2016–2020 that focused on equipping school students to create and use DT included:

- The University of Adelaide (UoA) DT Massive Open Online Course (MOOC) program—Providing online professional learning for teachers on implementing the AC: DT with professional learning support via project officers and a free digital technology lending library for schools (The University of Adelaide 2021), with a specific focus on supporting students from low socioeconomics schools (SES), remote and regional schools, in addition to schools with high Indigenous student enrollments.

- Digital Technologies in Focus (DTiF) delivered by ACARA—A team of DT educators working with school leaders of around 160 disadvantaged schools to drive change in their schools through face-to-face workshops, webinars, and online mentoring.
- STEM Professionals in Schools by CSIRO—A program brokering flexible partnerships between STEM professionals and schools.
- Digital Literacy School Grants—A funding scheme for schools to pitch and implement their own innovative DT projects.
- Australian DT Challenges by the Australian Computing Academy (ACA) at the University of Sydney—An online series of structured, progressive teaching and learning activities and challenges for years 3 to 8 students and professional learning workshops for teachers, coding activities, and challenges for years 3 to 12 students.
- digIT summer schools (Australian Mathematics Trust)—Intensive camps and mentoring to target students at risk of not benefiting from the AC: DT to engage them in ICT and future careers.
- A Digital Technologies Hub (Education Services Australia 2021) was launched in 2016 that continues to operate. The Hub is an online learning resource that supports the implementation of the AC: DT with support for schools, families, and students.

The majority of this funding came to an end in 2020, with new funding initiatives for STEM in early learning and schools announced in the 2020–2021 budget (Australian Curriculum 2020) ($40.6 million). In relation to DT, this initiative supports artificial intelligence in schools (e.g., through lending library equipment from the University of Adelaide and the expansion of the Digital Technologies Hub), and the extension of the CSIRO STEM Professionals in Schools program.

Australia has had a very collaborative stakeholder ecosystem working with a common goal to support teachers and students with the AC: DT. This has been encouraged through linkages in the NISA initiatives, national and local DT association conferences and events, and networking fostered through Google Australia's annual Partner Summit in which they bring industry, education, and academic institutions working in the DT space across New Zealand and Australia together to attend workshops, hear updates, and build networks.

There were 30,585 primary and 24,976 secondary (ACARA 2021j) pre-service teachers enrolled to study teaching in 2019. Early research found pre-service teachers were ill prepared to teach CT and required pedagogical strategies, experience with relevant technologies, and a better understanding of how computers work and what CT means (Bower and Falkner 2015). Some pre-service teacher programs include DT but (as is the case in New Zealand) this is not explicitly mandated yet, nor has there been a consistent national approach to embedding DT within teacher education programs. In recognizing that a pipeline of new teachers entering classrooms also needed support, initiatives such as Google's CS4HS and CSER (Computer Science Education Research Group) DT Education program provided support to interested universities through workshops and resources.

INTENTIONS

NEW ZEALAND

As described earlier, the part of the NZC relating to digital technologies is two series of "progress outcomes" (POs) (New Zealand Ministry of Education 2021c) that cover "designing and developing digital outcomes" (DDDO) and "computational thinking for digital technologies" (CTDT), respectively. For each of these two series, the final three POs correspond to the three levels of the NCEA qualification, which students typically complete in years 11 to 13 of their schooling.

The series of POs that correspond to computer science are the eight POs for "computational thinking for digital technologies" (CTDT). The (POs) are essentially cumulative, and the PO corresponding to what typical year 10 students are likely to encounter corresponds to what most students should get to during their secondary school education (typically by year 10). In CTDT, this is PO 5, which is:

> In authentic contexts and taking account of end-users, students independently decompose problems into algorithms. They use these algorithms to create programs with inputs, outputs, sequence, selection using comparative and logical

operators and variables of different data types, and iteration. They determine when to use different types of control structures.

Students document their programs, using an organised approach for testing and debugging. They understand how computers store more complex types of data using binary digits, and they develop programs considering human-computer interaction (HCI) heuristics.

CTDT POs 1 to 5 gradually introduce sequence, input, selection, and iteration so that by PO 5 students are accessing the full power of computation. In addition, evaluating interfaces (and a focus on the end-user) and the representation of data are introduced, as well as the idea that there can be multiple algorithms to solve a particular problem.

