# Literacy for Digital Futures

## Mind, Body, Text

Kathy A. Mills, Len Unsworth, and Laura Scholes

# LITERACY FOR DIGITAL FUTURES

The unprecedented rate of global, technological, and societal change calls for a radical, new understanding of literacy. This book offers a nuanced framework for making sense of literacy by addressing knowledge as contextualised, embodied, multimodal, and digitally mediated.

In today's world of technological breakthroughs, social shifts, and rapid changes to the educational landscape, literacy can no longer be understood through established curriculum and static text structures. To prepare teachers, scholars, and researchers for the digital future, the book is organised around three themes – Mind and Materiality; Body and Senses; and Texts and Digital Semiotics – to shape readers' understanding of literacy. Opening up new interdisciplinary themes, Mills, Unsworth, and Scholes confront emerging issues for next-generation digital literacy practices. The volume helps new and established researchers rethink dynamic changes in the materiality of texts and their implications for the mind and body, and features recommendations for educational and professional practice.

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In memory of Gunther Kress, whose thinking has influenced our work on multimodality.

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# FOREWORD

Literacy is no longer defined as just the ability to read and write in a decontextualised way. It has expanded to include the literacies required for specific school disciplines, trades and professions, the ability to understand and produce digital and non-digital texts that combine a range of modes of expression, and the 'soft skills' needed in contemporary workplaces, such as collaboration, communication, creativity, and problem solving.

In this book, the authors focus especially on literacies with new digital media. Convinced that the future of literacy will be shaped by digital technologies, they set out to map that complex terrain, surveying a wide range of technologies, from interactive graphics, animation software and videogames, to the latest virtual reality and mixed reality technologies, and an equally wide range of educational applications of these technologies, from teaching reading and finding information, to understanding and producing science infographics and story structures.

Digital learning resources are often produced as though they are self-sufficient, as though learning takes place solely through the interaction between child and machine, so that teachers are no longer needed. I remember doing a multimodal analysis of an educational CD-Rom in the late 1990s. As was often the case in that period, the home page was pictorial. It showed a classroom with monitors, computers, and other equipment, and in a corner, seated behind a small table with a vase of flowers, a teacher. All items of equipment could be clicked on, leading to a range of educational journeys. The teacher was the only element in the picture that could not be 'clicked on'. Being a teacher myself, it was a shocking moment. But the authors of this volume are firmly convinced that teachers have a fundamental role to play in helping children develop these new skills with digital media, and this book provides them with information and practical ideas for doing so.

Though often enthusing about the potential of digital technologies, the authors are aware of the risks these new media practices bring. Reading online, for instance, involves a loss of the multi-sensoriality of books – their smell, their tangible materiality, and their solid durability. Although digital technology is becoming more multi-sensorial, even experimenting with smell and taste, it will be important for teachers to do what technology companies cannot do – expose young learners to materials and embodied experiences and practices they might otherwise not encounter.

Online reading also brings many distractions, and can lead to all too speedy, surface-level information processing, standing in the way of 'deep learning'. Teachers can help children avoid this risk by setting tasks such as planning reading pathways and focusing attention. Finding information on the internet also has its risks. Algorithms can create 'echo chambers' where users only find what they already know and believe, rather than encountering other points of view. Teachers can help children to evaluate information sources on the basis of credibility, purpose, authorship, and so on – in short, to develop what the authors call 'epistemic critical literacy'.

The first part of the book draws, to a large extent, on experimental research which links forms of embodiment with positive literacy outcomes – words are better understood and remembered when their meaning is also enacted by bodily movements of one kind or another (e.g. making flying gestures when learning the word 'fly'), or when they are first written by hand. Later in the book, the authors draw on the social semiotic approach to multimodal communication to show, for instance, how, in the science classroom, children can learn to understand and produce effective connections between words and images in infographics, or in the English classroom, learn to understand and implement concepts such as 'characterisation', 'plot development', and 'point of view' by producing short animations.

In short, the book not only provides a wealth of information on available digital technologies and their potential for learning, it also shows teachers how they can help children realise this potential, how they can develop effective learning cycles and criteria for assessing children's work, and how they can make effective use of examples in the classroom.

As the book stresses, digital technologies continue to develop, and this can cause a sense of uncertainty. Questions inevitably remain, and the authors ask some of these, for instance, in the chapter on virtual reality: What existing skills will be relevant and what will become backgrounded or foregrounded, essential or cursory, in the identity performances today and in societies of the future? Who will be inducted into these hybrid assemblages of wearable media first, last, and never, and how often, and to what ends? What multisensory interactions, modes, bodies, and cultural content will be privileged in these virtual practices that are generated by technology developers in the entertainment and 'edutainment' industries?

Not all of these questions are, or even can be, answered at this point. But they must be asked and discussed, and this book does so admirably. It should be a great help in getting such questions also asked, and knowledgeably discussed, by teachers and teacher educators in Australia and abroad.

Theo van Leeuwen, January 2022

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# ABBREVIATIONS

| | |
|---|---|
| **AES** | Average Embeddedness Score |
| **AI** | Artificial intelligence |
| **AR** | Augmented reality |
| **CAD** | Computer-aided design |
| **DBR** | Design-based research |
| **DIL** | Digital interactive literature |
| **GPS** | Global Positioning System |
| **HMD** | Head-mounted display |
| **IOT** | Internet of Things |
| **IVR** | Immersive virtual reality |
| **LED** | Light-emitting diode |
| **MOOC** | Massive Open Online Courses |
| **MR** | Mixed reality |
| **NAEP** | National Assessment of Educational Progress |
| **NVR** | Non-immersive visual reality |
| **NZQA** | New Zealand Qualifications Authority |
| **OECD** | Organization for Economic Co-operation and Development |
| **PC** | Personal computer |
| **PIRLS** | Progress in International Reading Literacy Study |
| **PISA** | Programme for International Student Assessment |
| **RFID** | Radio-frequency identification |
| **SAMR** | Substitution, Augmentation, Modification, Redefinition |
| **SFL** | Systemic functional linguistics |
| **SMART** | Self-Monitoring, Analysis, and Reporting Technology |
| **SR;MP** | Skim-read; missed point |
| **STEM** | Science, technology, engineering, and mathematics |

**TL;DR** Too long; didn't read
**URL** Uniform Resource Locator
**VOIP** Voice over Internet Protocol
**VR** Virtual reality
**XR** Extended reality

# 1

# INTRODUCTION: BEYOND EDUCATION FOR INDUSTRY 4.0

## Next-generation literacies

The chapter conceives new possibilities for literacy education predicated on the transformation of a socio-technical revolution, one that has seen the advent of big data, dataveillance, and intense growth of artificial intelligence associated with Industry 4.0 (Australian Council of Learned Academies [ACOLA], 2020; Mills, 2019). There are developments in nanotechnologies moving toward quantum computing (Laucht et al., 2021), while organisations, governments, and markets look to new applications for IoT (Internet of Things), automation, robotics, wearable technologies, and biometrics for access control (Mills, 2019). Amid technological breakthroughs, there are seismic social shifts as the world encounters increasing global security threats, including climate change, terrorism, cyberattacks, bio-threats, and global economic instability.

While neuro-inspired technologies seek to develop implantable human–computer interfaces, like 3D printed bionic ears (Mannoor et al., 2013) and brain–machine interfaces, such as Neuralink (Musk, 2019), the shape of education, literacies, and textual practices will inevitably change. This chapter sets out a rationale for digital media literacies in education and their intrinsic connections to transformed minds, bodies, and texts. It explores the complementary relationships between these three key areas for the development of smart literacies in the volume, as the digitalisation of print and the social practices of reading and writing are redefined. It argues that information and communication technologies are moving beyond mere substitution, augmentation, or even significant modification, to require new forms of literacy curriculum and learning that were previously inconceivable (Puentedura, 2003).

Literacy in schools has conventionally focused on giving students complex, atomistic, and elaborate manuals on how to read and write, while in everyday life and interaction, students are similarly becoming literate by playing the

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game (Gee, 2012). Children and young people are now surrounded by digital literacy practices of a virtual era, where multiple digital screens and devices intersect with books, pens, and paper, while they navigate "idiosyncratic blends of prohibitions around…bullying, privacy, safety, risk, and their …digital footprint" (Luke, et al., 2018, p. 252). Likewise, governments and education systems have been preoccupied with standardised national curricula to regulate what students should think and know, while in a world where knowledge can be instantly searched and found online – along with misrepresentation and 'fake news' – students need to know how to think and act ethically. The influence of digitalisation, algorithm-based media, and the age of machine learning on everyday textual practices is different from times past, at the turn of the century, or even a decade ago.

Educational researchers have known since the 1980s that computers were changing the way we write, word process, program, and learn. Literacy theorists have conjectured since the mid-1990s, as increasingly more households were accessing the internet, that "literacy pedagogy must now account for the burgeoning variety of text forms associated with information and multimedia technologies" (New London Group, 1996, p. 61). At the same time bulletin boards and internet chats, with their radical interactivity and scrolling directionality, were changing earlier book-based notions of front-to-back, page-turning, linear strings of text (Burbules & Callister, 1996; see Chapter 2).

As the 21st century began, we had not yet heard of YouTube, Facebook, Myspace, Twitter, and Skype, while literacy theorists came to terms with features of social media and Web 2.0 (O'Reilly, 2005). The internet became a space where everyday internet users could upload short posts of 140 characters or less. Anyone could now share a video and have a voice amidst the noise of the so-called democratised age of new media, or create multiple online personae curated for different audiences (Mills, 2015; Mills & Chandra, 2011). By the 2010s, advances in mobile devices and applications on smartphones and tablets, and the widespread accessibility of faster internet, meant that literacy practices became ubiquitous, occurring anywhere, anytime (Mills, 2016). Virtual reality platforms also became of interest to consumer markets, providing textual experiences with immersive, 3D stereoscopic vision and motion tracking, and apps that overlay virtual content and information on the real world (Mills, 2022; see Chapter 7).

Now with the unfolding 2020s, artificial intelligence and chatbots are anticipated to transform communication, while algorithm-based media, with their predictive analytics, raise new concerns as data-driven technology curates and creates online content and influences people's behaviour. Machine learning algorithms that influence media consumption often create echo chambers through which users are fed information that is most like their earlier interests (Valtnen et al., 2019). The need for new kinds of critical media literacy combined with technology knowledge is heightened, as behavioural engineering that involves data mining and adaptive media keeps unsuspecting users addicted to apps and social media, able to sway the collective emotions of populations, and influencing election outcomes (Modreanu, 2017; see Chapter 11).

This volume – *Literacy for Digital Futures: Mind, Body, Text* – addresses three vital changes to literacies in digital communication environments that play a role in reconfiguring: (i) new readers and the *mind* (Chapters 2–4); (ii) new writers and the *body* (Chapters 5–7); and (iii) the hybridity and multimodal grammars of *texts* that we interact with in digital spaces (Chapters 8–10).

Part I on reading underscores the new cognitive or mental aspects of online reading including critical and epistemic dimensions, however, the use of 'mind' as a key organiser is about emphasis and distinction, without excluding the role of the body in reading practices.

Likewise, foregrounding the 'body' in Part II of the volume on digital writing is not to deny the role of the mind or abstract thinking in text making. Rather, this section makes a central case for reappraising the role of the body in digital composition, based on the view that cognitive processes of language operate in conjunction with recurring patterns of embodied experience and action in the world.

Part III of the book on 'texts' applies social semiotics to develop a new understanding of image-text relations and multimodal grammars of texts that are now frequently encountered in digital spaces. While the first two sections focus on the mind and body in the practices of reading and text production, the third section focuses on the textual changes and new multimodal grammars associated with the rapid circulation of digital texts. This section introduces systematic accounts of the patterns of representation and interaction that image-text grammars make available in narrative and non-narrative textual formats. It also importantly considers the relations between the makers and viewers of digital texts.

Based on this triadic structure the book has three main aims. First, we respond to the heightened need for frontier approaches to preparing students' minds and abilities to think, focusing on new research on evaluative thinking and the changed materiality of digital and online reading (see Chapter 2). Epistemic shifts are undeniable in the context of a rapid circulation of multimodal texts from varied knowledge sources on the internet. These changes are facilitated by digital information systems and new mobilities that underpin the ubiquitous practices of reading, playing, and tinkering with texts anywhere at any time, and which require the dexterous application of cutting-edge evaluative strategies and reasoning to read digitally across content areas, such as evaluating scientific information presented on the internet. Rarely addressed in new literacies debates, the book engages with the understanding of the skills that children and young people need to adjudicate conflicting digital and multimodal reading sources on social, economic, and scientific concerns, such as climate change, pandemics, and terrorism (see Chapter 3). The rise of video games as immersive digital texts also prompts more careful consideration of the critical thinking skills that successful gamers hone, and the myriad of opportunities for advancing young peoples' decision making. Learning to think in innovative ways, gamers may be better prepared for life beyond school as they develop essential futures-focused knowledge and skills to think in evaluative and creative ways (see Chapter 4).

Second, we suggest novel understandings of literacy practices and knowledge in digital times as significantly contextual and embodied, tied to experiences of the world, feelings, internal states, and bodies (see Chapters 5–7). Digital literacy practices are changing in terms of their materiality, corporeality, and sensoriality, presenting innovative ways of communicating that deconstruct sensory hierarchies that have often emphasised vision over the multiple dimensions of literacy practice. The book attends to unexplored elements of the somatic nature of reading and writing, including the multisensoriality of practices that engage the non-visual senses: touch and movements of the feet (see Chapter 6), and even sound, olfaction, and taste (see Chapter 5) in multimodal, digital, virtual, and material spaces (Mills et al., 2018). The particulars of these changes were previously inconceivable beyond worlds of science fiction, as literacies today can involve, for example, talking to someone remotely from a smartwatch, designing and printing 3D models to explain a concept, or making a mixed media sculpture with an electronic display to tell a message (see, for example, Friend & Mills, 2021).

Third, we extend the knowledge of systematic resources to account for how textual meaning is increasingly multimodal, combining two or more modes in complex and related ways, accelerated by the rise of mass media, multimedia, and the internet. Consider, for example, that coded animations use digital programming languages to compose moving sprites and backgrounds, written words, sound effects, music, narration, moving images, and interactive digital elements (see Chapter 9). Since the mid-1990s, theorists such as the New London Group (1996) have drawn attention to the new grammatical features of texts with global exchanges and movements of hybrid textual forms, while others have pointed to the power held by those who have access to the codes of multiple virtual communities or neo-worlds – the symbolic, iconographic, and dictive flows. Cultural capital belongs to those who can encode and decode these global flows within a surfeit of communication platforms, media, and applications (Featherstone et al., 1995, p. 8), and these multimodal meanings are taking centre stage in education, recreational spaces, global markets, and workplaces. While multimodal grammars have been systematised for some text types, new hybrid grammars have emerged. Part III, Texts and Digital Semiotics, in this volume underscores key digital text types that are becoming prominent in society, with direct application for educators to formulate next-generation school curricula (see Chapters 8–10).

## What are literacies, multimodality, and modes?

In the past, societal and technological changes were undeniably slower, and likewise, the literacies and knowledge that students needed were more stable and predictable, taught through time-honoured texts, curricula, and sources of knowledge. While much of schooling, including its routines and timetables, has remained unchanged, the unprecedented rate of global, technological, and societal change has called for a radical expansion of literacy practices and various kinds of schooling experiences. Newer literacy practices involve distributed and crowdsourced knowledge, new sensorial relations among bodies, minds, and technologies, and genre-blurred, digitally mediated textual practices that require the sophisticated deployment of semiotic resources across evermore complex confluences of modes. These issues are paramount for education systems in which teachers are entering a time of crisis – a time when extraordinarily less of the age-old curriculum and static text structures will survive in any recognisable form.

To appreciate the uses, potentials, or constraints of new technologies for literacy practices, it is important to understand the theoretical context in which literacy practices are conceived and researched. Literacy theorists have argued since the 1990s that conventional views of reading and writing involving the use of written words alone are not adequate to encompass the multimodal array of textual practices available (e.g. Green, 1995; Snyder, 1997). These literacy perspectives have included, but are not limited to, theories of multiliteracies (New London Group, 1996), multimodality or social semiotics (Kress, 2000), New Literacy Studies or socio-cultural literacy perspectives (Gee, 2004; Street, 2003), sensory literacies perspectives (Mills, 2016), and earlier theories that saw literacy and technology as separate disciplines becoming merged together (Bigum & Green, 1993). Each of these perspectives included a move toward understanding 'literacy' as pluralised 'literacies', rather than a single, universal form of literacy (Mills, 2010).

More recent definitions of literacies in digital contexts share an understanding that literacy practices are socially recognised or socially organised and use a symbol system and technologies to encode and disseminate representations (Mills, 2010; Scribner & Cole, 1981). While older technologies of encoding (e.g. quills, slates, pen, pencils, paper, and the printing press) reproduced literacy practices and texts in somewhat predictable ways, recent developments in digital technology – including the advent of the internet, Web 2.0, mobile devices, social media, and Industry 4.0 – have ushered in an era of exponential expansion of hybrid literacies and textual features. Sometimes theorised as computer-mediated discourse (Herring, 2007), digital composition can be seen as influenced by both the medium (technological) and the social situation, and the medium is clearly being radically altered.

A focus on language as situated social practice has made a valuable contribution to the field of literacy research, particularly in terms of recognising the marginalised practices of speech communities, and in understanding the literacy practices of children and youth in informal contexts beyond schooling. This volume seeks to extend this view by attending to the role of embodied human action in conjunction with the materiality of the medium in meaning making, from pens to personal computers, typewriters to tablets, and web to wearables. Some, such as Gourlay (2015), have argued regarding the sociocultural view of literacy practices that "this conceptual framing has fallen short in adequately theorising the role of material objects, in particularly, the material artefacts of literacy, such as papers, pens, keyboards, and mobile devices" (p. 485). Likewise, we seek to recentre the significance of embodied activity and sensorimotor experiences in literacy practices, a dimension which has often seen a "lack of attention" in semiotic theories of multimodality (see Ehret & Hollett, 2014, p. 429).

Also essential to this volume is the concept of 'multimodal literacy' based on social semiotics and Halliday's systemic functional linguistics (Halliday, 1978), which sees language as essentially social and cultural, able to be modified and understood by users based on the situational context. We have previously defined multimodal literacy as "communication practices that involve two or more modes of meaning" a fundamental premise and focus of this volume (Mills & Unsworth, 2017, p. 2). Importantly, 'modes' are defined here following the views of Kress (2017) as culturally shaped resources for making meaning. Examples of modes include speech, writing, drawing, music, and gesture, among many others. The rise of mass media and the internet has contributed to the ease with which users can now read and produce, remix, and share multimodal texts that combine modes, such as written language, still and moving images, and music.

The materiality of meaning making is also significant, because modes, such as written language, can be represented using different culturally specific media, such as on stone, clay, paper, canvas, computer screens, fabric, vinyl, billboards, shoes, toys, food packaging, and bodies (e.g. tattoos). The materiality of signs has an important semiotic function that intersects with modes (Mills & Unsworth, 2017). The choice of materiality of sign-making is influenced by historical and cultural values and uses, and the availability or accessibility of the medium. For example, in the foreword of Mills's (2016) volume, Literacy Theories for the Digital Age, anthropologist David Howes observes that the ancient quippu is a woven system of coloured cords and knots, thought to be a method for calculating and record keeping by the Andean Peoples of South America. In other words, the quippu is an ancient cultural example of a multimodal text. The materiality of meaning making also involves the body in various ways, such as through the physiology of speech and singing, hearing, seeing, touching, smelling, tasting, moving, and so on (Kress, 2017).

## Mind and materiality of reading in a digital age

New forms of embodied cognition are exemplified when readers decode in digital spaces and activate a network of human sensory modalities to facilitate comprehension and understanding. Reading involves much more than just the mind and needs to be understood in relationship to personal bodies and interactions in the environment. In the rapidly escalating digital world, decoding texts to access knowledge is complex and success requires new literacy practices that build on traditional conceptions of multisensory stimulation of vision, olfactory cues, sensations of haptics related to touch, and aesthetic enjoyment as readers move to screens. The materiality of reading experiences shifts in the move from linear print to digital hypertext or non-linear formats with physical effects on how we engage the body and mind (Wolf et al., 2012).

On-screen decoding changes experiences and increases visual sensory demands, while readers who enjoy the multisensory experiences ignited through smelling the paper, ink, and the glue used to make paper books, may miss the grassy notes and the tang of acids or a hint of vanilla over an underlying mustiness (Strlič et al., 2009). And what of the changes to sensory stimulation of a print-based book through touch and proprioception that most certainly takes on a different feel when engaging with an iPad or smartphone interface? The myriad of challenges to sensorial experiences are also made visible when young children need to call on fine motor skills for tapping, swiping, pressing, and navigation around screens.

The 'spatio-temporal' and the 'imaginary' thoughts that are seminal for creating scenarios from what we read are also challenged by decreased and unstable materiality of digital multimodal texts. Such imagery helps readers recall facts, sequence content, retell the story, or retrieve informational scripts from memory. Accessing information on e-readers, smartphones, iPads, and tablets with intuitive navigation of unstable texts challenges mapping the journey in the mind and monitoring personal reading pathways, potentially adding challenge to comprehension of such texts (Barzillai et al., 2018).

Semiotic resources on screens, such as layout, composition, text, image, graphics, and the range of colours, fonts, multimedia elements, animations, and interactive features add excitement and wonder, but also change the experience as readers need to filter information, make choices, and determine their personal pathway in hyperlinked spaces. And what about the continual interruptions and disruptions from popups, alerts, notifications, and hotspots that readers contend with? In this way, reading to make meaning on screens is fundamentally different to comprehension through print modes (Afflerbach & Cho, 2010; Leu & Maykel, 2016). In these digital spaces, we cannot just rely on traditional print-based text practices based on stable material anchors to aid memorising and comprehension, as digital texts are more cognitively demanding.

The role of the mind in decoding texts in the digital age has never been more important. An epistemological approach to literacies underpins the view of reading practices in this monograph, as we need innovative ways to consider evaluate reading and epistemic thinking as a form of critical digital literacy. We propose that beliefs shape evaluative judgements in critical literacy approaches and are the foundation for developing advanced critical readers. This is the view that reading practices on screens require sophisticated epistemic thinking – critical thinking skills to question, evaluate, and make judgements about sources of information.

Because information is not the same as knowledge, readers need advanced epistemic skills to forge personal pathways as they move from print to screens, as they investigate topical social issues on the internet as part of learning across the curriculum, and as they develop into active citizens in the digital world. The rise of 'fake news' has eroded trust in information in the internet age, and there is an ever-increasing vulnerability of young people who are engaged with materials that are regulated by algorithms and artificial intelligence that produce biased sources (Lazer et al., 2018). What kinds of thinking skills need to be foregrounded for futures-focused reading in societies of the future?

Epistemic approaches to reading offer exciting opportunities for advancing young people's critical literacy. Epistemology, derived from the Greek phrase 'study of knowledge', has ignited scholars to raise questions related to thinking critically about texts. A growing body of research has explored epistemological conceptions, and the core beliefs of students and teachers (e.g. Barzilai & Chinn, 2018; Barzilai & Weinstock, 2015). Greek philosophers, such as Plato and Aristotle, contemplated the sciences, philosophy, art, and politics by applying logic, reason, and inquiry, as they grappled with questions of right and wrong, and true and false, in attempts to understand the world and resolve complex issues. Socrates instigated exploration of ethics and questions of morality in society by inquiring to bring to the fore people's beliefs and values. While Greek philosophers shaped modern thought in a time when digital spaces and 'screenagers' or 'digital natives' were not even conceivable, such exploration of beliefs about knowledge is perhaps more important than ever today in our digital world.

Epistemic approaches to decoding texts are extended in this volume in Part I, Mind and Materiality (Chapters 2–4), to consider implications as readers move from print to screens, as they take a critical stance to decode conflicting multimodal media on topical social issues, and if they are going to succeed in immersive gaming spaces that demand razor-sharp decision making. As a provocation, the role of critical thinking for evaluating sources of information on the internet related to socio-scientific issues and associated tensions for readers are highlighted as seminal skills in the post-truth era, where there can be deep disagreements about knowing and knowledge (Chinn et al., 2020).

Decoding multimodal content on the internet demands sophisticated epistemic engagement but can also foster such skills. The role of video games is illustrated as an avenue for players to engage with critical thinking and problem solving to develop complex cognition needed in a world fast-tracked to continue embracing innovative technologies. Is video gaming perhaps a form of immersive digital text that affords the development of critical literacy and learning across the curriculum in a way that will propel students into the future and prepare them with 21st-century skills they will need for the workforce? In a digital world, teachers and students cannot avoid engagements with digital forms of multimodal meaning making and new experiences afforded by technology that fundamentally shift the skills needed for engagement with texts and digital semiotics.

## The body and senses in thought, language, and digital practice

A central problem of many conventional views of language is that they focus on meaning as conceived primarily through abstract symbols that are divorced from their grounding in ordinary human experience and real-world referents (Harnad, 1990). Likewise, much of cognitive science has emphasised the neural basis of language learning, while undermining the origin of all human knowledge – embodied activity in the world that begins from birth, and which continues throughout the life course. Recently, embodied cognition has sought to understand the scientific relations between mind and body, building compelling evidence for the role of bodily and sensorimotor activity in all aspects of language learning, from the development of early speech to vocabulary learning, and from comprehension to communication (Gibbs Jr, 2005).

A sensory or embodiment approach to literacies underpins the view of digital media practices in this monograph, a theory first formalised in Mills's (2016) volume, *Literacy Theories for the Digital Age*. This is the view that literacy and communication practices are established and developed using the full sensorium, and these practices vary across cultures, practices, and technologies (Mills et al., 2018). A hallmark of human thought and language is that it can occur decoupled from immediate interaction with the environment – seemingly disembodied. But theorists of embodied cognition have demonstrated that much of so-called mental activity is in fact, body-based. This is perhaps the most powerful concept of embodied cognition (Wilson, 2002).

How does this work? Humans internalise sensorimotor functions to become integral and automatic, operating covertly during abstract thought processes to simulate external events in the mind's eye, drawing on visual, auditory, and kinaesthetic imagery and memories. An example is how humans learn to count, first using one-to-one correspondence with material objects, such as one's fingers or the dots on some dice, and later using only mental pictures of what was first experienced bodily in the world (Wilson, 2002). This is crucial because the senses are integral to both the practical and abstract dimensions of thought and language.

Human perception and sensorimotor activity are not secondary to the development of thought and language but drive and maintain this development. For example, we talk, and we gesture: linguists might say that the spoken words hold greater importance, while the gestures are secondary, and only supportive in making meaning. Yet researchers of embodied cognition have found empirical evidence to support the view that speech and gesture are grounded in the same cognitive processes, with gestures having an active role in lexical access, helping speakers to organise spatial information into verbalised entities, and playing a critical role in planning and conceptualising the messages (Gibbs Jr, 2005). In other words, the movement of the hands as gestures helps the brain to tick, while lubricating the organisation and fluidity of speech.

Consider another example of how embodied cognition underpins language. Children can learn to write using a pencil or using a keyboard, but research shows that they will have stronger knowledge of letter shape and formation by handwriting, because the motor movement of the writing hand inscribes letter perception and word identification in the mind in a way that does not occur when pressing keys while looking at a screen (Mangen & Balsvik, 2016). Here, we see that embodiment matters to literacy practices, and so also does the materiality of the technology.

What then are the implications of the embodied basis of thought and language in a world in which the tangible materials or media of text production are rapidly transforming, positioning text users in radically diverse ways? Not only can humans handwrite with a pencil and type using a keyboard, but they can now read and manipulate holographic images overlaid in their real world using smart glasses. Advertising companies take images using drones, while teens receive calls with a smartwatch, paint a picture in a virtual reality world, or communicate with hugs sent via Bluetooth and with senders and receivers wearing e-textiles (see https://cutecircuit.com/hugshirt/). Each form of new media positions the reader, author, listener, and speaker differently, providing materially diverse ways for the bodily performance of literacy practices. This opens up unprecedented and unresearched opportunities for new forms of embodied cognition – yet these implications have often been ignored in much digital literacy research (see, for some exceptions, Haas & McGrath, 2018; Mills, 2016).

## Texts and digital semiotics

The systemic functional semiotic tradition developed by Michael Halliday and extended in Part III of this volume, Texts and Digital Semiotics (Chapters 8–10), not only attends to systematising grammatical choices in texts, but is grounded in important understandings about children and humans as semiotic beings who make meaning through fundamentally embodied ways. Focusing on young children's acts of meaning, Halliday (2006) theorised how language has a bodily basis. For example, he has used the illustration of babies who cannot use linguistic forms of expression, but whose whole bodies become animated when their mothers' faces come into view, including rapid and excited limb and head movements, and facial expressions of diverse kinds, then when a mother's attention is taken away, the infant's body becomes "listless and inactive" (p. 7). The sharing of attention between infant and mother is an exchange of material and bodily meaning called protoconversation. Halliday (2006) explains it this way:

> Matter is displaced, meaning is exchanged. I suppose we could use the general term 'movement' for both. My point is that in trying to understand early infancy we are faced with the unity of the material and the semiotic. I prefer to talk about matter and meaning – the material and the semiotic.
>
> *(p. 7)*

Halliday (2006, p. 7) explains that the human infant cannot yet talk, but "body and brain" are being "stretched in anticipation" of spoken language use. At the foundation of Halliday's systemic functional linguistics is the vital principle that language is motivated by recurring patterns of embodied experiences with the world – a view that is extended throughout the current volume in our focus on literacies of the mind and body.

Importantly, Halliday (2006) argued that by the age of three, a child's language development is systemic – with each language choice by a child having meaning by virtue of selection from a vast network of choices. These semiotic choices use a grammar and phonology that

> …interfaces with the material world – the grammar impinging on the world of the child's experience and interpersonal relationships…the phonology impinging on the world of the children's own body (the signifying body…) via…phonetics and kinetics, and each of these interfaces has, in turn, its own systemic potential.
>
> *(p. 8)*

Halliday's (2006) point above explains an important connection between the role of the material world in a child's language experience and socialisation, including the physicality of the body and the systemic potential of language systems, phonology, and grammar. There is no dichotomy between understanding the materiality of the body in language learning and systemic functional linguistic views of texts. This perspective is a useful basis for understanding the necessary relationship between the three main sections of the current volume on mind, body, and text.

The changing materiality of texts, and the resultant expansion of semiotic choices in a digital age, is a key theme of this volume. In a seminal and prescient paper in the *Harvard Educational Review*, the New London Group (NLG) argued that literacy pedagogy in education would need to take into account the burgeoning variety of text forms and representational modes that are associated with multimedia technologies (New London Group, 1996). They drew attention to not only the multiplicity of modes of meaning making, but also to the frequency of their integration so that communication involves both the construction and interpretation of meanings that are realised through the collaborative expression of multiple modes of meaning making, such as linguistic, audio, visual, spatial, and gestural modes. All modes express meaning separately or in combination so that semiotics – the study of meaning – is at the core of understanding and teaching the contemporary and emerging forms of multimodal literacies for digital futures.

Recognising the need for an expanded conceptualisation of literacy that incorporates multiple representational modes, the NLG coined the term 'multiliteracies' and emphasised a social semiotic perspective in describing the ongoing emergence of these multifaceted literacies. Social semiotics provides a robust, cohesive, inclusive, and meaning-centred basis for relating the diverse representational modes. The NLG used the term 'design' to describe the forms of meaning. They explained that this term has a felicitous ambiguity in that it can describe the semiotic expression or artefact, such as the design of a mime or of a text, as well as the embodiment of the process of designing or redesigning meaning.

The NLG regard all semiotic activity in creating or interpreting meaning as a matter of what they call Design, which involves three elements: Available Designs, Designing, and the Redesigned. Available Designs refer to the 'grammars' of various semiotic systems, such as images (Kress & van Leeuwen, 2020), sculpture and architecture (O'Toole, 1994, 2004), gesture and other forms of paralanguage (Martin and Zappavigna, 2019), and spoken and written language (Halliday & Matthiessen, 2014; Martin, 1992). Common to all modes of meaning making is the deep organising principle distinguishing three simultaneously occurring, distinct, and inter-related dimensions of meaning: ideational, interpersonal, and textual (Halliday, 1978; Halliday & Hasan, 1985). Ideational meaning refers to the representation of events, participants, and circumstances in experience. Interpersonal meaning refers to the nature of relationships among participants. Finally, textual meaning pertains to the relative information value and cohesion among semiotic elements.

Any semiotic activity, whatever representational modes are involved – whether the activity is interpreting or constructing meaning – is regarded as Designing by the NLG. There are two fundamental features of Designing: (i) It is always transformative and never simply reproductive of the meaning-making resources of Available Designs. All meaning making involves transformation of the available resources of meaning through re-presentation and re-contextualisation. (ii) All such transformative processes of Designing involve the co-articulation of ideational, interpersonal, and textual meanings. Designing produces new constructions and representations of reality and simultaneously transforms relations among the designer, the objects of designing, and those engaged with enacting or interpreting the designing. At the same time, coherence and relative emphases are established within and across the construction of reality, and the nature of the relationships among the people and other entities involved.

The Redesigned is the outcome through which meaning makers are transformed. Following systemic functional linguistics, the redesigned combines ideational, interpersonal, and textual meanings (Halliday & Hasan, 1985). While never simply a reproduction of any one Available Design, the new meanings that are made are certainly derived in a systematic way from the Available Designs in accordance with culturally recognised patterns of meaning. The concept of meaning as Design, with its three interrelated dimensions, captures the relationship between the dynamic processes of embodied meaning making, with the changing materiality of textual practices in digital literacy contexts. In terms of embodiment and language, theorists of the NLG, such as Cope and Kalantzis (2020) explain that meanings are configured by human bodies. This includes semiotic resources, such as gaze, facial expression, gesticulation, clothing, gait, posture, and demeanour. They similarly acknowledge that in digital environments, wearable devices can play a role in communicating bodily meanings across time and space, often making digital recordings of these corporeally generated meanings (Cope & Kalantzis, 2020).

Students need to learn how to negotiate not only what meanings are made, but also how they are made. To be able to do this, teachers and students need a 'metalanguage' – a language for talking about the meaning-making resources. The nature of the metalanguage continues to evolve with contributions steadily emerging from researchers in the systemic functional semiotic tradition, adapting and extending functional linguistic descriptions developed by Michael Halliday (1978, 1985, 1994) to many different representational modes beyond language (Kress & van Leeuwen, 2001; O'Toole, 1994, 2004). The evolving metalanguage needs to be accessible to teachers and students, and flexible to address new communication forms in digital communication environments. Examples of our contribution to augmenting this kind of functional metalanguage are explained in our account of new forms of multimodal condensation of meaning in infographics (Chapter 8), coding animated narratives (Chapter 9), and of new forms of digital literary texts such as those experienced through different forms of virtual and augmented reality (Chapter 10).

## Implications for curriculum and pedagogy

As classroom curriculum and pedagogy recalibrates and evolves to meet the learning needs of students for their digital futures, the role of critical thinking informed by epistemology approaches to decoding multimodal texts on devices will be seminal for meaning making and learning across the disciplines. Since the ancient Greeks, history has shown the need for questioning and inquiry if people are to be literate citizens of the world. Never has explicitly skilling young people with critical literacy for decoding, evaluating, and forming evidence-based perspectives been more important, as young people read online and engage with topical information and misinformation. Educators can play a critical role in preparing young minds of the future and preparing their students to meet challenges they face daily, as they defer to screens on devices for information that necessitate shifts in the mind and body due to the materiality of reading (Cho et al., 2018).

This volume conveys some urgency in understanding what takes place in the mind and relationships with materiality as young people move from print to unstable hyperlinked digital spaces, and how educators can support readers to enjoy success on screens and advance comprehension. The critical role of educators in specifically advancing their students' epistemic stance is highlighted. Drawing on strategies offered in this volume, educators can advance students' sophisticated approaches to decoding knowledge related to socially relevant issues across the curriculum. This is particularly important as readers with an evaluative epistemic stance can significantly outperform students with absolutist or black-and-white thinking. Another implication for the classroom is the role of video game play as a source of epistemic engagement that requires advanced cognition, but also as a means of developing sophisticated problem-solving skills, as decisions about truth are never black and white, and the mind needs to compute probabilities that require evaluative thinking – key skills for the 21st century.

The work seeks to attend to the corporeality of readers, writers, and text makers of the digital age, with a clear recognition that the sensorial and embodied dimensions of these meaning acts are not arbitrary (Mills, 2016), but play a vital role in structuring language, as well as abstract mental processes of the mind (Gibbs Jr, 2005). Throughout the book, we show how materiality and meaning making have an "inextricable connection" in producing texts in the classroom, whether of speech, writing, or digital composition. For example, theorists such as van Leeuwen (2017, p. 76), have illustrated this principle through the semiotics of voice quality. There is similarly a certain graphic materiality of writing, its substrates, and technologies of production. In each case, there are certain meaning potentials inherent in the materials that are socially and culturally selected over time, whether digital devices, parchment, wood, clay, or movements of the body, including fully articulated embodied systems of meaning, such as sign language (Kress, 2017). The materials that cultures and societies select to adapt as resources for making meaning have often "been neglected in traditional linguistics" (Kress & van Leeuwen, 2020, p. 237).

Our attention on haptics in digital media practices has implications for the classroom, including the remarkable evidence that shows differences in language learning outcomes for those who handwrite versus typing with a keyboard. Certain tastes – sweet, salty, and bitter – are associated with the angularity of fonts (Velasco et al., 2015), while writing flow differs when smelling certain substances (Gonçalves et al., 2017), or when hearing certain music (Ransdell & Gilroy, 2001). The way in which some digital tools bifurcate the visual and motor spaces (e.g. where the gaze is directed and where the hands are operating), makes writing less effective in certain ways, such as for knowledge of letter formation (Haas & McGrath, 2018). These and other implications for text production in the classroom, including virtual, mixed, and augmented reality spaces, matter to the future of literacy learning in a world where the materiality of the medium clearly matters to the message.

Likewise, literacy education for digital futures requires moving beyond the semiotics of logocentric texts in the classroom, and beyond a privileging of vision, to acknowledge the multiple modes of meaning making. This will necessitate curricular and pedagogic attention to how various modes make meanings, and how those meanings converge with or complement each other. To facilitate this, teachers and students need a metalanguage – a language for talking about the meaning-making resources of the various modes, and how they interact in multimodal texts (Forey, 2020; He & Forey, 2018; Love & Sandiford, 2016; Macken-Horarik et al., 2018; Unsworth & Macken-Horarik, 2015; Unsworth & Mills, 2020). The scope of a pedagogically accessible metalanguage will need to be expanded to accommodate new forms of meaning making through modes such as sound, movement, touch or haptics, olfaction, taste, gesture, and others, as literate practices are transformed in ways that were previously inconceivable.

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# PART I
# Mind and materiality

People have been decoding symbols for thousands of years with this process reorganising our minds and expanding the way we think. Print-based semiotics have provided stable linear texts since the invention of Sumerian logographs based on simple pictures in 4000 BC, the introduction of the Phoenician alphabet in 2000 BC, and later, the mass distribution of the written word via Gutenberg's printing press. The advent of the personal computer as a mass-market electronic device revolutionised consumer engagement in the 1970s; however, texts were still largely linear until hypertexts made their appearance in computing systems as part of the World Wide Web in 1987. Since inception, digital devices and the web have been rapidly expanding modes of communication, escalating access to information, and fundamentally changing the nature of the mind and body in decoding texts.

New modes of communication require new literacies, particularly as people engage with online search engines, hyperlinked webpages, multimodal media, video gaming, and immersive experiences, such as augmented reality and virtual reality. While new digital practices are quickly sweeping nations, readers can struggle to decode, evaluate information, and make meaning as digital hypertext environments demand more sophisticated skills than traditional linear text. As Leu et al. (2008) point out, new literacies of the internet and other information communication technologies include the skills, strategies, and dispositions necessary to successfully use and adapt to the rapidly changing information and communication technologies; however, a precise definition of these new literacies may never be possible to achieve because their most important characteristic is that they continually evolve. Coiro (2021) clearly highlights such tensions in the field over the last 30 years as scholars interested in digital reading continue to perpetuate a lack of conceptual clarity about such a notion, and risk oversimplifying digital reading as a singular entity analogous to reading text on a screen.

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In this section of the volume, we explore some of the new literacy practices emerging that challenge educators to think about how to conceptualise reading in digital spaces and, importantly, what this means for supporting readers to address monumental shifts in the skills they need (Bråten et al., 2020). Ongoing inquiry and robust discourse are needed to recognise, engage with, and conceptualise new literacies on a fast-tracked evolutionary trajectory. The chapters in this section evidence a range of reading practices in digital spaces – hyperlinked texts, multimodal webpages, video gaming environments – with a desire to stimulate innovative educational initiatives to recalibrate reading pedagogies for digital meaning making and shed light on the practices involved in successful digital reading in the 21st century.

In Chapter 2, we consider how readers face new challenges in making meaning of texts in digital spaces that change the materiality and embodiment of their experience (Delgado et al., 2018). The complexities of reading in digital environments are considered through a fine-grained lens to illustrate and clarify the processes involved. Central to this discussion is recognition of the way shifts from print-based reading to digital forms of decoding, comprehension, and meaning making have implications for cognition and the way children read deeply, process, and comprehend information that they engage with. In this way, we consider what happens to the mind when readers shift to decreased and unstable materiality of reading on screens, and how reading digital hypertext content requires innovative educational initiatives to recalibrate reading pedagogies for digital meaning making. As decoding texts is complex, careful orchestration of cognition is needed, but human sensory modalities, such as vision, olfactory cues, sensations of haptics related to touch, aesthetics, and the material world are also crucial. This chapter makes visible the critical role of multisensory stimulation and possibilities for supporting reader processes as they engage across a range of digital spaces.

The internet is a global networked digital space that provides readers with information from around the world. Information, however, is not knowledge. In Chapter 3, we consider why critical reading online requires sophisticated thinking skills and a recalibration of how we conceptualise digital reading in such spaces. Controversial information abounds on the internet, particularly when it comes to issues related to socio-scientific issues – or socially relevant debates informed by science – such as climate change, health pandemics, mobile phone health risks, and phenomena related to issues such as genetic modification (Lunn et al., 2021). New theoretical approaches show how young people can engage with evaluative thinking to make informed decisions about such socially relevant, real-world problems, as they develop a sophisticated epistemic stance (knowing about knowledge) to apply as they read, synthesise, make inferences, and justify their interpretation of multiple sources online (Barzilai & Zohar, 2012). In this chapter, we argue this processing is a new way to think about critical literacy and refer to this approach as critical epistemic literacy.

While Chapter 3 looks at critical literacy for engaging in hyperlinked internet spaces and evaluating controversial information on the World Wide Web, in Chapter 4, we consider why video gaming is an important digital practice that also engages epistemic thinking (Scholes et al., 2022). Illustrated are some of the advances in video games that provide opportunities for critical literacy as players decode, evaluate, and make decisions in collective spaces of self-generated ideas. While traditional educational practices often emphasise one right answer to a problem (objectivist epistemology) video game play has the potential to advance literacies and provide opportunities for engagement in situated, active, problem-based learning environments. While serious games are often epistemic focused, we also consider how action and multiplayer virtual gaming environments offer creative spaces for trialling alternative pathways and new innovations, or multiple right answers to a problem (subjectivist epistemology). In this chapter, we reconceptualise pedagogical approaches to knowledge and how video games can facilitate the epistemological to support learning environments that develop knowledge creation, while answering key questions about how to foster and develop new knowledge and critical literacies for the future.

Taken together, this section highlights literacy practices that disrupt traditional perspectives on decoding linear texts, adding scholarship on digital reading. Our provocations aim to challenge the status quo and encourage new ways of understanding readers immersed in exciting digital spaces that are changing the structures of the mind. At the heart of this section is our contribution to discourse about evolving practices and pedagogies for advancing literacy for digital futures.

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# 2

# MIND AND MATERIALITY OF DIGITAL READING

## How digital reading is reconceptualising literacy

The rapid evolution of new technologies has accelerated children's engagement with mobile devices, fundamentally changing the nature of reading. Young people today are immersed in a multitude of digital spaces, such as multimedia websites, interactive graphics, e-books, digital e-readers – like Kobo and Amazon Kindle – and social media. These spaces provide many benefits, including rapid and expanded access to knowledge and information; however, there are also unanswered questions about decoding texts on the many digital devices available. Engagement in digital spaces requires sophisticated skills for meaning making, arguably changing the traditional nature of reading and reconceptualising literacy.

Along with entertainment and global connections, digital spaces offer opportunities for accessing endless amounts of information that need to be processed by the reader. Readers increasingly face new challenges making meaning of texts in digital spaces that change the materiality and embodiment experience. In this way, shifts from print-based reading to digital forms of decoding, comprehension, and meaning making involve very different material experiences in how we engage the body and mind. Material shifts in experiences raise concerns about how digital reading differs from print-based reading, and whether these differences have implications for the way children read deeply, process, and comprehend information.

This chapter first explores how reading includes the 'spatio-temporal' that takes place in the mind during the act of reading, and the 'imaginary' – related to thoughts that are seminal for creating scenarios from what we read. In so doing, we identify how shifts from reading linear print to reading digital

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hypertexts – non-linear formats – have physical effects on how we engage the mind. As experiences of the body also change when readers engage with digital devices, we consider the role of multisensory stimulation through vision, olfactory cues, sensations of haptics related to touch, and aesthetic enjoyment in reading. These concepts of embodiment are further developed in relation to writing in Chapters 5 and 6 of this volume.

As the chapter progresses, it highlights challenges involved in decreased and unstable materiality of reading on screens, and how reading digital hypertext content requires innovative educational initiatives to recalibrate reading pedagogies for digital meaning making. These pedagogies account for the lack of material anchors and tendency for browsing and scanning, rather than deep reading, when engaged with reading online. Finally, digital reading is positioned as a seminal aspect of literacy that needs to be explicitly and systematically taught through the primary and secondary years of school to prepare young people for their digital futures.

## New understandings of the mind and materiality for digital reading

### *Shifts in processes of the mind*

Reading is often described as a cognitive function that requires linguistic processing. It is not, however, a natural process as we were never born to read – we were born to see, move, speak, and think. Human beings invented reading only a few thousand years ago, rearranging the organisation of our minds which in turn expanded the ways individuals think (Wolf, 2018). Underlying the brain's ability to learn to read is the capacity to make new connections among structures and circuits originally devoted to more basic cognitive processes that have enjoyed a longer existence in human evolution, such as vision and spoken language (Canolty et al., 2007). The properties of print-based text can support this form of cognition due to the stability and linearity of text, as well as the layers of thought and composition that print represents, while invoking a reader's full attention. Becoming fluent in the decoding process requires time and attention to the task through the activation of the spatio-temporal areas of the brain within distributed neural networks (Wolf, 2018).

Today, we know quite a lot about the workings of the mind, as hemodynamic measures show the location (space), and electromagnetic measures show the timing (time) of brain activity during language processing (Canolty et al., 2007). Spatio-temporal processing of texts takes place mainly through interactions of the temporal and inferior prefrontal areas of the left hemisphere, with understanding of a word peaking about 400 milliseconds after recognition (Canolty et al., 2007). The mind is also involved during the act of reading when we sequence plots and remember details of characters, settings, backstories, and conversations – as stories are one efficient way to convert information into long term memory (Park et al., 1996). The mind is extremely busy trying to organise and sort information while reading and works hard to predict what will happen next in the text. Readers also search to find connections between related events, thoughts, and details of what is read. Decoding texts on screens, however, can encourage fragmented reading or multitasking, which utilises a different form of attention, requiring a more nuanced speed of processing that may be changing our brains (Wolf, 2018). As part of these changes, processes for developing mental images may also be destabilised.

## *Mental images*

The mind is involved in the thoughts that take place as we create mental images and scenarios from what we read. While books can contain beautiful pictures to tantalise the viewer, children can also learn to make mental images as they read a range of texts, with this process very active in experiences with narratives. Mental images, or mental representation, resembles the experience of objects, events, or scenes, but occurs without the presence of a tangible stimulus (Pinker, 1980). Embodied representation in the form of simulation takes place as the mind enacts the sensory and motor (i.e. sensorimotor) experiences (Sadoski, 2018). Eating an ice-cream cone, for instance, would normally involve all the sensory experiences related to seeing, hearing, tasting, smelling, and the haptic activities of holding the cone, licking the ice cream, chewing the cone – with simulation this experience can be activated to produce the same sensory representations in the mind (Sadoski, 2018). Because a central aspect of embodiment is motor activity, reading words that are associated with different parts of the body (e.g. lick, kick, pick) activates corresponding neurological motor systems (Pulvermüller, 2005).

In this way, mental images are a form of simulation. When a reader comprehends texts, imagery and simulation are inseparable (Moulton & Kosslyn, 2009). Reading words that are associated with different parts of the body (e.g. licking an ice cream) activates corresponding neurological motor systems or what neuroscientists refer to as 'mirror neurons' (Dickerson et al., 2017). Mental images and scenarios created while reading can add delight for engaged readers. In an Australian study of elementary school students' reading habits, many children described intimate relationships with texts and a love of immersion in the storyline (Scholes et al., 2021). As Jasper, a ten-year-old avid reader from the study explains in the vignette below, he particularly enjoys imagining what the characters are doing as the narrative unfolds, and he also likes to imagine himself in the story:

> Not too long ago I finished Deltora Quest – Series Three. They're just really, really out of the ordinary, and I like that.... On the back of the first

> series of Deltora Quest it says: Deltora is a land of monsters and magic, and that's pretty much the thing with every single book Emily Rodda's ever written, and I like that it's all fantasy and strange creatures.
>
> For every sentence I imagine the people doing things, and I have my own little characters locked in my brain…if they're boys I just imagine them as me – you can just create the picture in your mind.

As Jasper constructs mental images, he draws on prior knowledge and background experiences and connects the author's story with a personal picture. This process can be enhanced for young readers through guided visualisation, as young people learn to create mental images rich in sensory content. This process supports comprehension as readers visualise the scenery, characters, plot, and actions as they read sentences in the text. These images include various forms of sensory stimulation, whether visual (characteristics of the objects), auditory (characteristics and intensity of sound), kinaesthetic (characteristics of movement and touch), gustatory (related to tastes), or olfactory (related to odours).

Such imagery can then be helpful for recalling facts and sequencing to identify the beginning, middle, and end of events, and the ability to retell a story. How does this process change, then, when readers move to screens and engage with e-readers, smartphones, iPads, and tablets, and the intuitive navigation of unstable texts challenges mapping the journey in the mind? There can be issues keeping track of the beginning, middle, and end of digital texts on screens, along with struggles monitoring personal reading pathways which, in turn, potentially challenge the comprehension of text (Barzillai et al., 2018). Where a print-based book includes pages with letters, words and sentences fixed in place, the texts that appear on a screen are ephemeral images. A reader of digital text might scroll through a seamless stream of words, tap forward and backwards as part of the meaning-making process, use the search function to locate a keyword or a particular phrase, and click on a text or an image that accesses related content. In this way, shifts in reading in the digital domain are more cognitively demanding as they require flexibility in processes in the mind. Reading, however, involves much more than just the mind. The mind needs to be understood in the context of inter-relationships with the physical body and the surrounding environment.

## *Shifts in embodied experiences*

While the mind is clearly involved in the task of meaning making when decoding texts, reading is also a highly embodied experience that activates a network of human sensory modalities. From an evolutionary perspective, humans evolved from beings whose neural resources were devoted primarily to perceptual and motoric processing, and whose cognitive activity consisted largely of immediate physical interaction with the environment (Wilson, 2002). Human cognition, rather than being centralised, abstract, or distinct from peripheral input and output processes, may instead have deep roots in sensorimotor processing. Research under the auspices of embodied cognition illustrates how neurophysiological and neuropsychological processes involved in perception, motor action, and cognition are more closely associated than previously understood (Calvo & Gomila, 2008). Based on this understanding, decoding texts is complex and includes careful orchestration of cognition, affect and emotion (Kress, 2003), bringing together human sensory modalities and the surrounding material world. Then what is the role of multisensory stimulation through vision, olfactory cues, sensations of haptics related to touch, and aesthetic enjoyment in reading, and how does the sensoriality of reading shift when readers move to screens?

### *Multisensory stimulation*

Skilled readers rely on vision and move their eyes during reading as movements (called saccades) bringing a line of text into foveal vision for detailed visual processing, with skilled readers making regressions back to material already read – about 15% of the time – and slower readers taking longer times, shorter saccades, and more regressions (Rayner, 1985). Educators often see aspiring readers who struggle to acquire new skills if their vision is compromised. As sight is clearly essential for reading, students feel they can 'see' more clearly when they engage with a print-based book, and they are also acutely aware that the visual sensory demands of reading on screens are harder on their eyes, with some students complaining about eyestrain (Baron, 2015).

In this way, lighting is also a salient factor as readers are fixed to devices for long periods of time, with concern that blue light shining from screens is harmful to health. While natural blue light from the sun boosts alertness, helps memory and cognitive function, and elevates mood, there are concerns about ocular overload (retinal cell damage, vision problems, macular degeneration, cataracts), with prolonged exposure to blue light on devices not in a natural setting (Chu et al., 2011). The role of vision in reading is highlighted and given prominence; however, the roles of the many other senses are also important.

While you might think that smell would be rather inconsequential in relation to the enjoyment of reading, it turns out that olfactory cues often elicit an emotional, nostalgic response to handling hardcopy books. Early in life, olfactory cues are important, and infants are attracted to maternal odours, with the smell of a mother's clothes comforting to newborns (Schaal et al., 2004). In a similar manner, multisensory experiences are ignited for readers through smelling the paper, ink, and the glue used to make paper books. In a study across five countries, Baron (2015) found that print was aesthetically more enjoyable for students who enjoyed 'the smell of paper'. According to Strlič et al. (2009), the aroma of an old book is familiar and even appealing to users of a traditional library.

With the combination of grassy notes, a tang of acids, and a hint of vanilla over an underlying mustiness, this unmistakable smell becomes as much a part of the book as its contents (Strlič et al., 2009).

The distinctive odour of certain books can certainly play an important role in aiding the recall of their content (Laska, 2011). Perhaps the popularity of scratch and sniff books such as *Do Dinosaurs Eat Cookies?* by Jane Yolen and Mark Teague are testament to the allure of olfactory sensations. With cookie-themed scratch-and-sniff lift flaps of scents throughout the book, children can experience the aromas of chocolate, cinnamon, strawberry, and more as they turn the pages. The multisensory experience adds to the joy, but also to the memory, of the experience.

Touch too has an important role in reading as hands sense, assist, direct, and sustain attention (see Figure 2.1). As hands touch books, the text can be manipulated, and the pages felt as they are turned – the reader can 'feel' where they are in the book (Baron, 2015).

The sense of touch in print adds a spatial 'thereness' to text. Readers like to know where they are in time and space so they can revisit pages often learning from such opportunities (Piper, 2012). This involves the ability to go back to check and evaluate the understanding of what was read.

The sensory stimulation of a print-based book through touch and proprioception, however, is very different to the haptics of the iPad interface. While an iPad can be appealing for young children, is portable, and has intuitive touch-screen interfaces, it is also materially hard, unstable, and offers a different tactile

**FIGURE 2.1** Touch too is important for reading
Photo by Stephen Andrews/Upslash

experience. The haptic feedback of a touchscreen is also more challenging as children call on fine motor skills to use their fingers for general tapping, precision tapping, swiping, and thumb pressing to navigate around the screen – which can manifest as a frenzy of haptic engagement for new users (Merchant, 2015). In this way, engagement with digital devices demands dexterity and cognitive attention to information that might prove challenging for some readers, depending on age. So, while there are some similarities between print and screen reading, there are also some distinct differences.

Excess information – or cognitive overload (Kahneman, 1973) – as readers tap, swipe, and thumb through a picture book, requires re-allocation of mental resources available for processing the central narrative towards engagement in materials (e.g. pointing, tapping, clicking, and swiping). In a recent meta-analysis, engagement with digital devices appeared to attract young children's attention at the expense of a focus on the storyline, even when the content of the paper and digital book was the same (Furenes et al., 2021). Increased and competing demands on cognitive resources have implications for teaching children to read on digital devices, as well as supporting digital readers when they transition to reading to learn.