There are six POs for DDDO that are focused on digital tools to design a range of "outcomes" (which could be a 3D-printed object, a website, poster, video, or anything where skill with a digital tool is central to the design and production process). There is a focus on the stakeholders for which the outcome is being produced, including ethical and social considerations (such as privacy). The outcomes expect increasing independence from students to select and apply tools. The DDDO PO corresponding to what most secondary students are expected to encounter is PO3 (see New Zealand Ministry of Education 2021c).

Beyond year 10, students typically start to specialize in subjects, and the curriculum offers the opportunity to delve deeper into computing topics. This structure is discussed in the following section under "Examination/Certification."

AUSTRALIA

The AC: DT presents content descriptions across bands from F–10 (F–2, 3–4, 5–6, 7–8, and 9–10). The content advises what students should be learning, and achievement standards describe what students should achieve by the end of that year level band, which we discuss next (ACARA 2021k). As mentioned previously, the AC: DT includes two overarching key strands similar to New Zealand's DDDO and CTDT technological areas (see figure 5.1). Knowledge and understanding contains ten content descriptions that address underpinning disciplinary knowledge of information systems, including digital systems—covering the components of digital systems: hardware, software, and networks and their use—and representation of data, including how data are represented and structured symbolically. To demonstrate the growth in complexity of knowledge and understanding required,

> By the end of Year 2 [the first band], students identify how common digital systems (hardware and software) are used to meet specific purposes. They use digital systems to represent simple patterns in data in different ways (ACARA 2021k).

Disciplinary knowledge deepens and “by the end of Year 10 students explain the control and management of networked digital systems and the security implications of the interaction between hardware, software and users. They explain simple data compression, and why content data are separated from presentation.”

Processes and production skills contains thirty-three content descriptions relating to the development of skills to create digital solutions to problems and opportunities. These specifically address collecting, managing, and analyzing data and the creation of digital solutions by investigating and defining, generating, and designing, producing and implementing, evaluating, and collaborating and managing projects. Implicitly, the curriculum requires the application of CT skills. In this strand, by the end of year 2,

> students design solutions to simple problems using a sequence of steps and decisions. They collect familiar data and display them to convey meaning. They create and organise ideas and information using information systems, and share information in safe online environments. (ACARA 2021k)

As programming is not explicitly mentioned in F–2, understanding of algorithms can be achieved with students engaging in algorithms with unplugged (e.g., the familiar “jam sandwich” activity), or plugged-in activities (e.g., a junior programming app or robotic device). From years 3 to 4 the curriculum prescribes the use of visual programming environments, involving branching (decisions) and user input, with iteration being introduced from years 5 to 6. From years 7 to 8 students are required to use general-purpose programming languages, using branching, iteration, and functions. In years 9 to 10, students move on to object-oriented programming languages by applying selected algorithms and data structures (this is in contrast to New Zealand, where object-oriented programming is not expected until year 13). This strand also includes content descriptions relating to the collection and visualization of data, intersecting with mathematics. As we move along the bands, students' digital solutions grow in complexity and by the end of year 10,

> students plan and manage digital projects using an iterative approach. They define and decompose complex problems in terms of functional and non-functional requirements. Students design and evaluate user experiences and algorithms. They design and implement modular programs, including an object-oriented program, using algorithms and data structures involving modular functions that reflect the relationships of real-world data and data entities. They take account of privacy and security requirements when selecting and validating data. Students test and predict results and implement digital solutions. They evaluate information systems and their solutions in terms of risk, sustainability and potential for innovation and enterprise. They share and collaborate online, establishing protocols for the use, transmission and maintenance of data and projects. (ACARA 2021k)

A number of key concepts and key elements of CT underpin the AC: DT, providing a framework for knowledge and practice and for approaching problems. ACARA identifies these as: abstraction, data collection, data representation, data interpretation, specification, algorithms, implementation, digital systems, interactions, and impacts.