The materiality of reading then epitomises the embodied and embedded nature of human experience reflecting the multiple entanglements of human senses with materials, objects, and artefacts, and the various supports these provide to human pursuits (Kallinikos et al., 2012). It may be that print-based experiences provide sensorimotor cues that enhance cognitive processing while learning to read (Mangen et al., 2019).

## *Learning to read*

Learning to read raises some critical issues for decoding texts in digital spaces. Toddlers these days spend quite a bit of time looking at screens and may well be shown a mobile phone as a pacifier (Chang et al., 2018), later progressing to learning to read through digital devices. Familiar children's stories can be found through a range of iPad apps, and bedtime stories can involve a device as easily as a printed book (Kucirkova et al., 2013). As noted previously, the materiality of experiences and the role of the mind in cognition change when readers shift from print to digital reading on screens in a multitude of ways. A good example is Jack, a five-year-old 'beginning' reader.

As Jack touches and turns the tangible pages of one of his favourite books, gazes longingly at the ice-cream cone in the illustration, follows the linear text rhythms with a wandering finger as the story progresses, and then slings the colourful artefact under his arm to return it to its rightful place on the bookshelf, he actively engages sensory, perceptual, motor, conceptual, and affective domains. This much-loved book can be retrieved and read, over and over. There is a tactile and engaging experience with the materiality of the book, and the stability of the textual structures. Jack learns through repetition and the flow of the narrative, how to predict the storyline, use visual cues, learn common sight words, and decode through tangible 'material anchors' to eventually navigate the text and make meaning (Hutchins, 2005).

The process of learning to read is difficult. It is not a natural process but requires learning to crack the code of written language, decoding meaning in texts, and drawing upon a range of cues. Phonics is part of the puzzle; however, children also need vocabulary knowledge and text decoding fluency, attending to grammar, punctuation, and sentence structure. Digitally based books expand access for students but also create different challenges. Tracking the eye movement of children using digital devices shows that they are more likely to skim or read non-linearly, looking for keywords to make meaning, and jumping to the end to find out the conclusion; in so doing, the plot and sequence of events can be lost.

For Jack, his favourite printed book is fixed in size and space and anchored by the cover. The multiple printed pages include both text and images, providing opportunities to engage repeatedly through perceptual, sensual, and motor processing, reactivating his memory. When diving into his favourite part of the story, Jack can flick through the pages to find his entry point quickly. In contrast, digital texts are fluid, often without consistent font size, place in space, or anchors to substrates, such as printed items with a cover (Rose, 2011). While digital enhancements aligned with the story content can support children's reading outcomes (Christ et al., 2019), digital books with unrelated enhancements, such as games embedded in story apps, can distract and impact comprehension, taking young children's attention from the task of reading (Munzer et al., 2019). Instead of turning the print-based tangible pages, the continuity of reading is disrupted by scrolling the text on screen and visual distractions. And while print-based books lend themselves to reading over and over, online texts are not necessarily developed for easy access and quick retrieval.

The ritual of engaging in a bedtime story with a parent, or the enjoyment of the warmth of a loved one's lap while exploring a favourite book, is seminal to Jack's experiences (Barzillai et al., 2018; Reich et al., 2016). As such social practices unfold, there are often interactions around print text that extend comprehension, such as asking questions, encouraging the use of contextual cues to make inferences, and helping Jack to relate texts to his own life (Mol et al., 2008). These material experiences with books provide ongoing interactions to enrich developing reading skills. Interacting with text on digital devices, including e-books and story apps, can be overshadowed by engagement in dynamic visuals, exciting hotspots, and endless hyperlinks to games, videos, and creative content, altering children's early literacy experiences. Interpersonal interactions are key to digital reading comprehension for new readers (Furenes et al., 2021); however, parents and toddlers tend to verbalise less with electronic books. There is less collaboration, and parents read the text less in enhanced electronic books, making more format-related comments and negative directives (Munzer et al., 2019). In this way, new readers' conversations during digital book reading can be dominated by talk about the device or the child's behaviours, rather than the story content (Furenes et al., 2021). That is not to say that children will not enjoy reading on screens with a carer or parent – however, the materiality of the experience shifts.

### *Virtual reality*

Readers can use the external world as an anchor for abstract memories as experiences with material objects come to mind and form a background tapestry for memory (Schilhab et al., 2018). Visual images of a familiar environment can prompt recall as they involve multimodal experiences of touch, odour, light, sound, and so on that can be ignited to recall memory. In this way, the mind is involved when children, such as Jack, read favourite books and use contextual cues to draw upon prior experiences that arise from bodily interactions with the world. For instance, Jack's previous experiences eating an ice-cream cone, involving the senses of seeing, hearing, tasting, and smelling along with the fine motor experiences involved in holding, licking, and chewing can be simulated in reading engagement through mental re-enactment of sensory and motor experiences (Sadoski, 2018). From an embodied perspective, meaning making is ultimately grounded in multisensory experiences.

It may be that platforms such as virtual reality (VR) that create sound, images, video, or other media experiences to give learners a full sensory experience and help them engage with the content offer ways to immerse readers by physically engaging the senses in a new way. The application of VR technology in children's interactive books has attracted much attention in education due to its unique features for providing children with interesting, interactive, immersive, and realistic reading experiences (Dong & Si, 2018). VR can already simulate sight, sound, and a sense of movement (see Chapter 7), but new technology adding smell can help stimulate memories and emotional experiences, making VR even more real. This works as a device called the ION, which contains vials of different scents, attached to a VR headset (see Figure 2.2). As users interact in the VR space, scents connected to an experience – say, the act of eating a chocolate ice cream – trigger a tiny electric charge releasing the matching chocolate fragrance.

The emerging capability to simulate a wide range of sensory experiences beyond sights, sounds, and the touch of conventional digital media, has the potential to re-engage future users with the physicality of traditional embodied experiences (Ovens & Mills, 2018). The human brain will naturally respond to the external stimulus with smell, for instance, closely linked to learning and

**FIGURE 2.2** Virtual reality encompasses the senses
Photo by Jessica Lewis / Upslash

memory. In this way, the seminal role of scent in a scratch-and-sniff book can be replicated in the VR space both affording important sensorial experiences but also potentially adding further distractions to processing the reading pathway (see Chapter 5 for more on olfaction and media).

## Critical issues for digital reading as a mode of making meaning

Ongoing debates centre on the impact of screens on students' reading experiences and their level of engagement with devices. Some studies suggest that young people's high levels of access to mobile phones, computers, and tablet devices now means that reading is an activity more likely to be on screen than on the printed page – escalated by COVID-19 lockdowns and reliance on remote learning (National Literacy Trust, 2020). Others hold fast to the idea that readers prefer print, especially in academic contexts (Baron et al., 2017). And while middle school students, particularly middle school boys, favour recreational reading in digital settings (McKenna et al., 2012), others insist that younger children prefer reading print-based books, particularly in their leisure time (Kucirkova & Littleton, 2016). Adding complexity, reports of reading comprehension on devices have had varied results. Some students read faster on devices and believe they comprehend efficiently through digital mediums though their assessed understanding of texts is more sophisticated when they read from print (see Clinton, 2019; Kong, Seo & Zhai, 2018; Singer & Alexander, 2017). Others report differences in reading comprehension depending on the task and the quality of the interaction, and point to technology advancements (e.g. artificial intelligence, augmented reality, virtual reality) as ways to improve meaning making (Furenes, Kucirkova & Bus, 2021).

The negative effects of digital devices on reading are not agreed upon, and some researchers believe that biological plasticity and bodily reconfiguration or re-embodiment will occur as individuals adjust to the affordances of new devices (Schilhab et al., 2018). One moderator of digital text comprehension could be reader experience using technology – and that comprehension difficulties will disappear once students are savvy with technologies (Delgado et al., 2018), or that their brains will reconfigure for processing on different devices (Schilhab et al., 2018).

In the meantime, digital text types are something that needs to be considered by educators. It may well be that when the texts are short – a page or less – and comprehension demands are light (grasping the main idea), students do well with both informational and narrative digital texts. But as learning demands increase and the texts are more extensive, paper-based reading affords better understanding. The level of skill required depends on a number of variables related to the task (Coiro, 2011). The superiority of print shines when recall requires going beyond questions that have superficial answers to those that require inferences, details about the text, or remembering when and where in a story an event took place (Baron et al., 2017). In understanding reading behaviours in digital spaces there are several factors that are important to consider, including whether the reading is done with time pressure, the length of the text, as well as the depth of processing that the task requires (Delgado et al., 2018). These aspects of texts then interact with the characteristics of individual readers to shape reading behaviours.

## Reading behaviours that impact on meaning making

With an increasing amount of time spent reading digitally, screen-based reading behaviours are emerging – with tendencies for browsing, scanning, keyword spotting, one-time reading, and non-linear selective reading, with less in-depth or concentrated reading (Liu, 2012). Multimodal semiotic awareness is also important for making meaning of digital texts. Semiotic resources, such as layout, composition, text, image, graphics, and the range of colours and fonts, can be distracting. Multimedia elements, animations, and interactive features can enhance the reading experience, but also require filtering and making choices about reading pathways. Nicholas et al. (2008) refer to such reading behaviours in the context of searching digital libraries as 'power browsing', where readers seldom sustain engagement with text online for a long period of time. These strategies do not involve going deeper to understand the complexity of issues.

In a print-based environment, the author determines the order or presentation of ideas – in hypertext environments the author provides options, but readers choose their personal pathway by activating hyperlinks. This non-linear reading (e.g. jumping from page to page and from site to site), can reduce the sustained attention to any one textual source and lead to more fragmented reading. While traditional print-based texts afford many stable material anchors to aid memorising and comprehension, digital texts are more cognitively demanding. Continual interruptions occur with disruptions from popups, alerts, notifications, hotspots, or links. Reading behaviours increasingly include 'stacking' – using multiple devices for conducting unrelated tasks – and 'meshing' – simultaneously communicating content being viewed (Davidson & Harris, 2019). This lack of engagement with digital material is illustrated by young people's use of the labels TL;DR (too long; didn't read) and SR;MP (skim-read; missed point). These behaviours and approaches to reading on screens can have negative effects that appear as early as fourth and fifth grades (Golan et al., 2018), and need to be considered in contemporary curriculum and pedagogy.

A paradigm shift is needed to support reading processes in digital spaces. Digital information presents both new richness and novel challenges for the mind – as the fluid, multimodal nature of the digital allows immersion in different modalities. Shifts from stable, linear texts to non-stable modalities require shifts in attention, decision making, and complex cognition to navigate personal reading pathways through hyperlinked spaces. Such cognitive functions relate to self-regulation and processes that enable us to plan, focus attention, remember instructions, and juggle multiple tasks successfully as the brain filters distractions, prioritises tasks, sets and achieves goals, and controls impulses (Kieffer et al., 2013). Children are not born with these skills – but they are born with the potential to develop them. It is these cognitive functions that are key to supporting reading and making meaning in digital spaces.

## Implications for literacy curriculum and pedagogy

Digital reading is now an important part of daily life for many students in classrooms across the globe. Due to the complexities of engaging with such texts, digital reading needs to be explicitly addressed with strategies systematically taught through the primary years as children learn to read, and then in middle and secondary years, as children read to learn. Although we do not fully understand the source of differences between digital reading and print-based reading, there are fundamental changes in experiences (Afflerbach & Cho, 2010; Leu & Maykel, 2016). Two significant moderators are important to consider. First, the time frame allocated for a task is critical as the advantage for paper-based reading is stronger in time-constrained reading than in self-paced reading; and the text genre makes a difference as the paper-based reading advantage is consistent across studies using informational text or a mix of informational and narrative texts, but there is often no difference for narrative-only texts (Delgado, Vargas, Ackerman & Salmerón, 2018).

There are a range of strategies, however, to address concerns related to how digital reading differs from print-based reading – particularly issues of focusing attention, deep reading, and how adults can scaffold experiences. Research is a long way from any definitive answers; however, educators can look towards emerging approaches to support their students' digital reading.

## *Scaffolding digital reading in the early years*

Many well-meaning schools have embraced technologies and incorporated the latest array of tools and apps into children's learning, despite a lack of research on their efficacy or guidance on how best to support their use (Kucirkova & Littleton, 2016). In an increasingly digital environment, young readers need to develop specific screen-based reading behaviours (e.g. skimming, browsing, keyword spotting, bouncing between multimodal texts), to cope with large amounts of texts and the abundance of information, and to overcome surface level strategies. The role of educators is critical for supporting new readers in digital spaces. Shared reading using digital texts does not offer the same rich language and bonding experience that occurs when children have close contact with a caring adult who scaffolds the reading journey. To address these differences in adult interactions when using these mediums, and the lack of dialogic reading that naturally unfolds through sharing print-based texts, educators need to explicitly scaffold and support children's decoding of texts for meaning making (Strouse et al., 2019).

The screen-inferiority effect on reading outcomes is strongest in the school context where group-based activities make it hard for children to engage with digital enhancement to support their decoding (Hoel & Tønnessen, 2019). 'Read to me' built-in functions offered by e-books and apps can be a problem when teachers utilise these modes for children's independent use of tablets and iPads, rather than engaging in joint reading experiences (Kucirkova & Littleton, 2016). For example, de Jong and Bus (2002) found that kindergarteners allowed to independently use electronic storybooks barely listened to the audio narrative, and navigated the story in a suboptimal manner, spending nearly half their time playing games. Therefore, children need adult interactions, perhaps even more in digital spaces, as they are confronted with so much choice and distracting features.

Building on print-based interactions between a child and adult can enliven digital spaces – with a focus on questioning, making links, and scaffolding the reading experience. In this way, reading is reconceptualised as an extension of print-based experiences. Adults can engage in discussions around the meaning of words to support children's efforts to relate the story to their own experiences, and to ask questions to identify events, characters from the story, and sequences of events, advancing superior recall while extending their reading communities.

With digital multimedia books, such as the *ME Books* app, personalised responses to a story can be embedded into the book as children or adults audiorecord their own story narration to become part of the story. In this way, digital books can outperform paper books when they include enhancements that increase children's meaning making of the narrative, for instance, by eliciting children's background knowledge or providing additional explanations of story events (Furenes et al., 2021). The use of open-ended apps can lead to more collaboration among children and higher-order talk including the use of questions, listening and building on each other's ideas.

New affordances are also provided through remote connection for children, families, and teachers for daily reading and online platforms for interactive reading communities. Online platforms, such as Twitter, Facebook, Instagram, Bookstagram, email, and school websites, along with communities, such as Biblionasium, set up spaces for young readers with virtual bookshelves that allow children to add what they are reading, want to read, and have already read. Sharing favourite reading preferences with peers, teachers, librarians, and family who all bring different ideas and experiences can be enriching, enjoyable, and extend reading experiences. Communities have never been more important as they can support readers, provide an online space to share ideas, enrich reading experiences, and through recommendations, discussion, and debate, become part of the digital reading experiences.

## *Supporting deep reading to learn in the later years*

As students transition and read to learn across devices, reading in spaces such as multimodal websites changes the experience of reading (Afflerbach & Cho, 2010; Leu & Maykel, 2016). The explicit instruction of comprehension strategies (predicting, thinking aloud, text structuring, visually representing text, summarising, and questioning) in a scaffolded digital environment, can prepare students with digital literacy skills to competently display their knowledge on computer-based measures of reading comprehension (Ortlieb et al., 2014). Students can also learn strategies to enhance decoding texts to make meaning and slow down, attend carefully to key criteria, and know how to filter information (Singer & Alexander, 2017). Teachers can find ways to capture and understand the full range of students' abilities so they can guide learners toward more strategic use of practices that will better prepare them to make sense of information in different online spaces (Castek & Coiro, 2015).

Deep reading involves slow, immersive processes, whereby readers take time and cognitive effort to engage in deep thought (Wolf et al., 2012). Digital spaces do not naturally encourage taking time (as readers jump around hyperlinked sites) or investing cognitive effort, as readers skip from one point to another without evaluation. Deep reading cognitive processes associated with print reading, however, can be translated to digital reading practices with the support of educators (Lauterman & Ackerman, 2014). To overcome the processing of information in short bursts, educators can help develop reading practices and encourage students to:

- Carefully plan the reading pathway;
- Choose credible digital sources;
- Focus attention related to the task;
- Prioritise tasks related to the goal;
- Re-orient after unplanned detours and distractions;
- Revisit instructions, map progress, and monitor pathways;
- Filter distractions due to hyperlinks, popups, media, and advertisements;
- Think flexibly and evaluate the usefulness of information.

Annotating and mind-mapping are important tools and note-taking can help summarise main ideas. This can be as simple as using Adobe Acrobat for students to highlight main points, apply sticky notes, and make comments on documents. Or it may mean creating a print-based web of a personal reading pathway across multiple digital sites. These skills are considered more closely in Chapter 4 with attention to how skilled readers need to simultaneously draw on print-based reading processes with more complex applications. Explicit strategies are required in the transformation to support focused, sequential, text-centred engagement instead of fragmented, restless, grazing behaviours of clicking and scrolling (Wolf & Barzillai, 2009). This type of reading, however, requires students to focus and sustain attention on a task. Reading online across multimodal websites can also be scaffolded by adult interactions as personal reading pathways are planned, revisited, and monitored. Social experiences and interactions that extend to interaction with other online experiences (e.g. gaming communities, online communities, or social connections) can bring about connections between prior experiences, interests, and communications with others online.

Educators cannot assume that students are competent because they have grown up immersed in a world dependent on technology, and they cannot anticipate that print-based reading skills automatically translate to digital spaces – such skills need to be explicitly taught so that as students progress through the school years they can decode texts, make meaning, and engage in learning across a range of digital devices. There is some urgency in addressing reading behaviours and advancing student digital reading skills as high-stakes assessments move to digital formats. International assessments, such as the Programme for International Student Assessment (PISA) (OECD, 2015) and the program known as Progress in International Reading Literacy Study (PIRLS) (Mullis et al., 2017) are instituting digital administration as well as scenario-based tasks that incorporate digital literacy, with consequences for readers. This approach is also echoed across various nations. For instance, to address the increased role of technology in classrooms, the National Center for Education Statistics in the US, is transitioning the National Assessment of Educational Progress (NAEP) from paper and pencil to digital assessments. This includes assessment of reading which is administered on tablets or laptop computers, raising issues of decoding and comprehension through such modes.

## Recommendations for research of digital reading practices

Digital texts are here to stay for all kinds of economic, social, cultural, and educational reasons. This chapter has pointed to how readers increasingly face new challenges in making meaning of texts in digital spaces that change the materiality and embodiment experience.

Research of reading practices in coming years will require transformed understandings of how reading practices metamorphose in digital spaces. To date, the majority of studies fail to clearly define or conceptualise what constitutes digital reading (Singer & Alexander, 2017). As yet, there is no cohesive theoretical framework that concurrently describes the different cognitive, motivational, and metacognitive processes involved in reading across different digital devices (Golan et al., 2018). There is some urgency in specifically defining digital reading, and recalibrating what it means to read in digital spaces. This means considering the issues raised in this chapter to expand traditional conceptions of reading for meaning making in ways that appreciate the complexities of digital texts and that situate literate practices on a continuum (Moje, 2009).

In light of the ongoing evolution in technologies, further research related to differences in decoding texts across multiple devices is needed. Current research in the early elementary years of schooling has focused on narratives (Singer & Alexander, 2017) with little known about student experiences reading informational text, which require higher-level processing, such as using complex academic vocabulary and structures, with less connection to real life. ePIRLS, an extension of PIRLS (Mullis et al., 2017), uses computer-based assessment focusing on informational reading to assess fourth-grade students' ability to use the internet in a school context. This focus is important for student skill sets in the future. What kind of reading practices ensure success in decoding conflicting sources of information on the web? Are these skills different to literacy practices involved in decoding to make meaning to solve problems, and to succeed in video games? These two very different kinds of textual decoding will be considered in Chapters 3 and 4.

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# 3

# CRITICALLY EVALUATING MULTIPLE SOURCES FOR DIGITAL FUTURES

## Why critical reading of online sources is important for digital futures

In the rapidly changing digital world, the internet is host to almost endless amounts of controversial information that young people can access at school and in their leisure time. This wealth of diverse and accessible information offers exciting opportunities to be immersed in information from around the globe with multiple perspectives and viewpoints on a range of socially relevant topics available at any time. However, conflicting sources abound, particularly when it comes to information related to socio-scientific issues that are by nature social issues informed by science (Zeidler et al., 2019). For young people to engage with evaluative thinking, and to make informed decisions about such socially relevant, real-world problems, they need a sophisticated epistemic stance (knowing about knowledge) to apply as they read, synthesise, make inferences, and justify their interpretation of multiple online sources. We argue this processing is a new way to think about critical literacy and refer to this approach as critical epistemic literacy.

Personal approaches to knowledge are important and affect both processes and outcomes of student learning through online sources (Bråten et al., 2011; Hofer & Pintrich, 2002). Futures-focused critical literacy research should pay attention to the important role beliefs play in students' meaning making about controversial, socially relevant real-world problems as they make decisions about the trustworthiness of websites and the integration of information to construct new knowledge (Barzilai & Zohar, 2012). While not all scholars agree on approaches to understanding epistemic beliefs, there is a shared view that personal beliefs about knowledge and knowing play an important role in formal and informal learning

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(Hofer & Pintrich, 2002), and that many students would benefit from a more sophisticated stance (Mason et al., 2011). This is particularly true for students engaging with information related to socio-scientific issues.

More than ever, young people around the world are engaged in social issues – including climate change, health pandemics, and phenomena related to genetic modification – which requires new epistemic forms of critical literacy. What is emerging is a range of scholarly work examining the cognitive strategies and skills adolescent readers use as they navigate these digital spaces in search of information (Castek & Coiro, 2015). As well as these cognitive decoding skills, students also require sophisticated personal epistemologies and processes to construct knowledge (Cho et al., 2018). As our world becomes more networked, connected, and smaller in the digital age, new approaches to critical literacy are essential to keep pace with evolving technologies and the innovations that are creating complexities in processing and making meaning in digital spaces.

Fundamentally different to accessing knowledge through traditional print-based books, multimodal texts related to socio-scientific issues on the web offer multiple accounts that differ in scope, argument, and evidence, with sources also varying in their purpose, credibility, and authorship (see Chapter 8 on Infographics and Scientific Literacy). New approaches to literacy can build on traditional reading skills to include critical thinking informed by sophisticated epistemology. In this way, approaches to reading to learn about topical issues online require some recalibration in terms of what it means to make meaning as these texts are not simply substitutes for print-based materials (Furenes et al., 2021).

Such shifts call for rethinking of what constitutes critical literacy for engaging with socio-scientific issues on the internet. This chapter will explore the intersections of evaluative reading, epistemic thinking, and critical digital literacies. Understanding how beliefs shape evaluative judgements is rarely discussed in critical literacy approaches yet is the underlying foundation for developing advanced critical readers. We need to consider what thinking skills should be foregrounded as essential for literacy in the classroom and in societies of the future. To this end, this chapter explores the importance of young people learning the skills to successfully think, evaluate, and make judgements about conflicting sources of information related to topical social issues as they engage in inquiry learning across the curriculum and develop into active citizens in the digital world. This chapter highlights some of the recent developments in understanding the role of epistemic approaches to knowledge and exciting opportunities for advancing young people's stance as a way of recalibrating critical literacy.

## *Socio-scientific issues in the networked world*

Never before have young people been so involved in socially relevant problems informed by science. Engagement with socio-scientific issues is now part of daily life for many children and adolescents across the globe. The rise of Greta

Thunberg as a 'famous' climate change activist has perhaps been pivotal in instigating young people from countries around the world to take a stance on such issues, walk out of class, and march in the streets to demand action. Where previously young people talked about climate change, the latest generation is protesting loudly with strong convictions about their interpretations of the science that they make visible on social media and various web platforms. In the context of issues such as climate change, however, contradictory information, misinformation (false), disinformation (misunderstood), and advocacy for competing theories abound. Much of this 'information' is translated on the net through international and government agencies, activist organisations, and blogs, but is particularly rampant via social media (Lazer et al., 2018). As information is not knowledge, students often have limited literacy skills to make the evidence-based judgements needed to engage as informed and active citizens in such contexts.

As countries look towards schools as a vehicle for teaching about climate change (Beach et al., 2017), nations such as Italy have made sustainability and climate crisis a compulsory subject for school children, and New Zealand's schools are looking to teach students about climate crisis, activism, and 'eco anxiety' (Erskine, 2019). These approaches bring to the fore increasing impetus for teaching critical epistemic literacy. It is essential that young people have a 'cognitive repertoire' – to understand the nature of disinformation to make informed decisions when there is high level of disagreement among experts (Van der Linden et al., 2017) – as well as relevant disciplinary knowledge and critical processing skills for understanding the complexity of issues such as climate change and how to weigh up the reliability of evidence.

An online context where conflict and controversy over information is evident has been heightened by the global pandemic. The internet provides almost unlimited links to opposing arguments regarding COVID-19, from disagreement over the effectiveness of face masks in preventing viral transmission, to competing claims about the promise of certain vaccines and treatments. A recent Google search of the term "corona" returned 3,334,000,000 results (see Figure 3.1) providing almost unlimited potential for misunderstandings. Confusion and the rapid flow of varying information impacts young people at school, in their home, and each and every day in their community, polarising people with different points of view. Instigating ongoing protests and marches against approaches to managing COVID-19, young people's beliefs should be evaluated based on the evidence presented to make informed decisions. This involves the skills to read, decode, synthesise, and evaluate conflicting sources of information that evolve daily.

The rise of 'fake news' highlights the erosion of gauges to filter the trustworthiness of information in the internet age – with concerns about the spread of disinformation now global (Lazer et al., 2018). Much remains unknown regarding the vulnerabilities of young people engaging with new forms of information regulated by algorithms or artificial intelligence that produce biased sources, with new approaches to savvy information consumerism needed. As young

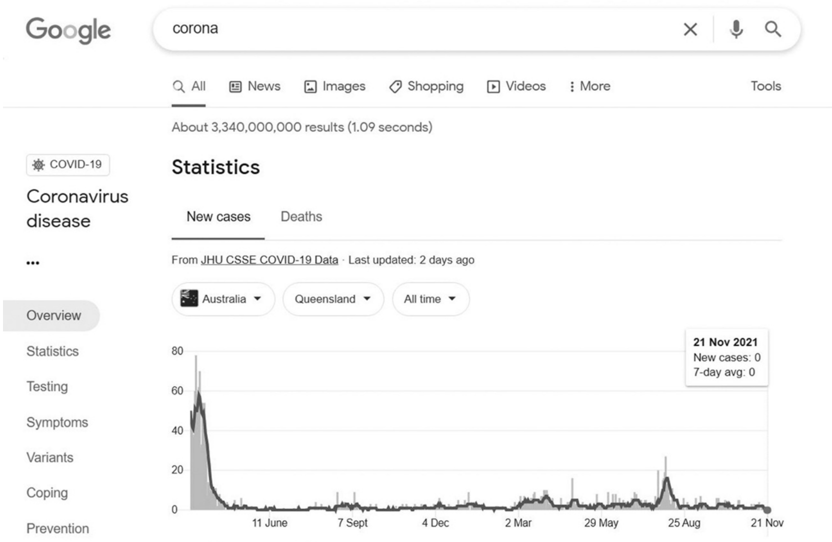


**FIGURE 3.1** Google search results for the term 'corona', November 2021. The high number of search results is shown, with 3,340,000,000 matches

*Note:* Google is a trademark of Google LLC and this book is not endorsed by or affiliated with Google in any way

people engage with online information around socially relevant real-world problems, without sophisticated processing strategies for directing personal pathways and managing the trustworthiness of content, they are bombarded with more of the same. This is because 'algorithmic bias' – a set of rules modulated by computer programs to determine the order in which search results are presented – promotes online content that is aligned with consumers' previous views rather than with trustworthiness, amplifying the psychological phenomenon whereby people prefer to consume information that matches their belief systems. This is known as 'confirmation bias' (Bessi et al., 2014). Internet platforms are also the most significant enablers and disseminators of 'fake news' related to topical social issues (Lazer et al., 2018). Reading to decode and learn from sources on the internet then presents some challenges, particularly when dealing with conflicting sources related to controversial issues.