EXAMINATION/CERTIFICATION

NEW ZEALAND

Formal examination for most New Zealand students starts at year 11, and the majority of students will study for NCEA (New Zealand Qualifications Authority 2021), which is a national qualification. The NCEA qualification in DT is assessed primarily through a collection of "achievement standards." A single subject for a year is typically assessed by combining several of these standards. For example, in DT there are (at the time of writing) eleven achievement standards available at "level 1" (typically year 11 students), covering topics such as "develop a proposal for a digital outcome," "develop a design for a digital outcome," "develop a computer program," and "demonstrate understanding of searching and sorting algorithms." These standards are worth between three and six credits (one credit corresponds to approximately ten hours of student work), and a typical school course would be assessed using around eighteen to twenty credits. This means that a DT course in a school would usually access fewer than half of the standards, and while there are some rules about combining them, this gives a lot of flexibility to the school to use combinations of these standards to offer courses that focus on areas as varied as web design, programming, and computer science, or designing and developing 3D-printed objects. Students within a class might even focus on different tools and technology, so the curriculum provides a lot of flexibility to adjust for local interests. For employers and tertiary organizations looking at qualifications, they will typically focus on the combination of achievement standards that a student has, rather than the name of the courses they have taken. For example, one student may have done a lot of programming and computer science in their DT classes, while another may have had a strong focus on designing and developing products in particular media.

This vast range of choices for students can be problematic since so many pathways are possible, and there can be a lot of decisions for a student to make. A “review of achievement standards” (RAS) was started in 2018, with a view to having revised standards fully implemented by 2025 (New Zealand Ministry of Education 2021f). This includes moving to fewer, larger standards with a simpler structure and clearer pathways for learners. The curriculum (i.e., the progress outcomes described earlier) is not changing, but the way it is assessed will be changed, which is likely to be reflected in less fragmentation of students’ coverage of the curriculum.

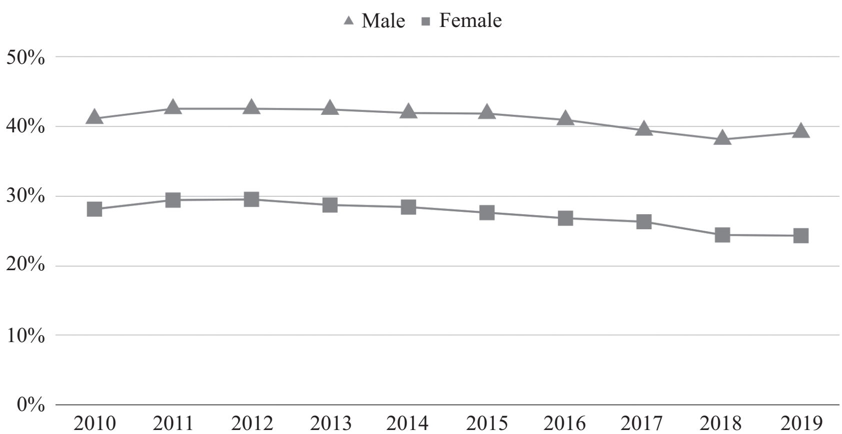
AUSTRALIA

Australia has final year examinations (year 11 and 12), but this is not captured in the Australian Curriculum, as it is up to the states/territories to develop and assess. States and territories vary in what year 11 and 12 subjects offer, and schools can vary within states and territories. For example, Victoria offers “algorithmics” (algorithmic problem-solving) and “applied computing” (involving data analytics and software engineering) under their digital technologies offerings with some also in a vocational education and training (VET) pathway (Victorian Curriculum and Assessment Authority 2021). Western Australia offers computer science, covering databases, systems, programming, and networks, as well as applied information technology, including the application of hardware and software to create solutions (Government of Western Australia 2021).

Queensland offers digital solutions, covering algorithms, computer languages, user interfaces, and generating solutions as well as ICT covering hardware, software, and ICT in society (Queensland Curriculum and Assessment Authority 2021). The differences in language, depth of CS disciplinary content, and offerings across the eight Australian states and territories make it difficult to ensure that students have access to the same CS opportunities following their F–10 curriculum and also make it difficult to measure the CS pipeline.