## *Investigating socio-scientific issues*

Let's take the example of Josie, an adolescent who has been asked to investigate health concerns related to mobile phone use by her middle school science teacher. This socio-scientific issue now confronts adolescents in the 'knowledge/risk' society where scientific knowledge plays an increasingly significant role in their lives.

The controversy here centres on potential health risks and competing claims related to radiation, the 'thermal' effect, and possible links to cancer. As such, mobile phone research is 'science in the making' (Latour, 1987), where young people may have to reason and justify their standpoints concerning trustworthiness and decision making on issues connected to health that are ever-evolving. Josie, then, during her inquiry task will be faced with conflicting evidence, theories, and views about the topic. While some sources claim that low levels of radio-frequency radiation emitted by mobile phones cause health problems such as headaches or brain tumours, other sources will indicate that no conclusive evidence exists that mobile phones are damaging to health in the short or long term.

As Josie approaches the inquiry task by googling mobile phone health risks on the internet, ideally, she draws upon a sophisticated understanding of knowledge to decode texts, navigate hyperlinks, and construct personal reading paths to access, synthesise, and reason about her findings in a multimodal digital space that can make critical evaluation challenging. Reliance on Google is increasing and as of June 2021, this search engine had a market share of 88% (Johnson, 2022) making this mode of exploration an everyday event for many young people. Such an approach in a hyperlinked space brings with it a lot to navigate. As well as print-based skills such as previewing the linear text, making predictions while reading, interpreting the meaning, making connections within and between texts and integrating textual clues with background knowledge, Josie also has to self-regulate her reading pathway amidst endless amounts of information available on the web, avoid distractions by hyperlinks, videos, pop-up advertisements, and the tendency to skim and scroll through texts and evaluate the sources. There is a lot to coordinate and navigate.

Biased information that appears after a search on Google is increasing as the platform interferes with search algorithms and changes results. Google is currently a leader in artificial intelligence (AI), raising problems of bias through its algorithms. Along with promoted sites, algorithms can also adopt personal, political, and information biases (Epstein & Robertson, 2015). Not surprisingly, companies now spend billions of dollars annually in efforts to be placed at the top of search result lists (Econsultancy, 2012) as people generally scan search engine results in the order in which they appear and then become fixed on the results that rank highest, even when lower-ranked results are more relevant to their search (Granka et al., 2004).

Once Josie selects her first web page, she must then decide which hyperlinks she wants to navigate, and in which order. Along with promoted sites, Josie may well continue to encounter the same views that she found in her initial search. Efficient navigation can be influenced by sequencing pages that are relevant for the goal to maintain high semantic coherence between the current and the linked page, avoiding big 'semantic jumps', however, Josie may also decide to just follow her interest or scan aimlessly (Salmerón et al., 2020). Once she has been confronted by several mixed modality sources representing different perspectives or contradicting information about mobile phone health risks, Josie's goal will be the often-challenging task of integrating information across multiple sources (Salmerón et al., 2020). In this way, Josie will become the author of an integrated mental representation by selecting and integrating different pieces of information (Afflerbach & Cho, 2009).

Josie's ability to distinguish the relative trustworthiness of the knowledge claims may rely on her quest for one right answer, or her first-hand knowledge as Josie compares what she has read about mobile phones against what she already believes to be true. People tend to prefer information that confirms their pre-existing attitudes (selective exposure), as this information is more persuasive than dissonant information – they are much more inclined to accept desirable information that aligns with their existing point of view (Lazer et al., 2018). Alternatively, Josie may come to a decision by scrutinising the source of information and questioning who to believe. If she does rely on source information to make trustworthiness judgements, she may consider the expertise or intentions of a source, the date of publication, and the extent to which information accuracy is assured through some criteria for quality check, however, she is more likely to rely on rather superficial cues, such as a professional-looking design (Salmerón et al., 2020; Strømsø & Bråten, 2014). In the end, how Josie approaches her mobile phone inquiry task will be informed by her beliefs about knowledge. Such beliefs will, in turn, influence her learning (Hofer & Pintrich, 2002).

## New directions for critical literacy online: the epistemic turn

As students with sophisticated approaches to knowledge can significantly outperform students with absolutist or black and white thinking (Barzilai & Zohar, 2012) developing epistemic approaches offers a new direction to inform critical literacy for online integration and construction of knowledge. To develop these sophisticated processing skills, we first need to identify the demands on individuals accessing conflicting sources of information online, the processes that support such inquiry, and the role of personal epistemology in the evaluation of both website trustworthiness and the integration of multiple accounts. Then we should turn our attention to how critical epistemic literacy can be advanced for online readers.

Advanced readers actively construct meaning through a set of powerful reading comprehension strategies when confronted with print-based texts, however, we are now learning about the new skills readers use to decode and construct knowledge on the internet (Barzilai & Zohar, 2012; Cho et al., 2018). While there are similarities in the processes required to comprehend via print and on devices, decoding to make meaning in digital spaces is also more complex (Coiro & Dobler, 2007) and involves evaluative reading practices (Fang & Schleppegrell, 2010) along with epistemic skills for self-regulation and processing (Strømsø & Bråten, 2014).

Skilled internet readers draw on their knowledge of the topic and printed informational structures to guide their reading pathways, using inferential reasoning strategies informed by their use of literal matching skills, structural cues, and context cues as they choose what they read, drawing on traditional self-regulated reading processes such as goal setting, predicting, monitoring, and evaluating (Coiro & Dobler, 2007). They also use new, more complex dimensions of reading comprehension as they navigate hyperlinked digital spaces that offer complex website structures and require forward inferential reasoning across multiple and multimodal texts, with the cognitive flexibility for rapid self-regulated reading processes (Mason et al., 2011).

Hyperlinked internet spaces change how information is accessed, organised, and presented. Importantly, young people also need knowledge of sourcing credible and reliable information on the web (Strømsø & Bråten, 2014). Hypertext environments require readers to make choices from a number of alternative sources initially identified by a title, an excerpt of text from a web page, authors' credentials, the logo of the institution that hosts the website, and URLs. While the wonder of the internet is the almost endless amount of information available at one's fingertips, sourcing the 'right' information requires navigation, while evaluating it requires accessing, synthesising, and reasoning about often conflicting views. Reading to learn and construct knowledge increasingly involves evaluative reading practices that rely on epistemic cognition for successful processing (Cho et al., 2018).

## *Epistemic cognition*

To appreciate the role of epistemic cognition in critical approaches to literacy it is important to understand theoretical approaches to epistemology. Epistemology, from the Greek, 'study of knowledge', has focused on defining what constitutes knowledge and discerning it from opinion, faith, and misinformation, while epistemic cognition is a body of work that refers to how people think about what they know (Sandoval et al., 2016). This approach to cognition is gaining increasing recognition in relation to young children's reasoning (Lunn et al., 2017; Scholes et al., 2021), comprehension of multiple texts (Bråten et al., 2011), and argumentation skills (Mason & Scirica, 2006), with some promising implications for online reading and inquiry (Barzilai & Zohar, 2012). In a 'post truth' era of alternative facts, enhancing cognition in the digital world would seem a priority.

Epistemic cognition is activated at multiple points during online inquiry and in judgements made (Mason et al., 2011). Judgements related to sourcing and processing information may be informed by simplistic understandings of knowledge or more sophisticated approaches to evaluation. Drawing on Kuhn and Weinstock (2002), epistemic cognition involves personal beliefs or perspectives that can be described through a range beginning with *objectivist beliefs*, moving towards *subjectivist beliefs*, and then finally developing into sophisticated *evaluativist* beliefs (see Table 3.1). These beliefs then become ingrained in a reader's stance as they approach and process multiple sources online. For instance, in terms of Josie's task related to mobile phone health earlier, her approach to sourcing information would be influenced by her specific stance.

If Josie was to approach reading conflicting sources online from an *objectivist* stance, she may seek out one source of truth that is certain. Online searching may be simplistic and brief as she may not see the value in searching for additional websites in order to integrate information or to deliberate about the credibility of the online sources (Kuhn & Weinstock, 2002). There would be belief in an objective reality which is directly knowable and a certainty of knowledge so that Josie looks for 'real' science without judging credibility or competing claims. A reader who views knowledge this way seeks a single source for information or a range of confirmatory information about a complex topic and accepts this as fact. This then articulates into 'confirmation bias' (Bessi et al., 2014). Readers justify their source of information based on the authority of the site for conveying the right answer or the 'truth' (Barzilai & Zohar, 2012).

As epistemologies advance, Josie may approach reading conflicting sources online from a *subjectivist* stance, approaching knowledge with a belief in many right answers. This inclusive approach values personal opinions and different perspectives as knowledge within individuals, and therefore as subjective and protected from judgement (Kuhn & Weinstock, 2002). Josie would believe that there are many right and valid answers to a problem without any evaluation of these diverse points of view or weighing up of the evidence. This approach can lead to

**TABLE 3.1** Epistemic approaches to knowledge

| *Epistemic stance* | *Approach to knowledge* |
|---|---|
| Objectivist stance | • One right answer, black and white thinking about *knowledge*<br>• Apply *simplistic* strategies to source the '*truth*'<br>• Limited consideration of quality of sources with justification based on passive reception from authority |
| Subjectivist stance | • Many right answers as *knowledge* within individuals so all perspectives valid<br>• Apply *fragmented* strategies to source *'multiple'* truths<br>• Consider a range of different sources with justifications based on personal criteria |
| Evaluativist stance | • Evaluate and construct *knowledge*<br>• Apply criteria to navigate sources and personal pathway<br>• Need to compare and contrast across sources to make judgement to integrate multiple sources to construct knowledge |

*Note*: The table lists the key differences in epistemic approaches to knowledge. The left-hand column lists objectivist, subjectivist, and evaluativist stances. The right-hand column lists three features of each of these approaches.

untethered, fragmented searching on the internet and restless grazing behaviours, with no defined pathway or criteria for searching as all opinions are deemed important. She may rely on simple criteria for inclusion such as website design, author credentials, domain names, or publication date with justification for her sources based on many right answers and personal opinions (Salmerón et al., 2020).

Once sophisticated epistemic beliefs are developed, if Josie takes an *evaluativist* stance – she would justify online knowledge by comparing multiple sources, drawing on criteria for evaluating conflicting perspectives and considering the reliability of the information she draws upon (Mason et al., 2011). The shift to an evaluativist stance includes the need to coordinate objectivist and subjectivist dimensions of knowledge as knowledge is constructed, can be uncertain, and is always evolving (Kuhn & Weinstock, 2002). Evaluativist thinking is a belief in the idea that knowledge is changeable and that ideas can be evaluated from a range of perspectives with the potential for new ideas to be constructed.

From this evaluativist point of view, there is an integration of sources of information and engagement in evidence-based reasoning to inform decision making. Approaching online inquiry from this stance may result in taking a critical gaze to sources and adopting thinking that involves evaluation of conflicting evidence based on criteria to establish trustworthiness and more awareness of bias (Barzilai & Zohar, 2012). Josie's justification of knowledge (e.g. why she believes a website to be credible) is associated with her perspectives on what counts as scientific knowledge and how to approach science learning – rather than finding the right answer, she conducts evaluative sourcing and integration of different perspectives that result in more advanced understanding or knowledge construction (Mason et al., 2011).

Ranging views, or epistemic stances, come into play during everyday actions that involve knowledge judgements and knowledge constructions, potentially informing how young people approach online reading and inquiry (Barzilai & Zohar, 2012). This becomes a manifestation of "theory-in-action" (Kuhn & Weinstock, 2002, p. 134) as readers approach intertextual online spaces. Locating relevant information effectively and efficiently is undoubtedly a crucial ability, but it must be accompanied by an ability to assess the value of online materials to come to reasoned conclusions. When applied to understanding socio-scientific issues that present opposing views and offer conflicting explanations, deciding what to believe and what counts as knowledge or who can be trusted as a source of information requires critical application and thinking (Greene et al., 2016), which are skills that can be taught in early elementary school (Lunn et al., 2017: Schiefer et al., 2020).

## *Beliefs in action*

Epistemic processing is particularly significant for inquiry related to socio-scientific issues, due to the uncertainties and possibilities of the non-linear, intertextual nature of the internet (Mason et al., 2011). Such approaches online include personal perspectives translated into actions of individuals (Kuhn & Weinstock, 2002). Cho et al. (2018) refer to the way beliefs about knowledge and knowing are activated during online reading; accordingly, more successful online readers tend to engage in higher-order *thinking processes* when *judging* information sources, *monitoring* their knowing processes, and *regulating* their alternative knowledge-seeking actions. Cho et al. (2018) describe the way these three processes need to be advanced to improve online reading.

- *Making judgements*. This process concerns readers' ability to evaluate the nature and quality of a source such as trustworthiness. It also includes awareness of how sources interact with one another (Do they agree or conflict?) and personal viewpoints (Do sources make sense or challenge my beliefs?). Successful readers notice source authorities and integrate multiple viewpoints to judge the legitimacy of certain ideas and claims and the sources that represented them, while using evaluative thinking to help them access useful information, assess source reliability, and construct understandings from sources.
- *Monitoring searches*. This process concerns readers' approach to monitoring the decisions they make when searching. It includes choosing where to start first, where to search next, and personal pathways – critical reflection on progress and views on the information intentions. Successful readers approach knowledge as complex and contextual rather than simple and certain, and they think of themselves as active agents able to interact with the situation of reading and to learn from available texts by using the knowledge.
- *Regulating knowledge*. This process concerns readers' regulation of the process of controlling possible actions that can be taken to support confirmation of knowledge and seek out more of the same or additional perhaps conflicting knowledge – evaluation of alternative approaches. Successful readers think about their actions to address their lack of knowledge, revise their current understanding, and build on what they know by accessing additional sources of information.

The key point here is that learners with sophisticated beliefs are more flexible in their adaption of learning strategies for making judgements than readers with naïve beliefs (Bromme et al., 2008). They may have more strategies to draw upon and demonstrate more complex integration of information to construct knowledge – important factors in processes and outcomes of learning (Bråten et al., 2011). From this perspective, advancing students' epistemic stance in the elementary school years would be a priority in educational contexts.

## Implications for educational practice

Epistemic engagement is undeniable in the context of the rapid circulation of multimodal texts from varied knowledge sources, however these higher-order skills – interpreting, making inferences and integrating multiple documents – particularly in relation to pressing socio-scientific issues, can be explicitly taught in the classroom as a new dimension of critical literacy. The internet potentially fosters student thinking as they access intertextual sources in a non-linear space to choose what to read, when to read, and navigate their personal pathways to explore new texts, diverse ways of thinking, and meaning making. Unfortunately, such engagement can also result in limited thinking processing with simplistic approaches and acceptance of unsubstantiated claims online.

Educators can teach critical evaluation of sources and the skills students need, bringing into the spotlight the role of epistemic cognition – or thinking processes related to understanding the fundamental nature of knowledge and how we justify the truth. Dialogic pedagogies are particularly important to advance such cognition (Lunn et al., 2017). Some teachers, however, may over-estimate their students' skills in navigating digital intertextual environments (Kirschner & De Bruyckere, 2017) as students, at all levels of education, often disregard the source of the information and only focus on the content of what they have read (Bråten et al., 2019).

Due to calls to advance students' epistemic cognition (OECD, 2016), there has been increasing interest in approaches in schools (see Trevors et al., 2017). Source evaluation for critical reading is a task that requires cognitive attention to discriminate between trustworthy and untrustworthy sources, and information about individuals and organisations that create and publish content such as when, where, and for what purpose the content is created, as these details are essential to evaluating the credibility, reliability, and value of the texts. This requires a complex cycle of self-regulation and evaluation that students learn to orchestrate.

As students seek out information about controversial issues (e.g. climate change, pandemics, health issues, mobile phone health risks and so on) from a variety of sources they will undoubtedly be presented with conflicting views and need to develop a critical-analytical stance towards reading information. Once they have established credible sources they will then compare, contrast, and make decisions from a critical perspective constructing knowledge from information. These decoding literacies raise challenges especially when they deal with ill-structured problems in the form of controversial issues (Yang & Tsai, 2010).

As noted earlier, successful online readers engage in higher-order *thinking processes* – when *judging* information sources, *monitoring* their knowing processes, and *regulating* their alternative knowledge-seeking actions – that need to be taught. Students' stances can be advanced by reflecting on issues to foster thinking skills for engaging with socio-scientific issues online. Facilitating strategies to make informed decisions, as they analyse, synthesise, and evaluate varied sources of data and information, while understanding the complexity of connections inherent within contextualised socio-scientific issues (Zeidler et al., 2019) is critical. This approach involves student engagement by:

- utilising personally relevant, controversial, and ill-structured problems that require scientific, evidence-based reasoning to inform decisions about such topics; and
- employing scientific topics with social ramifications that require students to engage in dialogue, discussion, debate, and argumentation (Zeidler, 2014 p. 699).

To advance such skills, Schiefer et al. (2020) implemented a science intervention to foster 7–8-year old's epistemic beliefs. The ten-week program involved students actively participating in the scientific inquiry process and reflecting critically on the epistemic issues that arose. While teaching science content was not the goal, related topics were used to illustrate aspects of science that provided opportunities to think critically in an inquiry-based environment. Students worked on topics already covered in their Year 3 and Year 4 classes (e.g. functioning of the human senses; physical experiments about speed, research in a student neuroscience laboratory).

Each science topic began with fully guided experiments and direct instruction, followed by structured inquiry, and guided inquiry that then transitioned from hands-on activities to more complex processes of reflection and thinking about knowledge and knowing (Schiefer et al., 2020). Exercises and demonstrations (in pairs or with the whole group) were conducted with an active inquiry phase (in groups of two to three children). Reflection on results and inferences was supported through group activity, guided by the educator. Making time and space for these dialogic exchanges, deliberations about evidence, and personal interactions is critical (Lunn et al., 2017).

Schiefer et al.'s (2020) science intervention positively affected students' epistemic beliefs and their stances about the certainty, development, and justification of knowledge – with shifts towards an understanding that scientific knowledge is tentative and evolving rather than certain and fixed; complex and interconnected rather than piecemeal; justified by appeals to evidence and coherence rather than authority; and, constructed by people rather than perceived in nature (Elby et al., 2016). After facilitating such a program, students can then have meaningful discussions to engage in explorations into knowing and productively discuss their disagreements based on their research findings (Chinn et al., 2020).

Drawing on evidence and sources of information students can engage in informed *dialogic argumentation* about alternative perspectives and justify their claims – leading to a better grasp of how scientific practices are evaluated and what kinds of arguments are relevant to evaluating them. *Dialogic argumentation* is an important avenue for developing competencies in identifying and weighing positive and negative attributes of conflicting perspectives on a particular issue, taking relevant reasons and evidence for the different perspectives into consideration (Kuhn & Crowell, 2011). This is an essential feature of scientific reasoning – the ability to construct arguments that relate claims to evidence is also important in informal contexts where people have to make rational judgements about controversial socio-scientific issues (Yang & Tsai, 2010). When coming across contradictory views on an issue, students should consider which claims can be justified as knowledge.

Engaging in controversy, educators can teach disagreement as a genuine, unresolved controversial issue on which even expert views diverge (Chinn et al., 2020). This type of interaction between peers who hold an opposing position on a socio-scientific topic can support development of students' skills as they produce two-sided rather than one-sided arguments (Crowell & Kuhn, 2014). As students become familiar with engagement in critical thinking, they can then move to sourcing further information online to integrate multiple texts on the same topic (Bråten et al., 2019). This processing can be taught – for instance, to Josie who has been given the task to research mobile phone health risks – by scaffolding research on a topical issue as she comes to *judge* information sources, *monitor* her knowing processes, and *regulate* her alternative knowledge-seeking actions (Cho et al., 2018). As Josie goes about her task to report on health concerns related to mobile phones, she can be supported to move through a number of steps:

- First, set goals based on the instructions, formulate questions, plan tasks, and map out a sequence to complete her report.
- Then, assess the information she needs. This may include getting her to think about her epistemic stance (she may need to be supported to move beyond seeking one right answer, many right answers, to evaluate knowledge). Her epistemic stance will influence her personal online reading pathway, including initial sourcing.
- In the next step, as she *judges* information her approach to knowledge can be supported to move from objectivist and/or subjectivist to an evaluativist stance. This will influence her consideration of the features of the sources such as trustworthiness of websites, credentials of the authors, and criteria for validity of information. Here, issues of confirmation bias can be addressed as Josie comes across information to support her own beliefs.
- Next, Josie uses the resources to generate her report. Her approach to knowledge is important for *monitoring* as she interprets the content to check if she has met her goals based on her epistemic beliefs. Can she find evidence beyond one right answer or 'truth' (objectivist), different opinions that all seem to have merit (subjectivist), to evaluate the information based on criteria such the credibility of sources or evidence (evaluativist)?
- In the final step, Josie reviews her report and is supported to present arguments and counter-arguments related to her topic and synthesise her findings. Entering into dialogic discussions with others at this stage will determine whether her goals have been achieved or whether she should re-cycle through previous processing steps to *regulate* alternative knowledge to achieve her goals.

Reflection on findings and inferences supported through dialogic interactions with peers and Josie's teacher will help her develop justification of knowledge – with shifts towards understanding that scientific knowledge is tentative and evolving rather than certain and justified by evidence and coherence.

Promising for educators, are positive relationships between beliefs in the need to evaluate and construct knowledge, learning on the internet and integrating sources related to socio-scientific tasks (Barzilai & Zohar, 2012). In this way, if young people believe in checking knowledge claims against other information sources, they can develop adaptive strategies to use for web-based inquiry learning (Chiu et al., 2013).

## Critical issues in approaches to evaluation of socio-scientific issues

Reading and evaluating sources of information on the internet related to socio-scientific issues can create tensions due to moral dimensions and individual disagreement. Societal dilemmas require advanced skills to evaluate information and moral reasoning skills that can be challenging for young people. A core 'post-truth' challenge is how to overcome the prevalence of deep disagreements between individuals about ways of knowing (Chinn et al., 2020). Moral reasoning involves the complex coordination of various beliefs (Scholes et al., 2021) as evidential reasoning (evaluating competing value claims and making a judgement based on the evaluation of such claims) that requires dialogic argumentation skills to effectively reason about a range of moral and social concerns (Reznitskaya & Wilkinson, 2017)

The ethical considerations of many socio-scientific issues (such as genetic engineering involved in cloning and gene therapy) have moral dimensions. For young people to make informed decisions regarding socio-scientific issues, they have to consider the moral ramifications (Zeidler et al., 2019). Many ethical questions may be raised, for example, in relation to the right for parents to alter the genetic composition of their children, or whether the human genome should be subject to artificial manipulation. To reach a conclusion, individuals draw on moral and ethical dimensions of socio-scientific issues and establish efficacy of justifications. This is evident in other contemporary issues as well.

Climate change is another such scientific issue and has been referred to as a 'perfect moral storm' as it brings together major challenges to ethical action in a mutually reinforcing way (Gardiner, 2011). For instance, climate change is a global phenomenon, with inter-dependence between nations with different vulnerabilities, inter-generational implications for decisions made now, and questions about the moral value of nonhuman nature, such as obligations to protect unique places. Facilitating strategies to make informed decisions, to analyse, synthesise, and evaluate varied sources of data related to socio-scientific issues often includes an ethical issue, adding complexity for young people (Zeidler et al., 2019).

At the same time, socio-scientific issues are contentious. Science is always open to new evidence. The great philosopher Karl Popper (2005) revolutionised contemporary thinking on science and knowledge, arguing that scientific knowledge is not the search for certainty as all human knowledge is fallible and therefore inherently uncertain. This position offers a myriad of questions: How will new technologies influence what is known in the scientific realm or potentially challenge long-held facts? What new dilemmas will arise with the raft of technology coming on the market that may change science endeavours forever? While once a bionic eye was the mainstay of science fiction, in 2021, an Israeli surgeon implanted the world's first artificial cornea into a bilaterally blind man (Solomon, 2021). What new ethical dilemmas might result from such scientific advances?

Personal approaches to evaluating knowledge, particularly related to socio-scientific issues, are complex and are also open to transition and change. As individuals move through life, their epistemological stance can change or be specific within a particular domain. Approaches to reasoning are understood to vary across a wide range of social contexts as individuals coordinate different forms of reasoning, values, and emotions with contextual and cultural variation in moral and non-moral social reasoning (Lunn et al., 2017). How best to prepare young people to critically evaluate multiple sources of information to equip them for their digital futures and for active participation and citizenship in the 21st century is therefore debated. While there are clear advantages to developing epistemically informed literacy skills, such approaches are relatively new, and scholars continue to discover understandings about best practices.

## Recommendations for research

Advancing research related to decoding sources of socio-scientific texts online is not only a matter of improving student disciplinary knowledge on topics and academic achievement in science and English subjects, but also a matter of educating for critical epistemic literacy. Eye-tracking software, for example, opens up opportunities for exploring more deeply how young people engage in internet searches as they explore hyperlinks, make decisions about personal reading pathways, and compare conflicting sources. Researchers can follow participants' eyes during online tasks and get insight into the processes underlying behaviours to reveal patterns of inquiry, learning, and interactions. Such software can capture this immersive exploration that results in exciting multimodal engagement and connections to things that were never possible.

As students tend to assume that information on the internet is true and have to learn about the nature of the internet to become critically informed, more sophisticated understandings of students' approaches as they engage in inquiry tasks can inform educational practice. Even good readers can spend an inordinate amount of time searching the internet and not be skilled at critically selecting online sources and developing reliable knowledge from information (Woodward &

Cho, 2020). We urgently require new knowledge to inform approaches to reading about controversial issues such as science-informed social problems.

How to prepare teachers to advance their students' thinking to engage in evidence-based evaluation of socio-scientific issues presents a gap in the research. Young elementary-aged children are more ready to advance epistemology than previously thought (Lunn et al., 2017; Schiefer et al., 2020). Teachers' beliefs, particularly their thinking about epistemic aims and reliable processes for achieving those aims may impact students' understanding of complex, controversial issues (Bråten et al., 2017). This is because teachers' beliefs may facilitate or constrain their implementation of strategies aimed at engaging students in reasoned argumentation through classroom dialogue. Discussions of teacher knowledge rarely query educators about the knowledge that they need for teaching and few studies probe their beliefs about the nature of such knowledge (Fives & Buehl, 2010). To address this issue, further work is essential to examine the connections between teachers' beliefs and the epistemic beliefs they foster in their students. This may require examination of how teachers reflect on their own beliefs in the context of dialogic-based instruction in order to calibrate it with the aim of deep understanding and the reliable process of reasoned argumentation for their students (Bråten et al., 2017).

More research, new data, and exploratory theories are also critical due to the rapid pace of evolving real-time information avenues and opportunities for learning. While algorithms and AI are part of everyday googling, what does the future of the Internet of Things (IoT) for example present? IoT integrates the interconnectedness of human culture with digital information systems – the internet – and young people will be able to have increasing access to endless information. Information, however, is not knowledge. What will be the role of reading in the digital future and how do we conceptualise evaluative critical reading in such a world? We argue decoding and evaluating conflicting texts online may need to become part of a new critical epistemic literacy paradigm.

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# 4

# WHY VIDEO GAMING IS AN IMPORTANT DIGITAL LITERACY PRACTICE

Amazing innovations in technology continue to advance video gaming experiences for children and young people around the world as they engage in immersive digital literacy practices. Each new generation of game adds to the excitement of the gaming experience, with ever-evolving high-fidelity graphics, facial and voice recognition, and new inclusions such as gesture control. Virtual reality (VR) headsets, wrap-around display screens, rooms augmented with wearable computers, and sensorial experiences related to scents and haptic devices are features games utilise to simulate real-world experiences. Advances in artificial intelligence (AI) generate sophisticated games that change and respond to player feedback, generating adaptive experiences that require cognitive flexibility and decision making by players.

And what about the potentials of cloud gaming? Instead of creating video game systems that require more powerful hardware, developers spurred on by the potentials of massive cloud servers have developed technology that allows sophisticated images to be streamed to a screen through the internet. Children and young people with internet connections no longer need devices such as an Xbox to play games, as cloud gaming streams to a range of devices, such as smartphones, tablets, and PCs. Such advances offer higher accessibility and more opportunities for young people to engage in thrilling play. Many young people spend their time in such digital spaces at home, and increasingly in schools, whether it is play through mobile applications (e.g. *Candy Crush*), online multiplayer sandbox modes (e.g. *Minecraft*), or virtual interaction with cultural places (e.g. *Assassin's Creed Odyssey Discovery Tour: Ancient Greece*). Likewise, gamers can now engage in simulations of real-life experiences (e.g. *The Sims, Real-Life*), action games that emphasise physical challenges (e.g. *Call of Duty*), educational

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games that promote coding (e.g. *Roblox Scratch*), or environments that merge construction genres and shooter games (e.g. *Fortnite*).