In terms of uptake of DT in schools in senior secondary years, the Australian government Department of Education Skills and Employment (DESE) data, available on the ACARA website, shows that in 2019, 31.5 percent (39.1 percent males, 24.3 percent females) elected to study ICT and design and technology in year 12 (figure 5.4). These are two distinct subject areas and reporting them together is problematic for monitoring DT uptake. Despite the introduction of the AC: DT and supporting initiatives, we are yet to see this translate to students' uptake of DT in senior secondary years. This could be due in part to the lack of years 11 to 12 DT in the AC, causing inconsistencies in the way states and territories implement within these years.

The National Assessment Program—Literacy and Numeracy (NAPLAN) is an annual national assessment for all students in years 3, 5, 7, and 9. All



5.4 Percentage of students enrolled in information and communication technology and design and technology by year (based on ACARA 2021l).

students in these year levels are expected to participate in tests in reading, writing, language conventions (spelling, grammar, and punctuation), and numeracy. Additionally, the National Assessment Program—Information and Communication Technology Literacy (NAP–ICTL), which commenced in 2005, measures achievement in ICT literacy. It involves the assessment of samples from students in year 6 and year 10 in schools via purpose-built software applications carefully designed to reflect "real-world" ICT contexts familiar to students (e.g., using the Internet for research and designing a digital poster). In 2017, the NAP–ICT Literacy Assessment Framework was revised to describe and represent its relationship to the AC: ICT Capability and AC: DT (see page 4 in ACARA 2018). DT links include those relating to managing and operating digital systems; accessing, evaluating, and analyzing data and information; creating with digital systems; collaborating and communicating; and using digital systems appropriately. The results of the 2017 NAP–ICTL report showed that, in comparison to the previous test in 2014, the results were stable and female students were outperforming male students (ACARA 2018).

EXTRACURRICULAR ACTIVITIES

Extracurricular activities such as coding clubs and robotics competitions are important to develop a pathway for students who want to pursue their interest in DT beyond the opportunities in their school. Prior to the introduction of digital technologies as an area in the curriculum, these were often the only outlet for students to explore these skills with like-minded peers. With many programs existing prior to curriculum efforts, primarily with the aim of building a diverse pipeline of prospective students and addressing gender equity concerns within industry, in many cases this provided readymade support for schools to explore this new curriculum effort, with an inherent focus on equity, diversity, and inclusion.

NEW ZEALAND

New Zealand has several robotics groups and competitions; most were operating from before the curriculum was introduced and are still thriving. These include Robocup Junior (Robocup Junior New Zealand 2021), which is based on challenges in specific contexts, such as playing a simple sports game; FIRST Lego League (FIRST New Zealand 2021); and Vex Robotics (Kiwibots 2021).

Several other national competitions also operate. The "123Tech" challenge (ITP NZ 2021) provides a range of competitions for students of all ages and is run by IT Professionals New Zealand (a national industry organization). Junior students have challenges involving CS Unplugged activities (Bell and Vahrenhold 2018), while senior students compete around designing applications. An annual final event with prizes provides an incentive for students to engage with digital technologies. New Zealand also has programming competitions, with the New Zealand Olympiad in Informatics (New Zealand Olympiad in Informatics 2021) as a springboard for school students to compete in the International Olympiad in Informatics (IOI). In an addition, an event called "Programming Challenge for Girls" (PC4G) has been run in main centers, giving year 10 girls an opportunity to learn programming and demonstrate their skill; this has led to the students finding their passion in programming and carrying on a digital technologies pathway. Another international competition that is gaining traction in NZ is the Bebras challenge.

AUSTRALIA

There are a growing number of extracurricular opportunities for students in Australia, including many that were established prior to the AC: DT with a focus on increasing equity and participating in computing, and a number of new programs supporting curriculum changes. Broadly, there are 496 activities for "robotics" and "technology and design" published on the STAR portal for students at the time of writing (Australian Government 2021), and sixteen competitions and nine challenges are listed on the Digital Technologies Hub. Code Clubs Australia, Bebras Australia, the Hour of Code, TechGirls Movement, FIRST Robotics, and NCSS Challenge have all been popular national activities. A number of extracurricular providers have started to map their programs to the AC: DT, which has supported schools to engage and align their extracurricular activities both inside and outside of the classroom with the intended curriculum. We discuss some examples in the following paragraphs.

The Grok Learning team have been running coding competitions for more than twelve years though the NCSS Challenge, a programming competition open to all school students and teachers. The NCSS Challenge is for school students from upper primary to all levels of high school with content aligned to the AC: DT for years 5 to 10, and streams to match a variety of student abilities. NCSS operates on a small fee per student that provides access to online coding tutorials, access to instructor support, and entry to the competition; it includes free access for teachers (pre-service and in-service). Participants compete against students from Australia and New Zealand and earn points to climb the leaderboard.

FIRST Australia is a program based on the original successful international robotics program (FIRST Australia 2021). It provides school students with a suite of competitions targeting different age groups from four to sixteen years of age, aimed at inspiring a passion for STEM through robotics challenges and competitions.

The annual "Search for the Next Tech Girl Superhero" competition aims to increase girls' participation in technology careers and engages up to one thousand Australia and New Zealand students per year with a total of over ten thousand girls since 2014. This competition, in which girls design, pitch, and prototype an app solution, is for ages between seven and seventeen. It connects girls to mentors as they work in teams. Most teams meet at schools and are facilitated by school teachers. In some cases, parents and other community leaders step up to facilitate teams. While mentorship competitions are having a positive impact, they do rely on volunteer mentors with the confidence to support a team; however, the program has also mapped to the AC: DT supporting teachers to integrate participation with school programs. Curious Minds, funded through the Australian government, is an example of a broader STEM program that operates with a similar mentorship process in which girls in years 9 to 10 attend two camps and work with their mentors on a project (Australian Science Innovations 2021).

Bebras is an international initiative, with some sixty countries and over 2.9 million students worldwide, that promotes informatics and computational thinking among students. Bebras, meaning "beaver" in Lithuanian, was started in 2004 by Professor Valentina Dagiene. Bebras Australia launched in 2014 and is now administered through CSIRO Digital Careers, taking place March and August–September each year. Students can participate individually or in teams (up to four people) on any day during a two-week period, providing flexibility for school schedules. The challenge is broken up into five age groups across years 3 to 12, with forty-five to sixty minutes for students to complete. Each challenge features fifteen CT questions to solve.

There are not many student-facing Aboriginal and Torres Strait Islander programs specifically in DT. However, one recent example is that in 2014, Indigital launched Australia's first Indigenous edu-tech company with a focus on training in digital technologies with a cultural lens (Indigital 2019). Indigital began "Indigital Schools" in early 2020, a student-facing program that enables Indigenous and non-Indigenous primary and high school students to "connect with and learn from Indigenous Elders about cultural knowledge, history, and language while learning digital skills" in technologies like augmented reality, animation, and coding.

MEDIA AND TEACHING RESOURCES

To deliver the new curriculum material effectively, good teaching resources are needed for teachers to use in the classroom. Most resources supporting the changes in Australia and New Zealand are online, although some books have been published that match the Australian DT curriculum.

In both countries, schools are not given required texts to use, so teachers are free to use whatever resources they consider suitable. This also means that the costs of such resources come from school budgets, and buying class sets or subscriptions to online systems can be a challenge for some schools where resources are spread thin, so free online resources are particularly welcome.

NEW ZEALAND

The official online repository of resources to support New Zealand schools is Te Kete Ipurangi (TKI), which means "the online knowledge basket" (New Zealand Ministry of Education 2021g). It is an initiative of the Ministry of Education and includes the curricula, guidance for teachers, and many teaching resources. There is an area dedicated to the technology learning area (New Zealand Ministry of Education 2021h) and within that, support for DT. Everything posted on the site goes through a quality assurance process.

When computer science topics appeared in NCEA standards in 2011, there was little supporting media for teaching these at the right level. For example, a teacher might be having to cover "formal languages" as a subject for the first time. It was unlikely that they had access to books on the subject, and if they searched online, they would either find lecture notes that quickly went to a depth way beyond the expectation of the standard or might be directed to explanations on formal *natural* language, such as business letters and sermons (Munasinghe, Bell, and Robins 2021). To address this issue, the "Computer Science Field Guide" (CSFG) was created at the University of Canterbury as an open educational resource that could be quickly updated to reflect the needs of schools (Bell, Duncan, Jarman, and Newton 2014). The title comes from Peter Denning, who envisaged a kind of handbook that school students could use for learning about computer science, particularly topics other than learning to program (for which many resources are available). The chapters in the CSFG primarily correspond to topics that appear in the New Zealand NCEA standards.