Understanding the affordances of gaming for literacy education is important as the gaming industry shows no signs of slowing down – the total number of gamers is currently estimated at over three billion across the globe (Clement, 2021). This is reflected in the number of Esports enthusiasts – multiplayer video games played competitively for spectators – that currently stands at 400 million, and growing (Gough, 2021). Young people make up a large percentage of Esports players with competitions based on video games growing rapidly in schools in the US, the UK, Australia, New Zealand, Asia, and beyond. For instance, the Federation of United Schools Esports – FUSE – Cup is a large international network of schools providing young students with an opportunity to participate in Esports competitions from the Asia Pacific Region (Australia, New Zealand, and Asia). There are three age divisions catering for children across the school years – Years 5 & 6, Years 7 & 8, and Years 9 & 10 (https://www.thefusecup.com.au/about-us).

Individual schools are also getting in on the action and creating networks, with *Kids in the Game* bringing Esports to New York City middle schools by creating an inclusive league for 16 schools across the city (https://www.kidsinthegame.com). Esports is also moving into the main arena of play throughout the US, with Esports degrees available at several tertiary institutions including the University of Kentucky and The Ohio State University, while Marquette University launched the nation's first Esports team at the highest level in college Esports in 2019 (ManpowerGroup, 2021).

Unprecedented numbers of children engaging in gaming offers the potential to foster students' critical literacy in virtual spaces (Qian & Clark, 2016; Scholes et al., 2021). From this perspective, immersive gaming literacy experiences facilitate embodied cognition and extend real-life time and space (Freina & Ott, 2015). Engagement in video game spaces not only develops literacy skills as players read, decode texts, and comprehend story lines, such spaces also offer opportunities for an epistemological shift in learning away from the acquisition of facts that are right or wrong, towards constructivist spaces of self-generated ideas that can be tested. As part of play, beliefs about knowledge come to the fore as gamers deliberate, comprehend, make decisions, and act in games (Gee, 2007). Decision making to solve problems demands critical thinking or sophisticated epistemology. These opportunities can develop and trial epistemic skills that support the development of 21st-century literacy skills (Qian & Clark, 2016). While dramatically different to traditional educational priorities, 21st-century skills include critical thinking for reasoning, systems thinking, computational evaluation, decision making, and problem solving (Binkley et al., 2012).

Gaming skills relate to these 21st-century skills that are prioritised in the workforce. As advanced economies transition from manufacturing to information and knowledge services, technology is transforming the nature of work with a focus on information sharing, teamwork, and innovation, with success measured by the skills of people enabled by technologies to use information to solve real-world issues. Video games have the potential to advance such problem-solving skills and cultivate the soft skills that are increasingly valuable as automation and machines perform more routine tasks, while making many careers obsolete in the future (Adachi & Willoughby, 2013; Mann et al., 2020). Such play improves critical thinking, creativity, emotional intelligence, and complex problem solving – soft skills that are hard to find and even harder to train (ManpowerGroup, 2021). An estimated 43% of employers are finding it difficult to teach the soft skills they desire, such as collaboration, communication, and the ability to learn skills that can potentially be developed through gaming (ManpowerGroup, 2021). Even the military is hiring gamers in their quest for soldiers who can assimilate information, react swiftly, and coordinate actions (Molloy, 2019).

The skills developed through game play are highly valued in futures-focused schools, with qualities developed through gaming that are transferable to the workplace (ManpowerGroup, 2021). Games that require strategic thinking and problem solving can translate to real-life problems and solutions. The future calls for a transformation of teaching and pedagogy that supports learners in developing thinking that involves boundary crossing, inter-domain knowledge, and flexible cognition that can be readily applied to unfamiliar problems (Harris & de Bruin, 2018). These skills can be supported through teaching approaches that maximise students' inquisitiveness to learn, immersive experiences that provide immediate feedback, and experiences embedded in real-world engagement (Gee, 2007).

As the gaming industry continues its skyrocket in growth in the coming years, and young people engage in increasingly complex and demanding cognitive, linguistic, and socio-cultural practices generated by game play, the potential of video games for 'hard fun' or 'serious play' has important implications for education (Beavis, 2015). While connections between video games and text-based literacy learning have long been recognised in education, the skills children develop through in-play decision making in terms of critical literacy, potentials for developing the thinking skills needed in 21st-century classrooms across the curriculum, and preparation for modern work–life trajectories have not yet been fully understood. Re-calibrating an epistemological shift moves beyond young people's acquisition of facts that are right or wrong.

While traditional educational practices emphasise one right answer to a problem (objectivist epistemology) within a framework of high-stakes testing reinscribe conformity and standardisation (Plucker & Makel, 2010), video game play has the potential to advance digital literacies and provide opportunities for engagement in situated, active, problem-based learning environments. These virtual environments offer creative spaces for trialling alternative pathways and new innovations, or multiple right answers to a problem (subjectivist epistemology), while working in teams or through individual endeavours. Players acquire practices and ways of thinking that are innovative for trialling alternative approaches to real problems. In this sense, well-designed games are more than immersive virtual worlds that can accommodate a myriad of possibilities, where experiential learning allows participants to learn by doing, taking actions, accomplishing tasks, and by thinking and making decisions that have consequences. In this way, players engage with ways of knowing that impact on their experience – essentially learning to think in innovative ways.

In the preceding chapter (Chapter 3), we looked at critical literacy skills for engaging in hyperlinked internet spaces and sourcing information on the World Wide Web. In this chapter, we consider some of the advances in video games that provide opportunities for critical literacy as players decode, evaluate, and make decisions in collective spaces of self-generated ideas. Drawing on gaming examples, we illustrate how educational change necessitates a reconceptualisation of knowledge goals that goes beyond the technological or pedagogical to envisage how video games can facilitate the epistemological. We argue for new conceptions of learning environments in education spaces that draw on and develop student expertise and digital literacies related to video gaming. This approach provides a response to future needs for digital knowledge creation and answers to key questions about how to foster and develop new knowledge and critical literacies for the future.

## Advances in video games and implications for epistemic thinking

Big tech companies are taking advantage of gaming phenomena and investing heavily in the development of gaming products. While video games were once thought to be the domain of geeky males, expanded market demographics have made video games mainstream to the point where people are playing games earlier in life, and the gender binary is blurring. Emerging technologies that are taking video games to new heights provide increasing opportunities for players' critical engagement as they assess the context, evaluate multiple options, work collaboratively, make decisions to solve problems, and constructively innovate and contribute new knowledge.

Knowledge – or how players think about knowledge – is important for playing video games. Theorists propose that individuals start out thinking about knowledge in objective terms, where knowledge claims are either true or false (Kuhn et al., 2000; Kuhn & Weinstock, 2002). They may then shift to a subjectivist perspective, where knowledge is considered uncertain, given many possible answers. Finally, some will become evaluativist, accepting knowledge as constructed and uncertain, but believing that knowledge claims can be evaluated against established criteria (see Chapter 3 for a review).

Engagement as a player in most video games involves a range of tasks that are epistemologically demanding and require rational decision making under uncertainty, pursuing the best course of action in light of one's beliefs or information (Peterson, 2009). Avid players' thinking processes become more efficient as they collect visual and auditory information to inform their decision making in the game. This process occurs much faster in gamers than non-gamers (Bavelier et al., 2011). Decisions are never black and white, as the brain is always computing probabilities that require evaluative critical thinking skills (Bavelier et al., 2011). In this way, experiences in gaming spaces can advance 21st-century skills required and necessary for educated citizens to think critically about complex, controversial issues (Greene & Yu, 2016). Video games offer opportunities for students to learn using techniques of innovation – ways of learning that facilitate immersion in a practice (Shaffer & Gee, 2005). These skills have application across the curriculum, which will be discussed in more depth throughout the chapter.

## *Epistemic video games*

When thinking about gaming and epistemology, the first thing that comes to mind may well be 'epistemic games'. This chapter, however, makes a clear distinction between the broad epistemic skills players draw upon (beliefs about knowledge and knowing) as they engage in a wide variety of mainstream video games, and traditionally defined epistemic games – games that enculture players into a way of thinking about a problem that is particularly relevant to a specific profession.

Traditional epistemic games are designed around a profession that has a culture composed of skills, values, knowledge, identities, and an epistemology that anchors how professionals operate (Shaffer, 2009). Nurturing a player's way of thinking in a defined context, these games teach skills that prepare individuals for the complex thought processes required in high-level professions, such as surgery, urban planning, and mechanical engineering. Opportunities are afforded for students to role-play professions and prepare for life outside of school. Players learn knowledge through action in specific contexts – as they make knowledge, apply knowledge, and share knowledge (Shaffer & Gee, 2005).

Games that are epistemic in nature have been designed to be instructional. For instance, Nephrotex, developed by the departments of Biomedical Engineering, Engineering Physics, and Educational Psychology at the University of Wisconsin, was created for first-year engineering students to allow them to engage in a virtual internship in a fictitious biomedical engineering design firm. The students face real-world stakeholders, such as collaborating engineers, marketing and product representatives, and feedback from focus groups as they make choices and create their designs in the game (Chesler et al., 2013).

Key to the design of epistemic games is the player's unique ability to engage in the environment as an autonomous character, as the freedom to develop a character engages and promotes ownership of the environment (Annetta, 2008).

Devlin (2011), a mathematician who launched the company BrainQuake to create mathematics learning video games, aimed to develop players' mathematical thinking and ability to adopt the identity of a mathematically able person. This requires moving from skill-and-drill questions to involve the player in genuine mathematics problem solving within the game environment – moving into the epistemic realm. This skill is increasing in demand as young people and future workforces need the ability to take a novel problem that is not well-defined and does not have a single 'right' answer (objective epistemology), and make progress with it, while coming up with alternative answers (subjective epistemology).

While epistemic games traditionally have a narrow definition, emerging mainstream games also include strategic play, with knowledge in complex domains based on the study of disciplinary communities, such as the social, physical, and biological sciences. While not designed as an epistemic game, *Minecraft* has been used in classrooms and with young people around the world to advance disciplinary knowledge (Lane & Yi, 2017; Short, 2012). *Minecraft* is constructionist in its nature, offering a different style of instruction than is typically employed in many classrooms (Cipollone et al., 2014). It is a multiplayer sandbox video game, meaning there is no linear narrative structure to guide players. In a similar manner to other sandbox games, such as *The Sims* (strategic life simulation video game), players achieve success as they experiment within the environment, individually or with multiple players. The *Minecraft* environment, however, is graphically very simple and encourages more interaction with naturalistic agrarian activities (e.g. mining coal, crafting shelters, or harvesting wheat) and urban environments (homes, buildings, cities, or public spaces). Like a virtual world of Lego, it invites players on a range of devices (see Figure 4.1) to create their own world of buildings, villages, and other spatial elements – lending itself to real-world applications in creative fields such as public space planning.

*Minecraft* has been used by the Block by Block project (https://www.blockbyblock.org), initiated in Sweden in 2013, to develop urban workshops to include youth in urban design. For instance, this process was used to design the first skatepark in Kosovo, one of the poorest areas of Europe. Other community projects have included young people in designing public spaces. Examples include the designing of a dump site (Nairobi), a park design (Gautam Nagar, Mumbai), a Market Hall development (Mogadishu, Somalia), and a playground (Gaza) (see Figure 4.2).

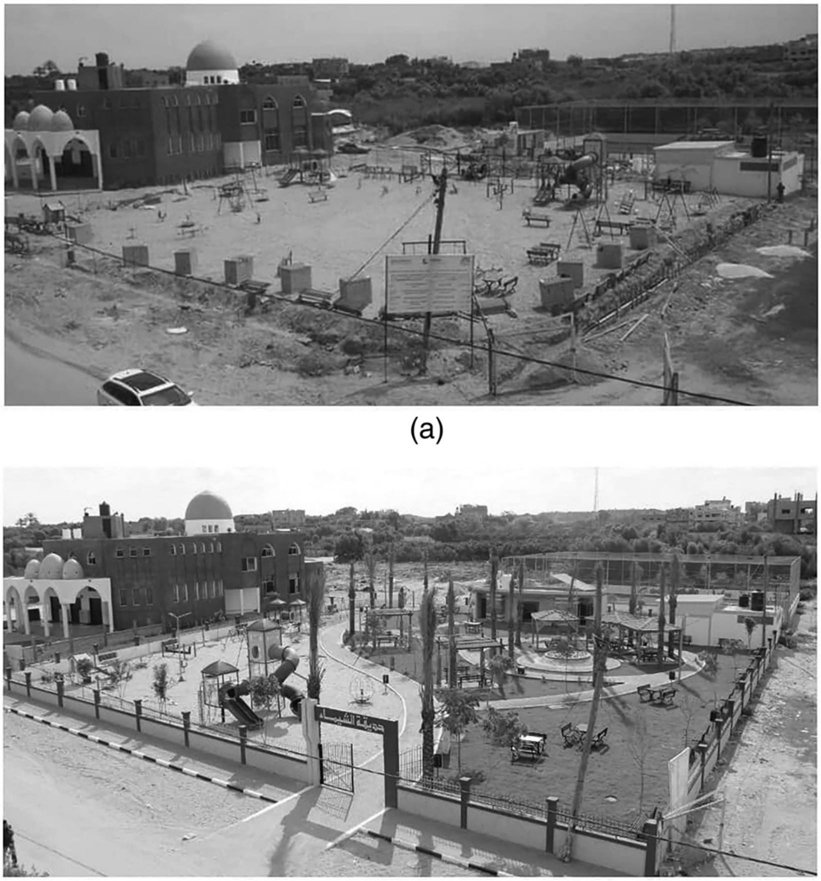
Using *Minecraft* to engage with communities across the world, individual projects engage young people who do not typically have a voice in public projects. Block by Block provides the training, the tools, and the *Minecraft* platform to participate, contribute ideas, and develop innovations through a collaborative process that helps all participants expand their perspective. This approach was used in a community project in San Paulo, Brazil (see Figures 4.3a, 4.3b, 4.4a, and 4.4b).

**FIGURE 4.1** *Minecraft* can be accessed on mobile devices
Photo by Mika Baumeister/Unsplash

*Minecraft* also provides a space for teams to try out ideas, present models, and advocate for their ideas to stakeholders and professionals including urban planners, architects, and local policy makers. In this way, young people have opportunities to think and act like urban planners, and to build the skills that are so important in 21st-century workplaces.

## *Serious video games*

Perhaps you may also think about 'serious games' when considering the epistemic nature of gaming. Similar to epistemic games, serious games are not designed for pure entertainment, but for training or skill development in industries like education, health, medicine, science, the military, city planning, and engineering. One nuance between traditional epistemic and serious games is that the 'serious' application articulates into education, defence, aeronautics, science, or health for the purpose of training to teach skills. These skills may not be epistemic related and may be drill-and-skill. They also tend to include fundamental elements related to game dynamics, such as rankings, rewards, badges, or points systems that are intended to motivate players. For instance, *Duolingo* helps users learn English, Spanish, French, or German as they receive points, go up to the next level, lose lives, or outdo their friends and relations.



(a) (b)

**FIGURE 4.2** Community design © UN-Habitat. (a) A playground in Gaza designed using *Minecraft* – before (b) A playground in Gaza designed using *Minecraft* – after

(a) (b)

**FIGURE 4.3** Community design © UN-Habitat. (a) *Minecraft* used in community urban design in Brazil – before. (b) *Minecraft* used in community urban design in Brazil – after

(a) (b)

**FIGURE 4.4** Community design © UN-Habitat. (a) *Minecraft* used in community urban design in Brazil – in progress. (b) *Minecraft* used in community urban design in Brazil – final *Minecraft* design

VR environments have been excluded from many educational settings due to the high cost of the equipment, with their usage over the past 50 years restricted to military applications and research institutes (Checa & Bustillo, 2020). Cost issues may also preclude their use in some mainstream school contexts where they could be most valuable. The launch of new high-quality affordable hardware and software media for VR since 2015, however, has boosted opportunities for such applications.

While serious games with VR options can improve user experiences, and therefore knowledge acquisition, this environment is still an emerging field. New questions continue to arise about the best way to design efficient serious games for such environments (Checa & Bustillo, 2020). Many games, however, are already moving into the VR space, with *Minecraft*'s VR version enhanced for playing solo or with friends. The platform includes 3D audio, a virtual living room mode (for a break from the first-person perspective), VR Turning (head swivelling motions), and VR Controls (to make in-game tasks easier).

New cutting-edge VR environments present highly learner-centred environments for serious game platforms that produce immersion and interactivity. These experiences can create situations that could not otherwise be experienced in real life, including ethical dilemmas, dangerous, and even impossible situations in terms of time and space (Freina & Ott, 2015). Players feel in control of an interactive learning process that facilitates active and critical learning. Role-playing through VR has been used in therapeutic contexts, conflict mediation, restorative justice, and many other fields to help participants visualise events and conflicts from the perspective of others (Bertrand et al., 2018). VR supports multisensory and motor stimuli in synchronicity with the first-person perspective of an avatar, so that players feel they have swapped bodies with another person through multisensory stimuli (Maselli & Slater, 2013). Manipulations of the senses can be used to modulate empathic responses with significant plasticity of empathic abilities even decreasing implicit racial biases (Peck et al., 2013). The ability of immersive VR to displace the first-person point of view relates directly to perspective-taking from another point of view – potentially fostering the ability to see alternative perspectives.

Serious games have also been touted as an avenue for fostering empathy. Players have the simulated experience of walking in someone else's shoes through the illusion of embodiment. Empathy, as an affective state, results as an interlay of multiple neural circuits related to motor, cognitive, emotional, motivational, and behavioural functions (McCall & Singer, 2013). Enhancing empathy in children has the potential for further developing social skills, such as interpersonal communication, problem-solving abilities, and emotional regulation, as well as other empathy-related phenomena, including perspective-taking. This allows children to better understand and learn from the actions of others (Bertrand et al., 2018). Role play in life simulation games, such as *RealLives*, can foster empathy because it allows players to inhabit the lives of individuals around the world. Students who play *RealLives* as part of their curriculum can potentially show more global empathy (observed in their identification with the characters played), and greater interest in learning about other countries (Bachen et al., 2012).

*RealLives* provides a simulation, where players test themselves against the many unpredictable life conditions that occur in the course of a lifetime – from birth to death. You can choose your occupation, living conditions, social activities, and start families, but all decisions can be affected by random events such as floods, outbreaks of war, disease, car accidents, and other major life-changing events. Players are given 11 attributes that include health, resilience, happiness, intelligence, artistic, musical, athletic, strength, endurance, spirituality, and wisdom, but these change through events and decisions in the game. The scenarios that play out over the course of the player's life are directly elicited from the data of the country in which the character resides, with tools available to learn about the culture, socio-economic conditions, and other metrics of the country of the character's birth in the game. This also provides a realistic narrative of various cultures, and political and economic systems. *RealLives* play allows individuals to try out options where there is no one right answer (objectivist epistemology), but multiple right options (subjectivist epistemology), with decisions that flow into different trajectories with associated consequences.

Many games also focus on physical or virtual interaction with a cultural or historical place and its objects. Games related to cultural heritage issues that are used in formal education still have many challenges, particularly related to effective storytelling and the evaluation of the effect on student learning performance (Malegiannaki & Daradoumis, 2017). The *Discovery Tour* game series that includes *Assassin's Creed Odyssey Discovery Tour: Ancient Greece*, released in late 2018, has made inroads in presenting a game designed with a lavish budget and informed by historical research. In *Assassin's Creed Odyssey*, you can choose to play either as a male (Alexios) or a female (Kassandra) – two siblings separated from their Spartan parents during childhood. When choosing to play as Kassandra, players take on the role of a young, ambitious, vigorous, frustrated character living on a remote island. As she sets out to search for her real parents, her memories suggest a traumatic separation and many unanswered questions. She knows how to fight; however, she also enjoys exploring the world and creating new friendships and possesses a sense of humour. The writers have succeeded in creating a character that players connect to, because Kassandra also possesses arguably human flaws, including naiveté, anger, and social awkwardness.

While playing *Assassin's Creed Odyssey*, gamers travel virtually to over 300 educational stations found throughout the map and learn history through characters portrayed in the Odyssey games, including the Spartan warrior king Leonidas, the historian Herodotus, and Barnabas, who served as a naval captain during the Peloponnesian War. *Assassin's Creed Valhalla*, launched in 2020, similarly offers an action role-playing experience for players, but this time the story is based on the Viking expansions into the British Isles. One of the many lessons that can be learned through these games is to listen when someone says something in the game that is important to them, no matter how difficult it is to perceive from the player's personal position or point of view. Learning about subjectivist positioning is also an element of multi-player games.

## *Action and multi-player video games*

Action and multi-player games, by their very nature, also have epistemological implications.

To be a successful multi-player, gamers need complex skills to select the best course of action in light of one's beliefs and the information available to them (Peterson, 2009). The consequences of one's decision depend on the choices of the other players involved in the situation and the context and are interrelated with pathway choices. In this way, while not always intentionally planned, many mainstream popular video games provide rich spaces for developing and trying out epistemic skills. Playing video games is associated with improved multi-tasking, memory, attentional control, critical thinking, and problem-solving strategies (Qian & Clark, 2016). Action games also promote creativity and the ability to develop new cognitive learning templates (learning to learn), due to enhanced perception, attention, and cognition to become better players (Bejjanki et al., 2014).

The potential benefits of video gaming are increasingly being documented, particularly in terms of the skills young people learn that translate to educational domains and workplace skills for the future (Muriel & Crawford, 2018). Advances in action games offer opportunities for fostering decision making and problem solving, and produce improved cognition related to critical thinking (Powers et al., 2013). Some have argued that action video game players can become more efficient collectors of visual and auditory information, and they therefore arrive at necessary thresholds of information they need in decision making much faster than non-gamers (Bavelier et al., 2011).

Playing action video games such as *Fortnite* trains young people to make decisions faster. Decision making is crucial to success as every scenario is unique, and there are endless decisions to be made during a match. There are even YouTube clips on how to improve decision making in the game. Tips include reviewing decisions and watching replay highlights to evaluate what could have been done better. Just like most things in life, decision making has consequences and players can learn through the experience of past mistakes. Improvement takes place as players develop a heightened sensitivity to what is going on around them, advancing their playing skills (Bavelier et al., 2011). *Fortnite* is not just a video-game shooter – it also has a creative sandbox mode in which users can create their own custom maps and game modes. This mode has the potential to encourage creativity and teach problem solving and engineering, similar to *Minecraft*.

Action game play substantially improves performance in a range of attentional, perceptual, and cognitive tasks (Bejjanki et al., 2014). While many multi-player games have a strong competitive focus, there is also considerable co-operation between players that can be understood only in the context of the situation. For instance, *Fortnite* is often played in duos, four-player 'Playground Mode', or in teams, where the casual and social nature of this game reinforces existing social relationships and provides opportunities to learn teamwork, collaboration, strategic thinking, spatial understanding, and imagination (Carter et al., 2020). In multi-player games, knowledge and information are shared between players using digital game paratexts and online communities (Apperley & Beavis, 2013). This knowledge exchange may be facilitated by co-operation, or it may involve a more direct mentorship, as a more experienced player leads another through a difficult part of the game. It may also involve the need to evaluate the best course of action given the available information (Peterson, 2009).

Regular action players also demonstrate perceptual templates better tuned to the task as they focus and centre attention (Bejjanki et al., 2014). Increased attention can aid faster visual search rate, a reduction in the size of the attentional blink, better change detection, and an increase in the number of items that can be simultaneously tracked. This attention control can also lead to improved performance in high-level cognitive tasks, such as mental rotation and multi-tasking, with benefits carrying over to real-world domains, given that pilots and laparoscopic surgeons have been shown to outperform their peers after fast-paced, action-packed video game training (Chiappe et al., 2013).

It may be that action games change the brains of players. Regular action players appear to be able to suppress distracting information better, allowing for increased focus on the goal at hand (Mishra et al., 2011). And they may be more efficient at directing attention during a demanding task, requiring attention networks to work less hard to perform at the same level of ability (Bavelier et al., 2011).

Now that we have looked at some specific examples of games that promote epistemic thinking, we turn to how these games can be utilised to promote both content knowledge and soft skills in classrooms.

## Video games for advancing critical literacy in educational contexts

The learning benefits of playing action video games as students make decisions and exert cognitive control to focus attention on a task goal are promising for education (Bavelier et al., 2011; Prensky, 2010). The metacognitive skill of learning to learn and cognitive flexibility to navigate a new learning goal also have important applications in the classroom. We argue that the opportunities to evaluate information and make informed decisions in game play also have implications for advancing epistemic skills. Cultivating critical literacy skills for classroom and real-world learning allows students to try out and advance their epistemic positioning by taking on different perspectives and evaluating different action options.

Early theorising explored the potential affordances of video games in school-based learning environments within the context of new technologies (Beavis, 1998; Gee, 2007; Ito et al., 2009; Jenkins, 2009; Prensky, 2010). Arguments were made that video games, as texts, belonged in the literacy classroom and had a place in educational endeavour in terms of opportunities to explore the construction of values and identities, the transformation of reading practices and new literacy practices, and abilities required by a digital world, building connections between in-school and out-of-school worlds (Beavis, 1998). With increased game play among children and young people, researchers have focused particularly on game-based learning (Gee, 2007), making links to educational imperatives such as media and literacy learning (Beavis, 2015; Dezuanni et al., 2015; Gee, 2007), and mathematics and scientific concepts (Lane & Yi, 2017). Some researchers have also provided specific examples of the benefits of serious games (Jones et al., 2020; Scholes et al., 2014), and games for use in education contexts (Dezuanni et al., 2015).

Video games that support real-world problem solving can complement school curriculum across the curriculum. The cubic geometry of a game such as *Minecraft* lends itself to the teaching of various academic subjects, as it has a functioning ecology, with chemistry and physics aspects interwoven within the game that can be used to develop the scientific literacy of players (Short, 2012). There are increasing illustrations of how *Minecraft* can facilitate problem-solving, self-direction, and collaboration skills for communicating scientific concepts and learning STEM skills like engineering (Lane & Yi, 2017).

*Minecraft* game play also promotes learning of mathematical concepts (e.g. dividing supplies evenly among players; estimating the area needed to build a city), historical concepts (e.g. famous buildings and landmarks), and STEM learning through modding and hacking – altering the original programming code of the game to enhance the game (Dezuanni et al., 2015; Lane & Yi, 2017). It is likely that playing *Minecraft* also offers students their first meaningful exposure to powerful fields in STEM, such as engineering, agriculture, and biology (Lane & Yi, 2017).

The conceptualisation of games-as-text provides a mode of connecting digital games and children's actions inside the game to the wider context in which they are situated, such as the classroom, out-of-school experiences, and world events (Apperley & Beavis, 2013). Our interest, however, is in epistemic affordances, and we are informed by Toh and Lim (2021), who recently built on Apperley and Beavis's (2013) model of games-as-text. Taking the original model further, Toh and Lim (2021) focus on critical playing and learning, proposing a metalanguage for digital play. Of interest from an epistemic stance, is their consideration of perspective – focalisation and shift.

***Internal focalisation on characters' perspectives***. Games such as *The Sims* (life simulation) and *Assassin's Creed* (discovery tour game series) convey the experience of subjectivity for the player, with the design presenting a diversity of perspectives including different ways of looking at and understanding virtual environments, narratives, and characters (Allison, 2015). This diversity of perspectives allows players to access modes of thinking that accord with a perspective other than their own. Internal focalisation occurs as players have insights into the characters as players are told only what a given character knows. In *The Sims*, this includes how hungry the characters are and what they are thinking. Such experiences potentially advance one's epistemic stance as players move from experiencing an objectivist position (one right perspective), to discovering a subjectivist position (experiences of many possible perspectives).