Other online resources to specifically support aspects of the curriculum have also appeared, including CodeAvengers (CodeAvengers 2021) and "STEM Online NZ" (University of Auckland 2021), which offer online lessons to match particular DT topics.

For teaching programming, there are many resources available internationally, although they often do not fit well with New Zealand culture (including simple issues like summer starting in December, the color of school buses, or the use of idioms), which means New Zealand students would not see themselves in the situations depicted in such material. Thus, New Zealand–based initiatives have also arisen around students learning programming, such as CodeAvengers (CodeAvengers 2021) and Gamefroot (Gamefroot 2021).

The DTTA teachers' association, which was created to support teachers involved in the DT curriculum change, was also an important source of resources. The association runs an online forum where teachers share resources, including those that they have generated themselves. The archives of this list became a valuable, even if difficult to search, repository of information. More recently, the DTTA supported the creation of the "DTHM4Kaiako" site (DTHM for kaiako 2021), which is intended to capture and index popular resources. The DTTA also piloted a lending library where teachers can temporarily borrow class sets of devices such as robots or micro:bits to try them out for a term before buying their own sets. In addition to the DTTA, TENZ (Technology Education New Zealand) is a professional association that supports teachers in the whole technology area.

AUSTRALIA

Prior to the launch of the AC: DT, a review of F–10 DT resources (Falkner and Vivian 2015) revealed that limited resources existed to support teachers in implementing the F–10 AC: DT. Many teachers have utilized familiar CS education software, digital technology, and lesson plans such as CS Unplugged (Bell and Vahrenhold 2018), Python tutorials, Code.org, Bee-Bots, and Scratch by MIT. As new technologies have emerged to support younger audiences, schools have embraced these; however, many schools rediscovered technology such as Bee-Bots sitting in their cupboards from prior to the introduction of AC: DT. Australia is a country with extremely remote schools and vast differences in resource availability. Teachers value initiatives and resources that present "unplugged" approaches for teaching CT and CS in situations in which computers and DT equipment are not readily accessible.

The Digital Technologies Hub (Education Services Australia 2021), funded through the Australian government, is a national platform for resources and support for the AC: DT learning resources and services for teachers, students, school leaders, and parents and is known as the place to go for DT resources and support with programs and curriculum in schools. The Hub also curates high-quality events and activities offered by education jurisdictions, industry, and other providers. Over the years, the Hub has expanded to provide additional support in specific areas as AC implementation and teacher needs have evolved, for example, assessment resources, inclusive DT education, and emerging topics such as AI. The site includes support for families and students. Having support for families is particularly important and shows recognition of the important role that families play in shaping students' attitudes as well as influencing what schools offer.

With NISA funding, the Computer Science Education Research Group (CSER) at The University of Adelaide in 2016 expanded their initial industry-funded F–6 DT MOOC with 5,727 teacher enrollments to an expanded ecosystem of program support for teachers in schools (Falkner, Vivian, and Williams 2018). The program included a series of community-centric MOOCs for teachers that break down the AC: DT curriculum, concepts, and class activities with connections to high-quality programs and resources; a free national digital technology lending library enabling schools access to DT equipment; and free professional learning workshops delivered by project officers across the country (The University of Adelaide 2021). In partnership with Google Australia, CSER launched a PL-in-a-Box program to support grassroots uptake of our MOOCs with readymade workshop packs. A team of project officers driving MOOC engagement and school access to free DT equipment, with priority to target schools (rural, disadvantaged, and schools with high Aboriginal and Torres Strait Islander enrollments), has been critical to engaging schools that need support the most and has been demonstrated with significant increases in target school participation, from 14.7 percent with a MOOC alone to 30.4 percent with additional support. Since 2014, the program has evolved to include eight MOOCs covering cutting-edge areas, such as cybersecurity and artificial intelligence, with industry and government support. In a government-commissioned evaluation of all NISA early learning and school STEM initiatives (Dandolo Partners 2020), the program was cited as a "stand-out NISA initiative" and "stakeholders interviewed consistently report positive feedback about MOOCs, in particular its ability to translate digital technologies concepts . . . MOOCs is widely credited as making a significant difference in teachers' understanding of digital technologies." The CSER MOOCs and PL-in-a-Box model, in combination with a national Hub of resources, has become a blueprint for the rollout of a government-funded national program for mathematics and numeracy education. During the NISA 2016–2020 period, CSER worked with over 38,000 teachers across Australia, including 11,300 teachers from priority schools. Project officer and lending library funding came to an end in December 2020, with the exception of an extension for a number of AR and VR kits until 2022 under an AI in schools initiative. The MOOCs and associated resources are creative commons open source and remain freely available.