***Perspective shifts***. As players take on the roles of different characters, they need to shift perspective. This shift is important for understanding the character in a narrative as the player projects the character's emotional, cognitive, and behavioural states. In games with multiple characters, the player's agency in the narrative gives them partial control to switch perspectives between different characters to piece together a character's story and to explore multiple approaches to progress the game. For example, in *The Sims*, the player controls one or more avatars that have wants and needs with qualities, personality traits, and dynamic statuses with other characters that influence their behaviours. As the player empathises with the character, they are motivated to provide for their needs. Players are privy to their character's thinking and are, therefore, afforded opportunities for experiencing different perspectives.

When engaged through a VR platform, such perspective-taking experiences can induce illusions of ownership over a virtual body as a fully immersive embodied experience (Peck et al., 2013). Multisensory feedback such as visuomotor synchrony may heighten this illusion, as virtual bodies may have particular 'semantics' associated with them – through normative beliefs and stereotyping. Peck et al. (2013) show how VR embodiment of light-skinned people in a dark-skinned body can lead to a comparative reduction in their implicit racial bias, suggesting new ways to address deep-seated issues, such as racial bias.

Serious games have the additional challenge over 'non-serious' commercial games to include learning opportunities as integral to the game play and story. It is critical that the game concept includes meticulous planning of each element of the game and integrating of elements so that a player's state of flow during game play is retained (Csikszentmihalyi, 1998). They need to include exciting graphics, storylines, instant feedback, creative haptics, and a great hook (Csikszentmihalyi, 1998) within richly designed spaces to help players solve a problem, and model environments, behaviours, and concepts that allow them to be led from concreteness to the abstract (Gee, 2007). When video games are well designed, they provide learning paradigms that evoke a sense of pleasure for the player, thereby facilitating intrinsic motivation and allowing the player to learn in order to achieve mastery. Games that facilitate productive learning provide spaces for players to have immersive experiences and receive immediate feedback with opportunities to try again, opportunities for players' scaffolding, opportunities to learn from the experiences of other players, and opportunities to learn about real life experiences (Gee, 2007).

Let's return to the video game *Minecraft*, and the two options for game play. In survival mode, the player begins resourceless and alone, but then has the opportunity to create a world by collecting resources, building structures, battling mobs, eating, and exploring the world in an effort to survive and then thrive. Players can craft tools including swords and axes from materials such as wood, gold, stone, iron, and diamond. This then allows them to harvest crops including wheat for bread and build houses or other structures to stay the night and to survive menacing threats like the Ender Dragon. Survival mode is a goal-oriented mode, and to be successful the player aims to thrive despite perceived threats.

The alternative game play option – creative mode – requires players to demonstrate creativity and skill in the way they chose to survive. There are elements of survival, creation, and multi-player collaboration that intentionally legitimise and rely upon the contributions of its player community in ways unlike many other games (Cipollone et al., 2014). Communities of players engage in practice that includes tutorials, modifications, communal servers for multi-player engagement, and creations that have incorporated *Minecraft*-based recreation of popular culture such as a scale replica of the Starship Enterprise and the Hogwarts School from Harry Potter (Cipollone et al., 2014).

In recent years, a modification called *Minecraft* Education Edition was created specifically for use in educational settings. This potentially extends *Minecraft* communities of players into schools where play is based on creative prowess, from the resourcefulness inside game world spaces to the creative modifications that players make, signified by the free exchange of users' creations (Cipollone et al., 2014). Here we not only see opportunities for constructing knowledge, but also creating spaces for the generation of new ideas, innovations in thinking, and fostering the development of new knowledge for the future.

## Critical issues, tensions, and debates

The potential relationship between violent video games and adolescent aggression is an ongoing contestable topic. Many parents and educators worry about the suitability of video games for their children and their relevance to learning. For over three decades, research has explored the possible links between video games and negative outcomes, including aggression, addiction, wellbeing, and cognitive functioning, with little consensus (Johannes et al., 2021). Furthermore, tensions have arisen because the reliability and reproducibility of valid studies are few and far between (Drummond et al., 2020). More recently there has been a shift from concerns about violent video games and aggression to concerns about the association between the amount, or nature, of the time people spend playing video games and their wellbeing (Przybylski & Weinstein, 2019).

The launch of the game *Fortnite* also heightened debates about childhood gaming addiction. There is limited research on the impact of game addiction on children, while there are calls for media debates around 'problematic play' to incorporate and be inclusive of the child's right to play, and the relevance of play for children's critical media literacies (Carter et al., 2020). While controversy will continue, recent research suggests video game play can be an activity that relates positively to people's mental health and, as such, regulating games could withhold those benefits from players (Johannes et al., 2021). That is, video game play has been found to generate positive affect and social functioning, contributing to and supporting mental health and wellbeing (Jones et al., 2014). That's right – playing video games can be good for your wellbeing and mental health (Gee, 2007; Johannes et al., 2021; Jones et al., 2014). Nonetheless, there are clearly ongoing concerns that impact on the take-up of video games in education, creating tensions for many educators who wish to embrace the positive learning experiences for their students through video games.

There are also broader issues. The advent and the global success of *Fortnite* is increasingly linked to school curriculums through modes such as *Fortnite* Creative – where students build their own world within the game, encouraging computational thinking and problem solving. However, its use raises issues of consent (13 years and older), privacy (voice-chat and text-chat capabilities), and appropriateness (violence). While these issues will be ongoing, discourse related to the value of games for learning is still critical (Scholes et al., 2021).

## Recommendations for research

Many consider gaming a powerful and exciting medium for engagement and learning in the classroom (Ito et al., 2009; Prensky, 2010). Video games in educational contexts can facilitate motivation, cognitive development, higher-order thinking, literacy learning, problem solving, decision making, multi-tasking, and collaboration (Gee, 2007). Serious games are often used in education to teach and improve concepts, including mathematics (e.g. *Mathletics*), and reading (e.g. *Teach your Monster to Read*). Such games, however, are often based on players progressing through drill questions such as mathematics games that quiz players on their times tables. Games designed to embed traditional curriculum can then lose the motivational, collaborative, engaging, and novelty aspects of the digital experience. When games emphasise external rewards and reinforcement for very school-like tasks, and educational content is forced into the video game medium, young people can quickly turn off (Ito, 2008).

While the efficiency of video games as learning tools has been applied to serious games or games-based learning as in disciplines, the importance of broader video games for epistemic literacy across the curriculum needs more research to make the educational application visible for educators. This is particularly true for educational change that necessitates a reconceptualisation of knowledge beyond the technological or pedagogical to envisage how video games can facilitate the epistemological. Ultimately, good games provide well-designed experiences in problem solving (Gee, 2007). More in-school research is needed, however, on how to implement games-based experiences in decision making to advance student epistemic skills and critical thinking. While VR environments have been excluded from educational settings, due to the high cost of VR equipment, new research opportunities are now available as schools move towards investing in more affordable opportunities for students to learn through immersive VR environments.

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# PART II

# Body and senses

The materiality of textual practices is continually changing as the substrates of reading and writing extend beyond paper to include a wide array of digital displays, from mobile devices to wearable technologies. The digitalisation of communication has clearly augmented the way texts are created, reproduced, and distributed. New fabrication technologies have transformed outputs for computer-mediated textual production that were previously limited to screen or coloured printers. Digital writing and graphic displays can be produced as physical inscriptions on almost anything – from fabric to vinyl – while texts can be tangible objects that are lathed, lasered, moulded, or extruded using 3D printing, rapid prototyping, 3D pens, computer-controlled routing, or laser cutting. Contrastingly, digital texts can be completely lacking material substance, such as virtual, augmented, and mixed reality objects that are overlayed upon the real world.

Amid the changing materiality of the textual environment, a renewed focus on embodiment in the following section of this book – Body and Senses – draws attention to specific and vital ways in which the body mediates the work of the mind and the material world of textual practices. Of particular importance, haptic perception and proprioception – the movement, position, and sense of a body's place in the world – are critical to literacy practices (Haas & McGrath, 2018). What is important here is that the sensorimotor interaction of reading and writing with the material tools of textual practices are inextricably tied to cognition. For example, different regions of the brain are active when a writer forms letters using handwriting compared to typing with a keyboard (Mangen & Velay, 2010). With each new technology for inscription comes new questions about how different proprioceptive actions of the body shape the mind, and in turn, how these actions shape the use of technologies for encoding and decoding.

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The section extends a sensory approach to understanding the body and the mind in literacy practices, an approach that was first developed by Mills (2016) to move from ocularcentric accounts of multimodality in textual practices to better account for the full sensorium. The recognition of embodiment in digital media practice is not simply to advocate that more movement, or larger body movement, is necessarily better for literacy practice. Rather, this paradigm involves a change in thinking from focusing exclusively on the cognitive, grammatical, or social dimensions of literacy practices, to take into account the material interactions with physical technologies that are mediated by the body in specific ways. We know that grammatical structures too are not arbitrary, attributable only to conventions, but are based on embodied experiences and image schemas that are established through interaction with the environment and often metaphorically extended (Gibbs, 2005). A sensory approach has new implications for understanding how readers process what they read, and for how writers engage with the materiality of texts.

Chapter 5 begins with a focus on sonic literacies associated with hearing and vocalisation, and then moves to consider the so-called 'lesser' senses of smell and taste in digitally mediated communication practices. The role of sonic experience in digital media is central in the body-mind-world nexus of new literacies, whether of recorded speech, music, sound effects, or silence. Likewise, olfactory-based multi-sensorial media are becoming more prominent in film and cinema, virtual reality technology, gaming, and alert systems (Murray et al., 2016). There are yet unexplored relationships between olfaction and remembering the past, smell and social interaction, and between smell and other forms of language, such as writing. Taste or gustation, which is seldom theorised in literacy studies, is considered, a sensory modality sometimes deemed a final frontier in the development of media simulations. Evidence is presented to demonstrate the connections between gustation and literary experiences, and new directions for gustatory output devices that may shape digital communication in the future. Finally, crossmodal relationships between various body-based modalities are examined, such as the effects of odours as authors compose texts, or the crossmodal meaning making that occurs when listening to music while tasting different flavours.

Chapter 6 unravels the key role of two main kinaesthetic and proprioceptive bodily engagements in literacy practices – first, haptics or touch; and second, locomotion or movement of the feet. It presents convincing arguments to demonstrate how sensorimotor experiences form a critical part of language and thought from birth and continuing throughout the life course. It critically delves into an array of new media that have opened fundamentally different opportunities for understanding and optimising body motion and locomotion for literacy learning.

Chapter 7 brings together the research on what is collectively called extended reality (XR), which includes virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies, as well as innovations still in development (Mills, 2022). The chapter provides what may be the first systematic framework for theorising the material and social facets of extended reality that condition the nature and interactive scope of these new literacies. It critically examines the tensions and constraints for literacy education, while envisaging the potentials for extended reality technologies in curriculum and pedagogy.

The common thread binding the chapters in this section is the relations between the materiality of media and the bodily engagement of text users, and their implications for embodied cognition. A central focus is an appreciation that the work of the mind in new literacy practices depends on embodied action with digital texts, whose materiality is undeniably being radically refashioned. The aim is to inspire new ways of conceptualising and systematising these media practices by taking account of the tangible substrates and implements of literacy, or conversely, the virtual immateriality of texts (such as mixed reality holograms), in digital worlds of language and social interaction.

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# 5

# EMBODIMENT, LITERACIES, AND DIGITAL MEDIA

This chapter argues for the continued development of a sensory literacies approach to revitalise thinking about the changing materiality of digital media and literacy practices, and relatedly, the transformed role of the body and mind in hybrid communication. A sensory literacies approach was developed by Mills (2016) in *Literacy Theories for the Digital Age*, building upon related research by Mills and colleagues (Friend & Mills, 2021; Mills & Exley, 2022; Mills et al., 2018). It is an approach that is supported by a growing body of evidence from research in embodied cognition that looks specifically at the effects of diverse kinds of human understanding on the performance of language and communication (Gibbs, 2005; Skulmowski & Rey, 2018).

There has been a renewed focus on the role of the senses and embodiment across a range of disciplines: sensory studies in anthropology and sensuous scholarship (Stoller, 1997), sensory research methodologies (Pink, 2015; Warren, 2008), sensory sociology (Simmel, 1997), architectural sensoriality (Pallasmaa, 2005), filmic sensoriality (MacDougall, 2005), culture and the senses (Classen, 1999), sensory marketing, sensuous geography (Rodaway, 2002), and many others. Yet many cognitive scientists have approached research of cognition and meaning making as an abstract process involving disembodied symbols, divorced from bodily experience (Gibbs, 2005). Conventional perspectives of language learning that are centred on its neural basis have given insufficient attention to the way in which bodily activity from birth – activity which continues to develop in specialised and expert ways throughout the life course – is based on real-world experience and referents, and ordinary kinaesthetic interactions in a mind–body–environment relationship (Gibbs, 2005; Mills & Exley, 2022). Likewise, the influence of embodied cognition on literacy theories, such as new literacy studies, multimodal literacy, and other perspectives of digital media

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production, has only recently begun to take centre stage (Ehret & Hollett, 2014). Others have noted a conspicuous gap in socio-cultural literacy research on materiality and the sensorimotor aspects of literacy practice (Mangen & Velay, 2010).

A sensory literacies approach foregrounds the role of sensorimotor processes as fundamental to language and literacies, both digital and non-digital. At the same time, the rapidly changing ways to engage in digital media practices and communication have opened a broadened range of bodily ways of interacting with information and media. For example, since 2008, the world has seen the public release of technologies such as touchscreen iPads, smartwatches, fitness trackers, Google Chrome, Snapchat, Pinterest, Instagram, TikTok, Google Drive, GPS from mobile phones, cryptocurrency and blockchain, wireless earphones, touchscreen gloves, Oculus Rift and HTC Vive virtual reality systems, Microsoft HoloLens (mixed reality), Google Glass, Apple Pencil, Amazon's virtual assistant Alexa, and widely known games, like *Pokémon GO, Minecraft*, and *Fortnite*.

Many of these technology platforms, social media sites, games, and applications involve the user in varieties of bodily interactions that have specific influences on everyday language and information use. A sensory approach to literacies acknowledges the inter-relationships between the mind, the body, and multisensory digital environments that can require the use of vision, hearing, touch, locomotion, olfaction, proprioception (body position awareness), equilibrioception (balance), and more, as users interact with corporeal and virtual technologies and materials (Mills & Exley, 2022).

The recognition of embodiment in digital media practice is not simply to advocate that more movement, or larger body movement, is necessarily better for literacy practice than less movement, or practices that involve only fine-motor movement. Rather, literacy enactments involve at least two key dimensions that can be used to classify the varieties of embodied literacy practices: (i) The degree or level of bodily engagement and (ii) the meaningfulness of bodily actions in relation to the specific literacy practice (Skulmowski & Rey, 2018). For example, tracing letters with fingers involves a small degree of movement and a high degree of meaningful task integration that can improve children's learning of letter recognition and handwriting letter formation (Brookes & Goldin-Meadow, 2016). Contrastingly, locomotion or walking while verbally responding to questions involves exceptionally large body movements, and produces increased creativity, compared to being seated (Oppezzo & Schwartz, 2014). Both large and small embodied actions that are meaningfully integrated can support literacy and digital media practices.

The meaningfulness or degree of task integration of embodied action in literacy practices is illustrated in a study of children's foreign language learning (Mavilidi et al., 2015). The researchers looked at how children enacted the meanings of foreign language words in bodily ways that were relevant to the word meanings. For example, for the word 'fly', children would extend their arms out to the side of their bodies as if flying like a bird. They compared this to the introduction of foreign language words while children performed an unrelated physical activity, such as running or walking for all words, with no relation to the meaning. Not surprisingly, the relevant task-integrated actions resulted in higher performance in foreign language learning than unrelated physical movement.

Our key argument then is not that more extensive sensorial activity is vital to all language and digital media practices, but rather we need to give higher priority to understanding the specific ways in which the body is related to the performance of new literacy practices. Specifically, embodied literacies can be considered in terms of the varied extent of bodily action (e.g. using game controller, gestures when presenting, walking in virtual reality gaming), in addition to the degree of meaningful body–mind–language integration (Skulmowski & Rey, 2018).

## Marginalised senses in embodied media literacies: Hearing, smell, and taste

New bodily and sensorial relations are being reconfigured in literacies and digital media practices that are changing much faster than in the previous centuries. This chapter considers the importance of sensorial and bodily interactions that matter for literacy learning in a contemporary world, with examples of digital and non-digital media practices. The examples in this section introduce hearing, and the so-called 'lesser' senses of smell and taste, and in the next chapter, haptics, and locomotion (see Chapter 6, this volume). Many of the visual meanings of digital texts are addressed in Chapters 8–10. The current chapter also explores the relations between the changing materiality of technologies and their relationship to digital media practices and embodied cognition.

### *Hearing: Sonic dimensions of language, literacy, and digital media*

The digital production and distribution of sonic media is a rapidly changing landscape, with some referring to an 'audiovisual turn' across a range of fields, from applied linguistics to media studies, and from musicology to philosophy. In the digital age, sonic elements often carry a significant functional load of textual meaning that is felt viscerally in the body (Cope & Kalantzis, 2020). Humans and civilisations encounter transformed soundscapes – sonic or acoustic environments – layers of meanings in our daily lives that are a vital part of our multisensorial emplacement in the world (Schafer, 1993). Elements of our perceived sonic existence, whether of sounds, music, speech, or silence, form an invisible presence that can be read as an "auditory epistemology of everyday life" (Bull, 2000, p. 73).

There has always been a fundamental relationship between spoken language and formal literacy learning because reading and writing are developed on the basis of one's oral or face-to-face language development. Being able to hear and produce the 44 speech sounds of English, as well as hearing the syntactic and semantic patterns of words spoken in phrases and sentences, is vital in learning to talk, and later, in learning to read and write (Tompkins et al., 2014). We know that children with severe to profound hearing impairment are placed at a distinct disadvantage to their hearing peers, in part because of the discrepancy between their incomplete spoken language system, and the related demands of reading a speech-based language system. Conversely, when children who are deaf or hard-of-hearing receive cochlear implants early in their language development (below the age of three), their rate of language growth becomes similar to their hearing peers (Geers, 2006).

Hearing and producing sounds have always played a vital role in the body–mind–world nexus of literacy practice. In the case of speech, embodied activity that includes gestures, facial expressions, posture, head and body movements, and eye contact help to establish the goals of a speaker that carry a considerable proportion of the speaker's meaning, while at the same time facilitating the speaker's spatial memory and lexical retrieval (Gibbs, 2005; Morsella & Krauss, 2004). When people read aloud, motor areas of the brain are activated, particularly when reading action words or verbs, since Broca's area is activated when people simply think about movement (Pulvermüller, 1999).

Speech production and singing, while able to be rendered digitally and synthetically (Cope & Kalantzis, 2020), are embodied modes that involve multiple bodily systems of voice production, including the air pressure, and vibratory and resonating systems. Produced by the body, speech and singing are undeniably embodied forms of meaning making involving the materiality of the muscles, vocal anatomy, and physiology of the singer. Likewise, noise is perceived bodily through the physiology of sound perception. Speech and singing are not only produced and perceived unmediated through the body, but the technologies for disseminating sounds have, over many decades, continued to become more compact, mobile, and wearable.

Sonic elements of digital texts, such as the qualities of recorded voice, are imbued with meanings that semiotic theorists have analysed using parametric systems. For example, van Leeuwen (2017) identifies key elements of sound quality as pitch range (high-low), loudness (loud-soft), articulation, and resonance, among other features of the voice-quality parametric system (e.g. rough/smooth, breathy/non-breathy, vibrato/plain, nasal/non-nasal). Van Leeuwen does not see that there is a chasm between semiotic accounts of speech through parametric systems, and the elements of voice that are uniquely constituted by the depths of one's physiology or materiality of the singing or speaking body. Rather, one's voice "can ultimately only be understood on the basis of our bodily experiences" (van Leeuwen, 2017, p. 77). Likewise, the semiotics of vocalisations is understood "by paying close attention to the physicalities of articulation" (van Leeuwen, 2017, p. 77).

The digital transformation of audio-visual media has been significant in the 20th century, as technologies for recording, amplifying, and distributing sounds (speech, music, sound effects, and silence) moved from cylinder phonographs and nitrate-based film to disc records (acetate and vinyl), compact cassette, 8-track tape, polyester film, floppy disc, compact disc, mp3, video games, and more recently, web video, streaming apps, virtual reality, and 360-degree film (Müller, 2020). Devices for transmitting digitally mediated sound are a growing part of wearable technology trends, such as wireless Bluetooth earbuds, headphones, Bluetooth headbands, smartwatches, and mixed reality smart glasses, that sonically augment the body anywhere, anytime, overlaying simulated soundscapes that often resonate with one's social and cultural identity.

There are many examples of crossmodal embodied relationships between aspects of hearing and literacy. The effects of listening to music while word processing, for example, has been researched, showing that participants write faster and more accurately in conditions of silence than when listening to background music. As 45 college-level participants authored brief expository essays, the background music was found to place high demands on their working memory, disrupting their word-processed writing (Ransdell & Gilroy, 2001).

Shared crossmodal matching tendencies have been found in terms of human sonic-gustatory patterns of meaning making. For example, when groups are asked to pair classical music pieces with fine wines, participants show significant agreement. Mozart's Flute Quartet in D major was found to pair well with Pouilly Fume white wine. Participants were also found to enjoy the experience more and the wine tasted sweeter when listening to the matching classical music than when tasting the wine in silence (Spence et al., 2013). In other words, sonic experiences are not simply a unimodal activity of the hearing ear but are often perceived and interpreted synergistically with other embodied forms of knowing about the world.

## *Smell: Olfaction in digital media*

Smell, or olfaction, is becoming increasingly relevant to digital media practices and communication, as technological advances in digitally mediated olfactory displays for the simulation of smell are developed for virtual reality environments and other digital communication applications, such as smell-o-vision, smell-enabled games, and scent technologies for other film and media (Olofsson et al., 2017). Of the senses, many consider olfaction to be one of the more enigmatic, since perceptions of smell have been found to be influenced by culture and age (Murray et al., 2016), gender (Shih & Blignaut, 2011), in addition to individual life experiences and even mood (Ghinea & Ademoye, 2011).

Smell is an important sense or perceptual function connected to memories and emotions, which influences the sense of realism, quality, and one's affective evaluation of experiences in multimedia contexts (Murray et al., 2016). Olfaction has been found to have greater independence from other modalities (Danthiir et al., 2001). Until recently, olfaction has been one of the less developed senses in the design of immersive virtual platforms (Howell et al., 2016), and relatedly, less understood than the visual mode in literacy research (Mills & Dooley, 2019).

A central aspect of literacy learning and reading texts is how words and their meanings are learned and processed in the brain. Olfactory research has demonstrated how the mind's processing of words strongly associated with odours activates the olfactory regions of the brain in an embodied way. In an experiment with 24 subjects, simply reading words with strong olfactory associations, such as 'fetid', 'cinnamon', and 'garlic', without being exposed to any of the odours, immediately and automatically activated semantic networks in the olfactory cortices of the participants (González et al., 2006). Smell is rarely referred to in teaching children to read, yet research points to the embodied nature of the development of our semantic networks associated with smell that are retrieved and activated during reading content with olfactory meanings (see Chapter 2 for other insights on olfaction and reading).

Research has shown the connection between olfactory and auditory cues to support creative writing. For example, students were asked to write a short story in 15 minutes about an imaginary path on an island under four conditions – neutral, pleasant smell (e.g. coffee, laurel), sound (e.g. music), and smell with sound. Based on a number of qualitative and quantitative measures, writers were found to be more creative and expressive in the "smell" condition. Participants reported that the pleasant smell condition enabled them to feel "more relaxed", "without any pressure", "more immersed in the activity", and allowed "a better flow of writing" (Gonçalves et al., 2017, n.p.).

Human communication and perceptions of others and our environments are influenced by the full sensorium and grasped holistically, with olfaction performing a critical role in communication, eliciting and processing emotions, retrieving odour-evoked memories, and supporting associative learning. Odours in human social contexts activate the amygdala-hippocampal complex for the emotional memory in an embodied way (Arshamian et al., 2013). Adequately harnessing the power of scent-based technologies for communication, emotions, memory, and learning is now a key area in the development of immersive and digital learning games (Olofsson et al., 2017).

Surprisingly, scented filmic media and gaming experiments were begun over a century ago, such as the theatrical use of rose essence which augmented a newsreel screening on the Pasadena Tournament of Roses Parade in 1906 (Olofsson et al., 2017; Paterson, 2006). Today, 4D film or cinematic experiences digitally and mechanically stimulate five senses using wind, water spray, scents, lightning, flashes, fog, motion simulators in chairs, and with back and leg ticklers to engage the viewer using multiple senses. Off-the-shelf devices for olfaction in contemporary multisensory media are becoming more readily available, such as a growing range of scent diffusers and electrical interface output devices (Saleme et al., 2018).

Smell training through digital odour learning games has demonstrated the potential for enhancing cognitive function (Olofsson et al., 2017). Researchers look towards future taxonomies for smell for a wide range of communication purposes, since olfactory taxonomies have often prioritised research for certain industries and markets, such as wine, perfume, and food (Murray et al., 2016). Future smell-enabled media will be used for sharing and communicating with friends, supporting online purchasing decisions, mood and stress regulation, and scent-enabled immersive virtual media (Obrist et al., 2014). Others have begun to develop serious games and brain training applications to enhance our human olfactory capabilities as an important end in itself, particularly given olfactory association with enhanced cognition and memory (Olofsson et al., 2017).

## *Taste: Gustation in digital media*

Like olfaction, taste – or gustation – has been one of the marginalised human senses in studies of new literacies, multimodal literacies, and communication studies (Mills, 2016) compared to visual, audio, and haptic media in human-computer interaction (Ranasinghe & Do, 2016). In fact, taste is currently regarded as one of the final frontiers in trajectories of simulated or immersive digital media technologies like virtual and augmented reality (Ranasinghe et al., 2012). Gustation is an important sense associated with cultural practices that involve connecting with others over food and beverages, while different taste sensations are often connected to personal memories, emotions, and everyday interactions with the world (Ranasinghe et al., 2011).

Research has demonstrated that gustation and literacy are connected through the body. For example, we know that gustatory disgust or a 'bad taste in the mouth' influences moral judgement when presented with a story or moral vignette. One experiment found that after participants consumed various beverages – sweet, bitter, and neutral (water) – the taste of the substances significantly affected moral judgement. Behaviours described in the moral vignettes from Wheatley and Haidt (2005) included stories of a congressman accepting bribes, a man eating his already-dead dog, shoplifting, and a student stealing library books. Participants used a multipoint judgement scale from 'not at all morally wrong' to 'extremely morally wrong'. Gustatory disgust in the bitter condition elicited greater moral judgement of characters in the vignettes than in the sweet and neutral taste condition (Eskine et al., 2011). This supports the recognition that gustation and the moral judgements of characters that we read in stories are part of a tightly coupled embodied system.

In another example of the crossmodal correspondence between taste (gustation) and literacy, researchers discovered that even the typefaces that we use in word processing are associated in consistent and predictable ways with the major gustatory categories of sweet, sour, salty, and bitter, and this is based on the roundness and angularity of the typeface. Participants associated angular typefaces with bitter, sour, and salty tastes, while rounder typefaces were associated with sweetness. Interestingly, rounder typefaces were also judged as more likeable and easier to read than angular typefaces (Velasco et al., 2015).

In terms of recent digital developments, two commonly known gustatory technologies for multisensory media are lollipop and beverage output devices (Saleme et al., 2018). For example, researchers have developed the 'digital lollipop' for simulating gustation by varying the frequency, polarity, and magnitude of electrical currents that are applied to the tongue (Ranasinghe & Do, 2016). The simulation of taste for four major flavour categories – sweet, sour, bitter, and salty – are produced using different currents on the relevant regions of the tongue. The sweet taste emerges via an inverse-current mechanism, while the sour taste simulations were controlled to produce three sour intensities – mild, medium, and strong. Such media may be used to enhance literacy experiences, particularly for digital gaming, social media, and filmic media.

Another novel example of utensil and beverage-based gustatory simulation is the platform Taste+, which involves two devices – a spoon and a drink bottle – that have embedded electrical modules to simulate three states of enhanced taste – sour, salty, and bitter. The Taste+ bottle uses electrodes on the tongue through a specially designed mouthpiece, supported by LED coloured lights, to alter the colour of water and has a mechanical dial used to select the flavour. The digital spoon enhances the saltiness and sourness of what is eaten from the spoon using two buttons on the handle, and electrodes on the mouthpiece (Ranasinghe et al., 2014).

There are emerging possibilities for simulated communication environments that harness the meaning-making potentials of taste simulations, from virtual and augmented reality games, 360-degree film and 4D cinema, gustatory enhanced online interaction, and experiences involving eating and drinking beverages with others on social media who are geographically remote. For example, during the COVID-19 pandemic, special occasions such as birthdays have been celebrated by virtual meetings, where shared gustatory experiences could be enhanced. Recent technologies have been developed that allow digital users to share tastes remotely through devices that are used in conjunction with the internet (Ranasinghe et al., 2011). Future multisensory media environments will continue to develop new ways of capturing, rendering, distributing, and synchronising multiple sensory effects (Saleme et al., 2018).

## Materiality in literacies and digital media practices and embodied cognition

The plethora of new digital technologies that have arisen in recent decades have a widening array of material forms that involve communicating and making meaning in tangibly diverse ways that matter for the mind. Information – depicted through words, images, audio, vibrations, and other modes – is recorded, displayed, transmitted, and reproduced on computer screens, mobile devices, tablets, e-book readers, wearables, drones, robots, and other hybrid digital artefacts.

This changing materiality of literacy practices is not an exclusively recent phenomenon – reading and writing have always made use of the cultural and material resources at hand. For example, early symbol-making surfaces or substrates by Indigenous peoples include cave walls and human skin in ceremonial body painting, as well as carvings with symbolic meanings on message sticks and musical instruments (Mills & Dreamson, 2015). The earliest known forms of clay tablet writing originated in Mesopotamia, where a stylus, thought to be made of reeds, was used to make wedge-shaped marks called cuneiform. Likewise, the ancient Chinese used carved inscriptions, as well as brushes and ink, on animal bones, called oracle bones, that were used in divination (Clayton, 2019). The materiality of encoding and decoding, and its relations with diverse bodily interactions, have changed across times and societies.

Understanding the relationship between the embodied cognitive, cultural, and changing material technologies of reading and writing is a continually evolving space in digital media research. In the context of the changing materiality of digital media practices the emphasis on embodiment counters views of literacy learning that focus on the mind or cognition alone (Haas, 2013). One of the key principles of embodied cognition is that humans offload cognitive work onto material environments as a cognitive strategy. Rather than manipulate extensive sets of symbols in our minds, we engage in forms of symbolic off-loading, essentially "leaving information out there in the world to be accessed as needed" (Wilson, 2002, p. 628).

To manage the limits of our memory, our mental problem-solving abilities, and our ability to manipulate objects spatially in the mind, humans physically inscribe or manipulate symbols in the environment in the form of material notes, mud maps, calendars, back-of-the-envelope calculations, and many other forms of symbolic off-loading. In this way, encoding materials and technologies becomes part of our cognitive apparatus to support short-term memory and language function. Likewise, materials can become part of our long-term archiving of information that we cannot store with the same accuracy in the mind, or beyond our lifespan, as tangible technologies in our environment are used in archival ways, such as books, documents, digital files, and reference materials (Wilson, 2002).

While there have been notable material shifts in literacy practices, from page to screen, desktop computer to tablets, mobile devices to wearables, what is seldom noted is the representational output bottleneck when writing and designing with computers. In other words, there is a limited range of material output devices by home users, with the predominant linguistic and graphic formats for multimodal designs comprising digital computer screens and colour printing (Seymour, 2011). The growth, affordability, and accessibility of additive manufacturing, rapid-prototyping, laser cutting, 3D printing, screen printing, computer-controlled routing, and other forms of digital fabrication in recent decades has opened an array of hybrid textual formats with a transformed materiality for multimodal representation and making. No doubt, the future of technology will see increasing capabilities for the digital and embodied expression of form-making across evermore hybrid material ways, gradually opening up literacy practices from comparatively narrow kinds of paper-based, screen-based, audio-visual, and document-based material formats.

## Tensions for engaging the full sensorium in digital media composition

Despite the support for embodied literacy and digital learning activity in research, formal schooling worldwide has tended to work against ideals of embodied cognition by requiring students to sit for extended periods at desks, while emphasising the performative aspects of 'listening' by controlling the expressive impulses, movements, and posture of the body (Luke, 1992). A criticism of research of embodied cognition in education is that often research focuses on the embodied action of the individual, rather than on the classroom collective, while research is yet to more fully account for how embodied cognition is shaped by the social context and groups within which learning occurs. In this way, research of embodied cognition and literacies can be aligned with socio-cultural theories of literacy learning, with individual cognition understood as connected to the broader social spaces in which digital media practices develop. A further tension is that there is often a lack of guidance for teachers to design literacies and digital media learning environments that optimise embodied learning in ways that have strong and meaningful task integration of sensorimotor action for optimal cognition (Danish et al., 2020).

One of the greatest constraints for introducing digital embodiment in meaningful ways in schooling is the ongoing digital divide. Research has consistently shown that access to technology alone is not sufficient to bridge the gap between the disadvantaged and the economically privileged (Warschauer & Tate, 2018). Even when technologies are provided to the marginalised, too often, the lack of infrastructure, commensurate training of teachers, development of curriculum, and related gains in educational outcomes are not given adequate attention, exemplified in the Los Angeles Unified School District iPad roll out (Blume, 2015) and the Alabama One Laptop per child effort (Warschauer et al., 2011). During the pandemic in Australia, students from low-income backgrounds, rural, Indigenous, and differently abled students were the worst affected educationally, particularly with lack of access to technology and reliable internet connectivity (Flack et al., 2020).

Teachers in low-income schools have significant challenges in promoting digital media inclusion, while research has shown that more technologies do not necessarily promote better literacy learning outcomes (Warschauer & Tate, 2018). Significantly, a wide variety of sensory literacy practices have been used in schools that promote meaningful bodily engagement with few, old, or common technologies, such as tapping out sounds, air writing, writing with fingers in sand, paint, or shaving cream, manipulating magnetic letters, and listening to audiobooks while reading a printed book. Mobile phones are the most accessible technology devices worldwide, including in developing countries such as Tanzania (Kafyulilo, 2014), while mobile phone-supported technologies for learning, such as e-books and augmented reality apps, are currently more widely accessible than more expensive immersive technologies.

Some of the most significant challenges for implementing literacy curricula that optimise a broadened use of the senses are fundamentally ideological and historical because compulsory schooling in Western societies has often given priority to scientific rationalism, hierarchical views of the senses (i.e. vision at the top), and a strong emphasis on governance and surveillance. The measurement of abstract cognitive skills that are most easily tested and compared *en masse*, such as through bureaucratic and top-down standardised testing regimen and regulatory uses of big data, is used as arsenal in nation-state apparatus of control. Such practices too often militate against embodied forms of cognition, communication, cognition, and creative literacy practices that are situated in real or lifelike body–mind–world interactions that are often difficult to measure through conventional testing.

## Classroom implications of the sensory turn for literacies

Literacies and digital media practices in social life will always be influenced by available technologies for reading, writing, listening, and viewing, with each digital media practice involving the senses and embodied cognition in particular ways. The body is constantly entangled as a vital sensorial instrument in a shifting print and digital media world, from walking or pacing to stimulate more creative oral language responses (Oppezzo & Schwartz, 2014), to smelling scent-based technologies for communication, emotions, memory, and learning in 4D filmic media (Olofsson et al., 2017). Bodily engagement matters whether listening to music while enhancing one's spatial–temporal reasoning (Hetland, 2000), or experiencing taste sensations that bring back personal memories and positive emotions while playing a virtual reality game (Ranasinghe et al., 2011).

The implications for the sensory dimensions of literacy learning in the classroom are far reaching, with teachers having the opportunity to design learning environments and curricula to optimise a range of sensory literacy practices. As mentioned earlier in this chapter, it is not that more bodily engagement is necessarily better for literacy learning, but rather, that the body is guided to move in ways that are meaningful and relevant to the learning task at hand (Skulmowski & Rey, 2018). For example, using gestures to act out unfamiliar word meanings consolidates vocabulary learning, while moving around in random ways that are unrelated to the word meanings does not have the same benefit (Mavilidi et al., 2015).

Likewise, teachers have long sought to provide learners with opportunities to engage with texts in materially diverse ways, from handwriting and drawing on paper with pencils and crayons, to keyboarding and using tablet touchscreens. Educators need to be equipped with knowledge of how the material affordances of different literacy technologies, such as varied writing substrates (e.g. paper, canvases, smartboards, touchscreens) and writing implements (e.g. pencils, pens, styluses, 3D pens, keyboards), support different outcomes for embodied cognition.

For example, graphonomic research has demonstrated that the fine-motor formation of letters using conventional handwriting implements, such as pencils, plays a vital role in the development of young learners' letter perception abilities and letter categorisation skills, with children developing more enhanced word identification skills after writing words (visual-haptic) than after viewing them alone (Mangen & Balsvik, 2016). Likewise, tracing letters using fingers is shown to improve letter knowledge and decoding (Bara & Gentaz, 2011). Sensorimotor aspects of early writing are shown to be important for both short-term and long-term language learning, and the losses of not handwriting are exhibited in adults' declining abilities to draw straight lines (Mangen & Balsvik, 2016). Keyboarding does not facilitate the same cognitive outcomes for early letter recognition but can help students to recognise variable font styles, while preparing students for computer-based writing in study, life, and work (Li & James, 2016).

Some of the key growth areas of embodied technologies for meaning making in education are e-learning, digital games, video-assisted learning, mobile devices and tablets, wearable technologies, and immersive augmented and virtual reality. In higher education, courses such as Massive Open Online Courses (MOOC) may use blockchain technology, while artificial intelligence, such as AI tutors, chatbots, and automated grading will support learning and marking writing. Big data and learning analytics will continue to be more widely used for monitoring and supporting learning, while social media continues to support the dissemination of videos and resources among learning communities (Bui, 2020). Each of these trends has specific implications for embodied cognition and meaning making, with digital tools changing the way texts are created, read, viewed, assessed, and shared by learners.

## Future directions for researching embodiment in digital media practices

In the future world of work requirements for literacies and qualifications for Industry 4.0 – the next industrial revolution – will influence new directions of research of digital media practices and embodiment. Conceptions of literacy and technology practices have been steadily influenced by successive industrial revolutions – mechanisation, electrical energy, and electronics and automation – along with consequential changes across all levels of the curriculum. As a corollary of these revolutions certain occupations are replaced, while new professions, formerly unconceived, have emerged (Benešová & Tupa, 2017). Amidst these transformations, conventional embodied relations between literacy practices and their mediating technologies have been destabilised, with their modified physical and virtual materiality – from robotics to additive manufacturing and 3D printing applications – involving multimodal modelling of data in fabrication industries. Rapid prototyping technologies, 3D hubs, fab-labs, and makerspaces will increasingly be used in earlier levels of schooling to induct students into life and work in the new digital age (Ford & Minshall, 2019; Kostakis et al., 2015).

Digital communication environments and globalisation are two key drivers of educational change requiring hybrid ways of teaching and doing literacy as we have known it in the past. While much reading and writing has shifted from paper to screen, rapidly changing online communication environments now require multimodal text composition (e.g. digital image, audio, video, 3D models), while digital comprehension involves complex ways of synthesising vast amounts of information across multiple media formats via the internet (Leu et al., 2015). Each of these changes to literacy practices influences embodied cognition in diverse ways that, to date, have not been fully explored.

Further research will be needed to examine the relationship between sensorimotor elements of new digital reading and composition practices for embodied cognition and communication. Internet-based and hypertextual reading involves strategies that have no counterpart in traditional offline reading, requiring navigating reading paths in a shifting visual and problem space (Leu et al., 2015; See Chapter 2). Additionally, participation in digital communication environments requires the development of new transcultural digital literacies and digital citizenship skills (Rapanta et al., 2021; Third & Collin, 2016). Students need to negotiate transnational connections with others, representing their identities in hybrid material and virtual ways for multicultural audiences via the web, accessed through computers, mobile devices, and wearables (Kim, 2016).

The future of the sensory turn in literacy practices remains relatively uncharted territory for researchers and educators, as emergent media shape the reading and writing landscape. A new generation of literacy and digital media scholars are embracing the realisation that the body matters to literacy practice in essential ways that are fundamental to the mind and to meaning making. The implications for schooling are far reaching, as the entire educational enterprise is now grappling with the rise of global pandemics and natural disasters.

Consequently, educational systems and teachers are delivering remote and online schooling impromptu and *en masse*, which has propelled thinking and scholarship globally towards new ways of doing school, of schools without walls, and of schooling anywhere, anytime. By necessity, literacies continue to be intricately connected to communities of practice that are strongly intertwined with home life, and to the wider digitally social world in which we live.

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# 6

# HAPTICS AND MOTION IN LITERACY PRACTICES WITH DIGITAL MEDIA

## Why touch and motion matter to literacy practices with new digital media

Multiple sensory modalities are central to literacy practices, old and new, digital, and non-digital, used to both perceive and express information, including sign making and creative textual production (Mills, 2016). From ancient cave wall inscriptions to clay tablets, and from papyrus to birch bark, wax, cloth, and parchment, writing and representation has always involved the materiality of a medium, in addition to haptic and cognitive skills (Bolter, 2001; Haas & McGrath, 2018). Haptics here refers to sensory tactility or touch (Paterson, 2007). Today human beings interact with multimedia textual environments using a vast array of movements of the hands, supported by other larger limb and body movements, such as in the case of documentary filmmaking on location (Mills et al., 2013). The current expansion of technologies and the changing materiality of media for interacting with texts has opened an ever more complex array of language practices involving touch and motion in new ways – embodied ways that are also intrinsically connected to cognition (Gibbs, 2005). This chapter explores the role of touch and motion in a literacy landscape that has, until recently, given greater priority to the visual mode in textual practices, including in theories of multimodality and new digital media (Minogue & Jones, 2006).

Theorists have long identified a Western cultural bias towards the privileging of vision and the consequential backgrounding of other senses, such as touch and motion. A hegemony of vision has pervaded contemporary culture, while also framing understandings of learning, education, and literacy practices. This ocularcentrism has been associated with empiricist views of knowledge, where what is perceived and observed through the eyes counts as truth in science and

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other knowledge domains (Mills et al., 2018; Pallasmaa, 2005). When theorising literacy practices, we see that research has typically focused on either the cognitive or social dimensions, while the role of the body in literacy practices has only recently received serious attention (e.g. Bezemer & Kress, 2014; Jewitt et al., 2021; Walsh & Simpson, 2014). Mangen & Velay (2010, par 54) have made this argument quite strongly:

> Currently dominant paradigms in (new) literacy studies (e.g., sociocultural theory) commonly fail to acknowledge the crucial ways in which different technologies and material interfaces afford, require, and structure sensorimotor processes, and how these in turn…*shape*, cognition.

While it might seem that touch and movement are supportive or peripheral to the main work of literacy practice, researchers have demonstrated that haptic perception and movement are indeed important because readers and writers are always in touch with the text that they interact with – cognitively, phenomenologically, materially, and physically (Haas & McGrath, 2018). For example, Mangen and Velay (2010) discovered that the sensorimotor interactions of writers with physical writing tools influence cognitive processing in significant ways. Various regions of the brain are activated when one types letters using a keyboard, compared to handwriting a text. Visual attention was found to be more focused when writing by hand, with space and time converging, hand and vision conjoined. In contrast, keyboarding involves the splitting of the visual space and the haptic or motor space (Haas & McGrath, 2018). Another study found that students perform higher on conceptual application of lectures when they take notes by hand, compared to notetaking with a keyboard, a condition in which students tended to record more verbatim language and a greater number of words at the expense of deeply processing the knowledge (Mueller & Oppenheimer, 2014). Clearly, haptics or touch is vitally connected to literacy practice and the workings of the mind, rather than detached or incidental to it.

Haptics is superior to vision at perceiving certain properties of the physical world, including microspatial properties of viscosity, elasticity, compliance of materials, and pattern. Likewise, touch is the human sense most able to differentiate between textures, like rough and smooth, hard, and soft, wet, and dry, sticky, and slippery (Minogue & Jones, 2006; Zangaladze et al., 1999). Touch can be used to perceive the temperature of objects (cool, warm, hot), and can be used to discern the weight and volume of objects held in the hand (Minogue & Jones, 2006). Contrastingly, human vision is capable of discerning colour and macro-geometric properties, such as shape. At the same time, haptic and visual information are often processed in complementary ways, with vision discerning macro-geometric properties, and touch perceiving microspatial attributes (Verry, 1998).

When we consider the vast array of haptic and movement-based interactions that humans can experience through digital media practices, the possibilities and complexities begin to be seen. For example, Friend and Mills (2021) generated a typology of touch derived from the analysis of children's touch in an international array of education settings and maker spaces. Students were found to use *explorative touch* deliberately enacted to explore the world, technologies, materials, and texts. Students often use *auxiliary touch*, which is touch via tools such as through a paintbrush, pencil, or keyboard. *Evocative touch* is tactility that evokes feelings, memories, or connections, such as when one runs their fingers over a finished sculpture emotively. Finally, students drew upon *creative touch*, touch that is inspired by the mind's ingenuity, such as when in a state of flow while drawing a sketch (Friend & Mills, 2021). Literacy practices entail interpreting and producing representations of knowledge that involve sensorimotor origins and embodied cognition.

Motion or body movement is similarly replete with different perceptual and meaning-making potentials from those of touch and vision, while also functioning in complementary ways to the other senses. For example, recent research shows that humans are better at visual motor targeting tasks while walking (e.g. press if it is a red target, but do not press if it is green). Pointing accuracy improves when in a state of locomotion, as opposed to when standing still. This suggests that walking facilitates the flow of visual information and action from the environment in a perception-action loop, supporting cognitive activity and decision making in rapidly changing environments (Mokhtarzadeh et al., 2021). Conversely, multisensory research from the cognitive sciences has shown that restricting the use of the senses to vision results in perceptual processing deficits, as well as reduced efficiency for memory, learning, and communication, which includes writing and speaking (Shams & Kim, 2012).

Theorists, such as Ingold, have long argued that locomotion is a portal for accessing memories and understanding place and "culture on the ground" (Ingold, 2004, p. 166). Literacy research has demonstrated the role of locomotion across a range of meaning-making situations, such as when scaling walls or moving with the camera in documentary filmmaking (Mills et al., 2013). Locomotion is central to virtual reality media designing of three-dimensional representations with motion sensors (Mills & Brown, 2021). Similarly, movements of the feet are an important part of Australian Indigenous 'Welcome to Country' ceremonial practices, where body movements and smoke are used to sensorially and symbolically clear away the wrongdoings of the past (Mills & Dooley, 2019). The changing potentials of haptics and motion in digitally mediated practices – from using a 3D pen to using wearable technologies while on the go – add a new layer of complexity to understanding and theorising the material and virtual enactment of literacy practices.

## New opportunities for touch and motion in literacy practices with digital media

In contemporary digital society, most of our reading and writing is done using a digital device, whether on a computer, mobile phone, tablet, e-book reader, or other digital display. Many people also use pen and paper to make notes, sign documents, personalise greeting cards, or to keep a private journal. A more personal form of communication that can reveal traits of the writer (e.g. shaky writing of the nervous), handwriting is a unimanual activity, while keyboarding on a computer or other digital device involves distinctly different bimanual haptics. For example, in handwriting, the writer forms each letter using graphomotor skills to represent conventional shapes of letters. Contrastingly, there are no graphomotor skills involved when using a QWERTY keyboard, since the writer's task is to locate and press the letters on the keyboard (Mangen & Velay, 2010). Since the advent of word processing software, computer-mediated writing of any kind radically alters the haptic dimensions of the writing process and continues to do so as technologies evolve. At other times, haptics may not be involved much at all, such as when using voice dictation for text messaging with a virtual assistant.

Communicating with others through oral language, the foundation of literacy learning involves observable movements of the body, including motor control of the tongue, lips, and head, and supporting movements and positioning of the eyes, head, torso, arms, and legs (Gibbs, 2005). Similarly, reading, writing, and other literacy practices are not exclusively performed while seated in a single location but are often carried out while on the move. Many digital media and multimodal language practices are supported by movement of the whole body, including the action of the legs and feet. For example, the movement of the body is vital across a range of expressive multimodal practices, from non-digital language practices, like spoken presentations, role plays, discussions, and interviews, to digital practices such as filmmaking, interacting with information in virtual reality simulations, programming an animated story, or creating a 3D model using a mixed reality headset (e.g. smartglasses).

Digital reading and information practices that depend on movement include interacting with a 360-degree film, using augmented reality apps with geo-spatial tracking, navigating a journey using Google maps, using an activity tracker, reading an e-book on public transport, reading digital signs and environmental print, using a self-serve checkout, and many other social situations. A clear example from classroom research involved students choreographing a dance and programming a complementary virtual character's dance based on curricular content, which involved an assemblage of multimodal literacy practices to improve students' computational thinking (Leonard et al., 2015). Interestingly, the students first created the dances with their own bodies, which enabled them to easily transfer the patterns of movement when programming the robots, demonstrating the centrality of movement in a digital media practice.

### *Bodily basis of meaning making and early language learning*

One might argue that in many of these movement-based literacy situations, the body's location and movement is merely peripheral or backgrounded, while the workings of the mind at an abstract level is dominant and somewhat removed from immediate perception. However, a growing body of evidence has indicated that all cognition is body-based (Mills & Exley, 2022; Wilson, 2002). Research on embodied cognition draws attention to mind–body processes, which counters the Cartesian dualistic view that separates perceptual experience from cognition or reasoning (Mangen & Velay, 2010). Many key features of cognition are, in fact, dependent on perception, movement, and action, with the body playing a fundamental role, often working subconsciously. For example, gestural movements are not only used for speaking and communicating information but play an active role in supporting fluency of thinking (Pouw et al., 2014). Research has shown that human evaluative judgements based on presented information are more positive when the research participant is simultaneously pushing upwards on a table (Robbins & Aydede, 2009). Likewise, abstract concepts are developed fundamentally from metaphors that are first realised as bodily experiences and interaction in real-world environments (Cox et al., 2017). Counting is first performed using fingers or one-to-one correspondence between the hands and the objects, to be later rehearsed and recalled in the 'mind's eye' as mental arithmetic. Likewise, early language learning is aided by music, clapping, and rhythmical actions, and body movements to discern patterns in language. When children learn to talk, one of the earliest necessary skills is for the infant to understand the meaning of the caregiver's pointing gestures as an exophoric reference to the person or thing being named. The development of this shared intentionality is vital in vocabulary learning and social development. As Goldin-Meadow (2007, p. 741) has argued, "children enter language hands first".

When children learn abstract graphic forms, control groups show that those who both study the forms visually and trace the forms haptically with their index finger have better memorisation of the graphic items compared to those who only learned them through the visual mode (Hulme, 1979). In other words, the haptic and visual information is better combined for such tasks, such as letter recognition, than reliance upon visual memory (Mangen & Velay, 2010). Similarly, researchers demonstrated that when pre-reading children and adults were learning to recognise symbols and letters, characters that were learned by copying the letters using handwriting were recognised more accurately than symbols that were learned by typing them using a keyboard, which applied to both pre-reading children (Longcamp et al., 2005) and adults (Longcamp et al., 2006).

### *Haptics in digital media practices*

Researchers acknowledged in the 1950s that communication tends to be considered as perceived through the eyes and ears and that other sensory channels are forgotten (Parisi & Archer, 2017). When we look at the history of the senses, there have been calls to acknowledge haptics or touch across a range of media practices for some time. Walter Benjamin in 1935 (2008) drew attention to the role of the hand in digital photography in that the finger arrests a view of reality at the press of the shutter release button, mediated through the photographer's eye and position of the body (Parisi & Archer, 2017). Similarly, in the field of human–computer interfaces, research since the 1970s has aimed to develop new media that would centre touch the way television had centred vision, and radio had done for sound (Noll, 1971). Others in psychology, such as Sherrick (1975), observed the paucity of psychological research on touch compared to vision and hearing, calling for investigations in skin-based communication (Parisi & Archer, 2017).

Many educators see the potential of video game play as interactive literacy practices because they call on the user's knowledge of narratives, decision making, critical literacies, multimodal texts, and gaming paratexts (game fan sites, wikis, books, magazines, etc). Haptics has become more visible in the design of game controllers, which since the 1990s has moved towards more embodied user interfaces (Fishkin et al., 1998). Games began to involve more direct physical manipulation of the technology to control events in the game, such as through tilting devices, shaking, or rotating them, or by blowing air directly into the microphone. Game controllers today also include vibrations or rumbles (Paterson, 2007), which have been adapted for use on mobile phones, and as reminders for sedentary wearers of smartwatches, Fitbits, and other wearable technologies (e.g. 150 steps to win the hour). Vibrations are difficult to ignore compared to screen displays, particularly when one's concentration is focused elsewhere. These haptic sensations are sometimes referred to as 'taptics' or vibrotactile sensations, simulating human tapping on the wrist (Lupton, 2017; Paterson, 2017).

Immersive virtual reality technologies with head-mounted displays support an array of sign-making practices, with motion tracking to allow users to perform a wide variety of manipulable haptic functions in a 3D world. Current examples include users shaping pottery from diverse cultural traditions (e.g. *Pottery VR*), virtual, in-air brush painting (*Google Tilt Brush*), and spray-painting graffiti (*Vive Spray*) on simulated buildings, subways, and walls. In some 360-degree interactive films, users can manipulate textual artefacts that are laden with print. For example, in the award-winning virtual reality film, *The Book of Distance*, Randall Okita engages in personal storytelling about his grandfather in Canada in the 1930s, who was imprisoned because he was Japanese. The virtual reality version of the film that can be played wearing a head-mounted display and motion sensors, invites users to touch, hold, and read archival family parchment, photographs, passports, letters, and newspapers, and other texts in an emotionally moving, simulated personal account of vibrant textual practices (Oppenheim & Okita, 2020). Because the user has a 360-degree view as a participant in the film, spotlighting is used to direct the reader's gaze to interact with texts in turn. Once the user has finished touching and reading certain textual artefacts, the next part of the film unfolds, making haptics salient to the pacing and flow of the filmic narrative.

Another innovative example of how haptics and the tactility of media are changing with new possibilities pertains to data materialisation. For example, researchers have used 3D printers to fabricate customised, edible chocolates that translate self-tracked heart rates after physical activity into a material form – the size of the chocolate reflecting the amount of physical activity undertaken by the participant as a reward. The chocolates were also inscribed with encouraging emoticons and words to support continued health gains. Personal digital data was no longer represented as abstract 2D mathematical and linguistic symbols, but could be viewed, touched, and tasted in novel, multisensorial ways that were memorable and meaningful for the participants (Khot et al., 2015; Lupton, 2017).

Sign-making practices extend well beyond print, with designers and data artists creating materialisations of data through 3D fabrications of data sculptures that invite tactile interaction. Such practices involve the aesthetic physicalising of information. A good example is the weather bracelet by Whitelaw (2009) that translated meteorological data in Canberra to a tangible and familiar tactile form. The highs and lows of the jagged contours of the bracelet show the maximum and minimum temperatures for each of the 365 days of the year recorded by the Bureau of Meteorology for Canberra. Small holes show the weekly rainfalls. The bracelet makes weather data tangible, but also invites an intimate, tactile familiarity with local, place-based information that can be 'read' and felt through touch.

Recent research on haptics in three different makerspaces with upper elementary children explored how touch was orchestrated with other multisensory resources in students' multimodal designs. Learners were engaged in making technology-enhanced modelling clay and recycled junk sculptures with moving parts, and sculptures with 3D pens. They made kinetic e-paintings combining conventional painting with embedded flashing lights coded using Arduino kits so that the paintings exhibited flow and movement. The students filmed 'slime videos', a popular YouTube craze involving the tactile and acoustic exploration of the viscosity of slime. Students also engaged with non-digital forms of drawing, painting, and sculpting (Friend & Mills, 2021). The research highlighted distinct ways in which touch, as a central part of the sensorium, contributed to thinking, creativity, feelings, and multimodal representations of knowledge. Movement of the hands did not simply carry out the work of the mind, but touch was involved recursively. As one student explained: "I'm just drawing, and then I get ideas. I'm drawing a rainbow, but it will probably change", while another said: "I'm using touch as in…if I can connect myself to the artwork, it just seems to flow better" (p. 10). In other words, sometimes touch leads the direction of the mind, in creativity and designing, rather than simply following.