The Australian Computing Academy (ACA) at the University of Sydney was formed with Australian government NISA funding to develop a series of online free coding challenges and resources for students in years 3 to 8 (Australian Computing Academy 2021) extending the work of the NCSS challenges by Grok Learning. ACA used the existing Grok Learning platform, an education start-up from the University of Sydney that operated a subscription model for coding challenges. After government funding ended, ACA and Grok Learning merged to form the Grok Academy, a not-for-profit organization providing online DT resources. As ACA's DT Challenges were funded by the Australian government until the end of 2020, from 2021 onward, the DT coding challenges and any new content developed require a paid Grok Academy subscription. The ACA's unplugged activities that were developed with government funding (e.g., DT@home, Unpacking the Curriculum guide, and webinar recordings) remain free on their website. With recent interest and focus from the government, ACA has also developed a Schools Cyber Security Challenges series for years 5–12 in partnership with AustCyber and Australian industry partners. This is currently free for Australian schools.

As the majority of government funding has come to an end for a number of NISA programs supporting AC: DT rollout, those projects are now navigating how to move forward in a sustainable way so they can continue to support schools with free resources and programs.

Besides government funding, there are some other broader STEM initiatives that support AC: DT in schools, such as Refraction Media's Careers with STEM platform (Refraction Media 2021) that includes digital magazines and articles covering careers with code and special editions such as cybersecurity and data science. They are funded by industry, print subscriptions, and an advertizing model. These magazines have been popular for advocating career awareness and are sent to schools across Australia, reaching 750,000 students annually in person, print, and online. With the success of Careers with STEM, they have expanded to new international audiences, including New Zealand and the United States of America.

While some of the NISA initiatives have had a focus on prioritizing support for schools with high Aboriginal and Torres Strait Islander student enrollments and some resource development, such as ACARA's DTiF classroom ideas and worked examples (ACARA 2021m), many of the current initiatives teach primarily Western views of DT, and more work is required to support teachers to integrate DT with Aboriginal and Torres

Strait Islander peoples, cultures, and histories. Examples of programs leading in this space include the Stronger Smarter Institute (SSI) partners with schools across Australia to embrace their pedagogical framework centered around honoring a positive sense of Aboriginal and Torres Strait Islander cultural identity and positive community leadership (Stronger Smarter Institute 2017). A number of new elaborations have been developed in the proposed revised curriculum to further support the cross-curriculum priorities. The AC: DT elaborations provide a reference point for ideas, but investment in teacher professional learning and resources is required.

There are a number of computing associations across Australia that provide networking and professional development for teachers, including the national Australian Council for Computers in Education (ACCE) and local state and territory technology associations for teachers (e.g., ICTENSW, TASITE, EdTechSA, INTEACT, QSITE, and DLTV). Prior to the AC: DT these associations focused on using ICT; however, with the introduction of new computing curriculum, they have expanded their focus to include DT.

CURRICULUM ISSUES

Introducing a new curriculum in school systems where many of the staff have not had the subject as part of their own education is always a challenge. As well as the usual confusion around the term "digital technologies" being about "using ICT" rather than developing systems, there is the issue of fitting the material into an already crowded curriculum.

Of interest in this situation is the "enacted" curriculum—what actually happens in schools compared with the intended curriculum. For example, in Australia a pilot study (Falkner et al. 2019b) found that the most enacted part of the DT curriculum was the design process (reported by 86 percent of teachers); 79 percent reported teaching programming skills and concepts, 57 percent had taught data representation (e.g., digital data, binary), and only 29 percent enacted DT ethics. On the other hand, topics that were *not* specified in the curriculum were also enacted, including robotics (79 percent). These differences could be explained by the availability of professional learning as well as an emphasis on "concepts that teachers find are useful or relevant to include or link to within the intended curriculum" (Falkner et al. 2019b). The low level of engagement with ethics could be improved by offering more structured support for teachers to consider ethical issues through appropriate lenses and at a level of technical depth. Any move in this direction should also be wary of detracting from the technical aspects of a topic, as teachers who are still developing their understanding of advanced topics may be tempted to spend *too much* time looking at ethics instead of the technical considerations of a topic. As an example of keeping this balance, there would be value in looking at specific algorithms or data encryption techniques and their implications for individuals and law enforcement rather than just having a general discussion on whether technology is good or bad.

In New Zealand, some data is available through two Education Review Office (ERO) reports. The first is a July 2019 report titled "It's Early Days for the New Digital Technologies Curriculum" (New Zealand Education Review Office 2021a), which used data collected in September 2018, along with case studies in early 2019. This report notes that "the assumption that teachers are digitally fluent as they participate in the support for the DT curriculum content does not hold" and that "only seven percent [of schools] said their teachers sufficiently understood the DT curriculum content and its place in the NZC and had enough knowledge and skills to implement the DT curriculum content." The second ERO report (New Zealand Education Review Office 2021b), from January 2020, focuses on three stages that schools were at: "On Your Marks" (e.g., very early stages of unpacking the DT curriculum content), "Get Set" (e.g., DT curriculum content most likely delivered in a club, specialist classes or subject specific setting), and "Go!" (e.g., in the process of rolling out DT curriculum content across all year levels). The report does not give statistics on how many schools were in these different stages, but it provides examples of what these stages looked like across a range of criteria, such as school leadership engagement, curriculum integration with other learning areas, and professional development content.

New Zealand and Australia have adopted two different approaches to an inclusive curriculum for First Nations peoples. Australia has included Aboriginal and Torres Strait Islander peoples, cultures, and histories throughout the AC, whereas New Zealand provides a model for how a country can operate a school system under two curricula: the "New Zealand Curriculum" (NZC) for English medium instruction, and Te Marautanga o Aotearoa (TMoA) for Māori medium instruction (New Zealand Ministry of Education 2021a). New Zealand has also invested in programs supporting Māori education with DT, such as the bicultural Kia Takatū ā-Matihiko program, providing teacher support and resources in both English and te reo Māori for DT. Australia has provided targeted support to schools with high Torres Strait Islander enrollments.

While the changes to the curriculum are important, considerable resourcing is needed to support teachers and schools to make the change, and while a good start has been made in both countries, there is still a lot of work to be done to have the subject fully available as intended for students and to upskill the vast number of teachers. Additionally, support for new emerging areas of DT, such as cybersecurity and artificial intelligence, bring new opportunities and will require professional learning and resourcing to evolve.

CONCLUSION

Both New Zealand and Australia have strong curricula for introducing all school students to digital technologies as a discipline, including elements of computational thinking, particularly computer programming. Although good progress has been made implementing this in schools, there is a long way to go as the subject becomes normalized in the curriculum, it is understood properly by school management, and teachers develop the professional skills to deliver the curriculum as intended. Additionally, Australia has reached a point where the AC: DT is now undergoing a curriculum review, which will determine what the intended DT will look like for classrooms for the near future and possibly any further strategic directions for implementation. Following initial bursts of funding and efforts to support new computing curriculum rollout, there is a challenge to establish sustainable models of accessible and equitable support for schools and for teachers to engage with the intended curriculum. Ongoing research will play a critical role in monitoring the intended curriculum as prescribed by New Zealand and Australia, and tracking the enacted and assessed curriculum that happens in the classroom will be important in understanding how teachers are embracing these curriculum changes many years after its implementation. Work by Falkner et al. (2019a) to develop the MEasuring TeacheR Enacted Computing Curriculum

(METRECC) instrument to measure the enacted and intended curriculum across several countries may provide a tool for ongoing measurement within and between the two countries.

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