### *Body motion, language learning, and digital media practices*

Human language and thought are fundamentally grounded in the felt experiences and action of the body; likewise, language and cognition are developed through the performance of a recurring bodily activity (Gibbs, 2005). Language and literacy practices can be understood by examining the ways in which the body engages with the tangible world – people, objects, texts, and other experiences in the environment. This recognition is supported by research in embodied cognition and language, which attends to sensorimotor experiences in cognition (Wellsby & Pexman, 2014). This view differs from classical cognitive science which gives priority to the minds' processing of abstract symbols, while de-emphasising the role of the body.

While theorists such as Piaget (2005) have drawn attention to the role of sensorimotor experience in childhood, with humans showing greater ability for abstraction later, recent theories of embodied cognition show that the role of embodiment in conceptual processing is always present, recurring, and continues through the life course (Wellsby & Pexman, 2014). In other words, the function of sensorimotor experiences does not stop or change fundamentally throughout development, but rather, becomes more agile, refined, and specialised over time as humans acquire new experiences and knowledge from the environment that build on earlier experiences (Antonucci & Alt, 2011).

Motion is vital to speech in the sense that speech and gesture activate each other, beginning firstly in infant development with manual motion, which forms the basis for the entrainment of speech production through the coordination of hand and mouth in speech (Iverson & Thelen, 1999). In other words, infants develop their representational system and speech through perceptual and motor interactions with their environment, sensorimotor experiences forming a critical part of language and thought.

Research demonstrates that sensorimotor knowledge forms the basis of language and higher-order thinking development among children of school age (Kontra et al., 2012) and throughout the life course (Thelen, 2007). For example, humans draw on sensorimotor information that they have gained through prior experiences in the world to comprehend language as they simulate vocabulary and sentence meanings (Glenberg & Kaschak, 2002). Similarly, humans have been found to draw on sensorimotor experiences when they describe and understand the orientation of objects, such as the relative position of items (Stanfield & Zwaan, 2001), and when they explain object affordances, such as the functions of tools (Myung et al., 2006; Wellsby & Pexman, 2014).

As children understand and build up a vocabulary of nouns – the name of an object, place, or thing in the world – sensorimotor experiences influence their categorisation of objects and their vocabulary learning. For example, Smith (2005) conducted experiments with two-year-olds who were given two different experimental conditions – one in which participants could move and manipulate an object before being asked to name and distinguish the object from among a group of very similar objects, categorising and describing it using appropriate vocabulary; and the other group that could only observe the object which the experimenter moved for them. The participants who were encouraged to explore and move the object around were able to provide descriptions that showed more accurate language and judgements of shape, function, and categorisation decisions based on the performed action than the group that was limited to using the visual mode (Wellsby & Pexman, 2014).

Experiments with toddlers have also been performed to understand how body positioning and spatial location influence vocabulary learning of nouns. They found that children used the location of labelled objects to reidentify them, not just attributes of the objects themselves. Toddlers also performed differently in their functional knowledge of objects and their label based on whether the child was standing or sitting, suggesting that children's body posture can play a role in linking objects to their noun label (Smith & Samuelson, 2010).

Similar findings were identified in children's learning of new verbs because motor areas in the brain were activated only for verbs that the participants had explored through their own sensorimotor action, and not for verbs learned by hearing the label and watching the experimenter do the action (James & Swain, 2011). When learning new adjectives pertaining to tactile qualities of objects (e.g. spongy, spiny), two-year old participants who were taught using tactile gesture, such as the experimenter squeezing the spongy object performed better than those taught through the experimenter pointing to the object (O'Neill et al., 2002; Wellsby & Pexman, 2014).

In contemporary digital media environments, the use of anywhere, anytime literacies through mobile technologies – invoking locomotion and other emplaced and embodied meanings – is worthy of research attention. Technologies that are used while on the move are now ubiquitous, such as video cameras, mobile phones, tablets, and other wearable devices, inviting greater involvement of large-body movement, such as walking or locomotion. Mills et al. (2014) describe research in which children moved through different natural and built environments while walking with video cameras to create documentary films about healthy places and the connection to emotions. Locomotion and moving through places on foot was essential in this process, as children captured and reflected multimodally on film, the materiality of lived, embodied, and situated experience of places (Mills et al., 2013). A repeated motif in the films was that students often recorded their feet walking to locations, along walks and footpaths, while lying on the ground to admire the blue skies, and in front of them as they glided down playground slides. The research highlights the way in which knowledge making and representation through documentary filmmaking on location, directly involved active participation through practical bodily and sensorimotor exploration, locomotion, and lived experience of places (Mills, 2016).

Others such as Ehret and Hollett (2013) have explored how middle-school adolescents produced texts and media through mobile devices (iPod touch) while wayfaring around school spaces – a distinct form of ambulatory and embodied movement that is not focused on simply getting to a destination – theorised by Ingold (2011). Researchers focused specifically on how students moved with their devices and the effect on their composition as they took photographs, film, and wrote. They observed that students became more attuned to the features and affordances in the environment for composing, while producing texts that challenge those scripted for formal school-based literacy practices and routine uses of the spaces in the school.

A growing range of digital media, from immersive virtual reality to mixed and augmented reality technologies, and from robotics to drones, have opened fundamentally different opportunities for understanding and optimising body motion and locomotion for literacy learning. Researchers and teachers who have access to novel media can teach students to encode and decode language using new virtual overlays, augmented reality books and apps, 3D holograms, simulations, 360-degree films, and other digital texts that have multisensory elements, and which track the user's movement or geo-spatial positioning (see Chapter 7, this volume). The specific outcomes of these kinetic-based digital media practices for multimodal composing and language learning, particularly their body-based potentials for extending human thought and language, remain largely uncharted territory.

## Tensions and challenges for touch and motion in literacy practices with digital media

Drawing attention to the role of haptics and motion in literacy and digital media practices does not negate the realities of politicised notions of literacy standards, exams, and assessments, requisite for many higher education opportunities and employment, where linguistic competencies are given privileged status over non-linguistic modes (Pahl & Escott, 2016). Our argument is not that linguistic elements of literacy should not be given priority in the curriculum; rather, there are many haptic elements of writing, keyboarding, drawing, public speaking, and using new technologies for interacting with texts that should not be taken for granted, skills which often require many years of training to move from rudimentary levels to expert accomplishment (Haas & McGrath, 2018).

Likewise, few have attended to the way in which literacy practices, thought, and language, are always first apprehended in movement, in forms of ambulatory knowing and pedestrian activity of the limbs and body (Mills & Dooley, 2019). The development of language and literacy practices are part of childhood and maturation, as terrestrial and embodied beings, who without transportation technologies, live and learn on the ground (Ingold, 2010). The repeated engagement in language and literacy practices, digital and non-digital, gradually become part of one's muscular consciousness, so that motion becomes taken for granted often until humans encounter an unfamiliar technology or tool when the haptic elements need to be learned with some intentionality. This has been seen, for example, when introducing a new virtual reality technology to students, such as immersive, three-dimensional painting in a virtual world – a context in which students need sufficient time and guidance to become familiar with the haptic controls and affordances for designing (Mills & Brown, 2021).

Yet many digital technologies for reading and writing are designed in ways that separate the workings of the hand or body from the visual space of the text, positioning the body in new ways, such as in the case of a computer monitor and keyboard (Haas & McGrath, 2018). Each new technology, from interacting with a 360-degree, virtual reality film, to filming movements to popular music excerpts on social media sites such as TikTok, calls for different kinds of body-knowing and body-communicating, with a vital interconnectedness between body, motion, space, and the mind (Ntelioglou, 2015). Perhaps somewhat surprisingly, technology developers do not always seek to apply research from embodied cognition, phenomenology, and neuroscience about the connections between hand, body, and mind (Mangen & Velay, 2010). Allen et al. (2004, p. 229) argue:

> If new media are to support the development and use of our uniquely human capabilities, we must acknowledge that the most widely distributed human asset is the ability to learn in everyday situations though a tight coupling of action and perception.

When teachers implement learning experiences that draw on use of haptics and motion using digital media literacies in the curriculum, principles of good pedagogy still matter, including the teacher's discerning selection or adaptation of technology applications in which haptics and motion are meaningful and purposefully used. Likewise, any technology for literacy can be used for ideological purposes: no technology should be used uncritically (Haas & McGrath, 2018; Luke, 1992). The ethical and civic consequence associated with the use of any newly produced technology should always be critiqued, asking questions such as: Who benefits and who misses out? Whose political or commercial interests are served? and What digital data traces will be used and for what purpose? How will haptic activity and geo-spatial movements be traced and shared with technology developers, and for what purpose? Research has found that most users of digital technologies have little knowledge of how their personal data is used, where it goes, and in what ways third parties are involved in its use (Lupton, 2017).

## Implications for digital media practices involving touch and motion in the classroom

Research has long demonstrated the vital role of haptic play and motion from birth that equips humans to learn about the world through the use of the full sensorium (Heath, 2013). Brain development requires the stimulation of whole-body motion and haptic interaction, with hand-thought-language relations occurring during playful manipulation of the environment. This forms the foundation for early language and literacy learning, including elements of imaginary play that evokes story creation. Heath (2013, p.191) has elaborated on these early learning haptic events:

> The hand – as investigator and manipulator of the environment – calls on all the modal systems necessary to produce these representations, especially so when the hand is shaping, grasping, drawing…or moulding materials… Questions that ask, 'What if? and 'What's this about?' result from the force patterns the brain exerts through the fingers, hands, and forearms.

Haptic feedback is vital in the performance of literacy practices, produced by the gripping action around media, such as crayons, pencils, and pens. Yet the body–brain–language connection for humans continues to develop throughout the life course, as the heuristic role of haptics and motion is developed through creative, skilful, and controlled use, such as for experienced musicians, orators, authors, dancers, artists, crafters, architects, graphic designers, stenographers, and many others. In terms of writing, for example, research demonstrates that handwriting speed and ease is not tangential to learning, but forecasts students' future ability to compose lengthy texts (James & Engelhardt, 2012). At the same time, the recognition that sensory learning should occur in the early years is not universally applied in classroom practice. Australian scholars have observed the reduction of multisensory learning environments across many early learning classrooms – a consequence of national assessment pressure for the development of formal literacy skills to be taught fast and furious (Somerwil et al., 2020).

A key implication of the essential role of haptics and movement in language and literacies development is that simply giving students opportunities to press buttons on digital game controllers or to swipe a touchscreen, does not guarantee that language learning is occurring optimally (Heath, 2013). For instance, apps for early language learning often involve haptics and movement, but these are not all equal in terms of learning gains. For example, when Mills et al. (2018) compared *The Heart and the Bottle* in print and e-book versions, we found that only the e-book version uniquely invites the readers' physical participation in activities of the main character that enables the reader to take part vicariously in the character's experiences and feelings. An instance of this is when the reader must shake the mobile device or tablet as the character shakes the glass bottle to release the visible heart inside, as well as sawing, drilling, and other actions that frustratingly fail to retrieve the heart. This kinaesthetic focalisation enables the reader to align their experiences and feelings with the character in meaningful ways (Mills et al., 2018). In contrast, interactive e-books can also be poorly designed, so that readers are distracted from the storyline with peripheral, gratuitous, or meaningless haptic actions, such as repeatedly touching background animations that are not relevant to the central narrative (see Chapter 10, this volume).

It is important for students to experience a range of haptic and motion-based literacy activities that are both digital and non-digital. This is because research has shown that some dimension of touch-tablet experiences, for example, if used alone, do not supply many opportunities for students to apply varied pressure on objects to produce different effects, as occurs when increasing pressure to create thicker lines using pencils, crayons, and paint brushes (Crescenzi et al., 2014; Neumann & Neumann, 2014). An exception would be the use of certain technologies, such as the pressure sensitive stylus pens and associated drawing applications, that simulate these effects of pressure to modulate line thickness.

Tablets and virtual reality technologies also restrict certain rich, sensorial haptic experiences, such as being able to touch varied textures, determine the degree of wetness or dryness of surfaces, perceive the temperature of things, and feel the viscosity of flowing substances, such as paint, modelling clay, sand, and other representational media. At the same time, virtual simulations of creative activities, such as virtual painting and pottery making have different advantages for haptic and bodily movement that can be explored with older students, given that virtual reality technologies with head-mounted displays are currently marketed to older children and adults.

A variety of digital and non-digital tactile and motion-based experiences that optimise meaning making should involve at least six distinct types of exploratory touch (Lederman & Klatzky, 1987). These are lateral motion (to perceive texture), pressure (hardness), static contact (temperature), unsupported holding (weight), enclosure (global shape, volume), and contour following (global shape, exact shape). Additionally, digital controls and technologies can invite two other types of exploratory touch: 'part motion testing' which is the human ability through the hand to explore what moving parts can do, applying force to the part while stabilising the rest of the object. Likewise, 'function testing' involves executing haptic movements to perform certain functions, such as putting one's hand inside a puppet, or testing the game control functions in a particular software application (Lederman & Klatzky, 1987).

In terms of body movement and motion, literacy practices that afford opportunities to use larger body movements contrast conventional reading and writing that is too often limited to fine-motor movements while seated or stationary indoors. Reading and composition can be digitally mediated by immersive virtual reality with head-mounted displays and motion tracking, mixed reality headsets and augmented reality applications that track the user's body, outdoor filmmaking and photography, and other activities involving encoding and decoding with mobile or wearable devices.

## Recommendations for researching touch and motion in new literacy practices

As the world of media and communication technologies rapidly shifts around us, so too must research of literacy practices that engage new forms of haptics and motion. A large number of studies compare the haptic dimensions of older technologies, such as handwriting to keyboarding (e.g. Longcamp et al., 2005, 2006; Mangen & Velay, 2010; Mueller & Oppenheimer, 2014) as well as a growing number of studies involving touchscreen tablets for children's learning (e.g. Crescenzi et al., 2014; Neumann & Neumann, 2014; Walsh & Simpson, 2014). However, there are new generations of digital applications, such as the Internet of Things (IoT) and wearable technologies (Lee, 2016), that have received lesser attention in terms of haptics and body movement, and particularly for literacy learning, representation, or decoding.

There are also more studies of touch or haptics in literacy learning (e.g. Bezemer & Kress, 2014; Haas & McGrath, 2018; Heath, 2013; Hulme, 1979) than of body movement and locomotion. This is a significant gap in research that will need to be filled, particularly when examining literacy practices across cultures, such as Indigenous narrative practices and ceremonies that give priority to painting of the body, dance, percussion, and movement – many of which have become part of a growing digital and social media heritage (e.g. Giaccardi, 2012; Mills & Dooley, 2019; Mills & Dreamson, 2015). It is anticipated that the rapid growth and technology development in augmented and virtual reality technologies for educational purposes (e.g. Eldequaddem, 2019) will give rise to a new wave of research to identify constraints and affordances in terms of their materiality and their sensorial potentials for literacy learning.

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# 7

# VIRTUAL, AUGMENTED, AND MIXED REALITY

## New literate bodies

Literacy and digital media practices, including multisensorial interactions, have undeniably changed in recent years, with transformed texts and the embodiment of practices through virtual, augmented, and mixed reality technologies. In societies in which there is a trend towards increasing digitalisation and detraditionalisation of conventional forms of communication, there are complexities concerning the very constitution of a text.

One example within a VR environment is *Let's Create! Pottery VR* where users can mould, bake, and paint life-sized, immersive, three-dimensional pottery with visual designs and hieroglyphics on a virtual wheel (see Figure 7.1). Such virtual texts are created while wearing specific apparatus: a headset to create an immersive textual experience – blocking out a view of the real world – and hand controls or sensors, like mechanical appendages that augment the user's body.

Or consider MR HMD smartglasses, which have a built-in microprocessor, such as Microsoft HoloLens. These hybrid technologies allow users to interact with floating touchscreens, control panels, and three-dimensional texts that are surreally anchored to one's real or corporeal world, but which have no tangible substance. For example, Figure 7.2 shows screenshots of stories created by children who used the Hololens 2 MR headset to illustrate oral narratives using 3D holograms. This is one scene from each story, selected from a series of events. The first is a story about a unicorn finding treasure at the end of the rainbow in an arctic scene, while the second is about a superhero in a cityscape. The students used in-air haptics to manipulate the 3D models that were superimposed over the physical world.

Such virtual, holographic texts, like manipulable sketches, labelled three-dimensional molecular structures, or forests of virtual trees superimposed on the

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**FIGURE 7.1** Roman pottery by an 11-year-old student using VR and in-air haptics

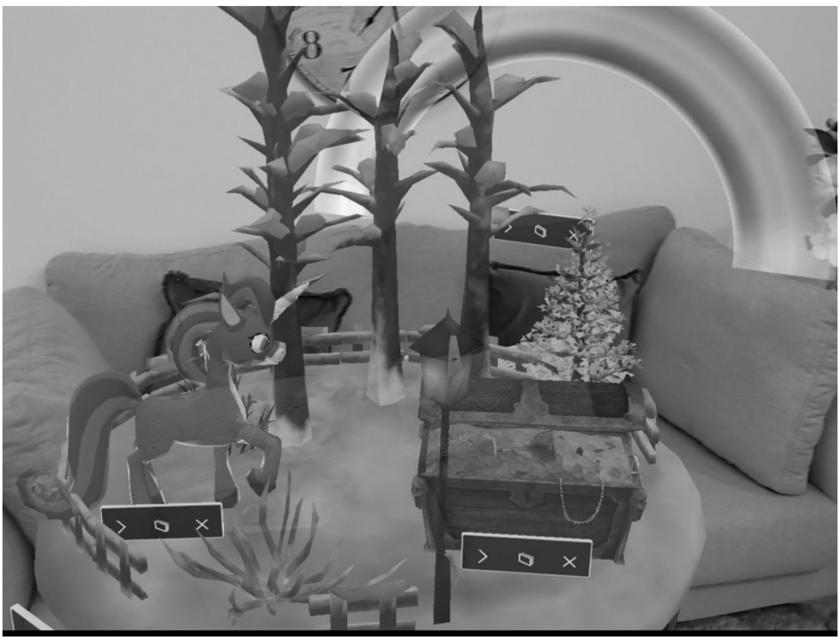

**FIGURE 7.2** Mixed reality narratives: 3D holograms viewed through the Hololens 2

real world, are imperceptible to others who are not wearing the smartglasses. For those wearing the digital device, the holographic images can be viewed, touched, and directed using one's fingers in the air.

These augmented and virtual reality texts, with their new modal affordances for three-dimensional representation, will not eradicate literacy traditions and routine bodily interactions with texts, such as using the alphabet, reading, spelling, drawing, or typing on a keyboard. Neither should these virtual and augmented texts be seen as diametrically opposed to, or competing with, conventional literacy practices, such as using newspapers, books, and pens on paper. Instead, their use can be complementary. For example, some researchers have begun to employ VR technologies to teach conventional literacy skills, such as English language learning or foreign language learning (Mills, 2022). AR technologies have been used to support early language acquisition reported in at least 52 studies, used for spelling games, word knowledge, interactive reading, and location-based word activities (Fan et al., 2020; He et al., 2014). What is emerging is a co-existence of multiple, differentiated, material, and virtual practices that are becoming more novel, affordable, and widespread, opening up an exponentially expanded number of representational choices, media, textual features, and hybridised practices for different social purposes.

Such shifts call for the ongoing rethinking of what constitutes literacy and media practices. We need to consider: What existing skills will be relevant and what will become backgrounded or foregrounded, essential, or cursory in the identity performances today and in societies of the future? Who will be inducted into these hybrid assemblages of wearable media first, last, or never, and how often, and to what ends? What multisensory interactions, modes, bodies, and cultural content will be privileged in these virtual practices that are generated by technology developers in the entertainment and 'edutainment' industries? This chapter charts some of the new territory and implications of these recent developments that have taken the technology industry by storm (Johnson et al., 2010), but for which the important technical facets that are common to these media, and that shape their potential as social practices, are largely unexplored.

A range of virtual, augmented, and mixed reality contexts are opening up possibilities for literacy practice, collectively referred to as 'extended reality' (XR) that includes future technologies still in development (Mills, 2022). It is difficult to ignore that these platforms are often developed and used in the context of gaming and entertainment. While some applications are designed for productivity and commercial use rather than play, such virtual, augmented, and mixed reality platforms are typically supported by gaming wearables and hardware. Games are defined here, following Salen and Zimmerman (2004, p. 80) as a practice involving players who typically engage in artificial conflict within a system of particular rules with 'quantifiable outcomes'. Games typically create an environment that contrasts with the seriousness of ordinary life, and in the context of education, with the seriousness of schooling, while often absorbing the player so that they become fully and seriously engrossed in the game.

Researchers have argued that a key advantage of games for learning is the provision of space for experimentation, role play, and simulation that is less constrained by conventional social norms. In many cases, such as for serious gamers, gaming is integral to the construction of social roles and identities (Garcia, 2018;

Scholes et al., 2021). VR, AR, and MR technologies have been identified as some of the fastest-growing developments in the commercial market, but also now in education, and predicted to increase exponentially in the next decade (Eldequaddem, 2019).

So how do theorists define and describe these mediated technologies that have new literacy and social potentials? AR technologies overlay virtual content, such as animations, products, and other information, over the real world. In this way, elements of the virtual and real world coexist in useful ways for learning, social purposes, and text creation (Chang et al., 2011). AR applications can employ a head-mounted or handheld display, webcam, or projector-camera system (Fan et al., 2020). The expansion of AR technologies has been strengthened by the development of mobile devices with internet access, GPS, cameras, accelerometers, and gyroscopes to track the orientation and rotation of a mobile device (Dunleavy et al., 2008). MR is an overarching term to cover the spectrum of different technologies, including AR, that to varying degrees, fuse or anchor the virtual and the real (Maas & Hughes, 2020). These simulation technologies generate an enhanced sense of immediacy, presence (the sense of being there), and in some applications, immersion (Bronack, 2011), with emergent potentials for literacy and media practices.

VR also simulates virtual objects, but typically without anchoring the virtual to the real world as occurs in augmented and mixed reality environments. VR involves immersive, three-dimensional experiences of simulated worlds using an HMD and haptic controls with motion sensors to manipulate objects in a computer-generated, multimodal environment (Velev & Zlateva, 2017). Unlike augmented and mixed reality platforms, the immediate physical world is completely blocked from view to simulate full immersion in the virtual environment (Jensen & Konradsen, 2018). This renders the physical or real world barely perceptible in the VR experience, only sensed by incidentally touching objects in the play space that are concealed from view (Mills et al., 2022).

VR texts are fully immersive, three-dimensional spaces, enhancing the user's sense of presence, of actually being in the text, with a strengthened degree of immediacy. For example, in recent research (Mills & Brown, 2021), researchers observed students re-enacting Greek myths using a virtual painting program, Google *Tilt Brush*, mediated by an HTC Vive VR headset. Many of the students were amazed by the sense of immediacy of the historical scenes that they imagined and painted. In the students' words, their ideas literally "came to life" and the VR space created "a sense of it's here" and "it's real". As one of the girls explained of her Trojan war painting: "You can go towards it", and "it feels like it's an actual world you can be in." Similarly, one of the boys depicted Icarus's glowing wings projected from the sides of the student's own body, while the form of Icarus was conspicuously absent. This is because the boy imagined himself to be Icarus as he viewed the scene in first person perspective, flying towards the radiant sun with the expansive sea below (Mills & Brown, 2021).

Virtual and augmented reality textual practices typically involve three-dimensional digital imagery, which differs from the plethora of two-dimensional textual forms (e.g. web pages, blogs, still images) that circulate on the internet. These virtual texts are simulations, and thus objects represented in a virtual world have a distinctive kind of virtual materiality that lacks physical tangibility and is distinguished from conventional literacy and artistic representational media, such as books, pens, or paint and canvas. At the same time, these simulated, three-dimensional texts and objects typically have multisensory interactive elements that are responsive to user movement, such as in the case of VR, offering different locomotive and haptic engagement and action within virtual texts, including locomotion and movement of the whole body throughout the virtual space.

## New directions for VR, AR, and MR literacies

Literacy practices, whether digital or not, whether virtual, augmented, or other, can be classified by social context, participation structure, participant roles, purpose, topic, tone, activity, norms (conventional practices), and language code (Herring, 2007; Hymes, 1974). While literacy researchers have referred to waves of digital and media literacies practices, sometimes grouped by their affordances or enabling features (e.g. Wohlwend, 2017), the distinctive possibilities of virtual, augmented, and mixed reality texts in education have not been given sufficient attention. Within educational research, these technologies and their application are most frequently researched and theorised in science, technology, engineering, and mathematics (STEM) education (e.g. Hussein & Nätterdal, 2015), while their potentials for language and literacy learning are much less frequently explored. For example, in a review of original VR studies, only 27 of 167 had some relevance to language learning (Reisoğlu et al., 2017). Even when the studies address literacy, the educational applications do not typically reflect how technologies are used in social sites beyond schooling. For example, early literacy skills are often presented through 'skill and drill' exercises, such as matching games and spelling quizzes, akin to many previous technologies for education consumer markets, but with immersive displays and, in the case of MR, a blend of virtual and real objects (e.g. Fan et al., 2020).

### *Social factors: AR, VR, and MR*

It has long been thought that the medium influences the meaning of communication, as reflected in McLuhan's (1964) phrase "the medium is the message". Yet the significant facets of novel media, immersive VR, and MR have not yet been categorised in terms of the technical dimensions that condition these emerging practices with social, textual, and communicative potentials. Posited here is an original classification system, drawing on a range of empirical studies to explain their inclusion. It is acknowledged that these technologies, while having some common facets of the medium, are also changing, and that other studies and future research may contribute additional factors (Mills, 2010).

In terms of *social factors* of discourses, these can be readily applied to virtual, augmented, and mixed reality. For example, any virtual, augmented, or mixed reality activity occurs in a particular *social context* that shapes technology use, such as recreational sites, educational contexts, home, or commercial settings. For instance, medical training programs have experimented with VR to simulate surgeries that would be too difficult or dangerous to perform in real life (Pottle, 2019); while in museums, young people and families have used VR technology to support knowledge of 3D museum objects in relation to their historical context (Rae & Edwards, 2016). The social context includes networked gaming cultures and communities, commercialisation, and marketing of technologies, ideologies, and worldviews that influence the history and design of the technologies. The social factors in any interaction influence the literacy practice, conditioning variations in discourses, with many social facets operating simultaneously. Social situation facets can be categorised, as indicated in Table 7.1.

The notion of *participation structures* includes the number of active participants, turn-taking, setting-shifts, and duration of turns. Currently, VR headsets and AR smartglasses – eyeglasses that overlay virtual information over the glass's lens – are mostly designed for individual users in homes or in commercial game arcades. Early adopters of technology in higher education are researching large group use of these wearables (Birt et al., 2018). *Participant characteristics* that influence the discourse can include factors such as player and observer roles, gender, age, dis/ability, culture, social status, experience with the technology, knowledge of the content or game, attitudes and motivation, and other attributes, both in real life and in terms of virtual personae.

Other social elements briefly summarised here are *purpose* (e.g. recreation, knowledge, skill development), *topic* (e.g. narrative, conceptual), *tone* (formal/informal, serious/playful), *activity* (e.g. game, navigation, model, simulation, book reading), *norms* (e.g. conventions, game etiquette, online social status), and *language code*. The *language code* used across a variety of VR, AR, and MR can include an array of features, such as the language (e.g. English, Spanish), language variety, dialects, vocabulary, grammatical forms, orthography, fonts, length of text, and text presentation (Herring, 2007). *Visual grammar* incorporates 2D and 3D imagery, reading pathways, narrative and conceptual depictions, viewer position through representation and interaction, modality and validity, and compositional meanings. Principles of colour from visual design, such as value, saturation, hue, purity, modulation, transparency, luminosity, and differentiation (Kress & van Leeuwen, 2020), are equally applicable to virtual and augmented reality environments.

**TABLE 7.1** Social situation facets of AR, VR, and MR

| | | |
|---|---|---|
| 1 | Participation structure | o Group size, e.g., one-on-one, one-on-group<br>o Public or private<br>o Formal or informal participation structure<br>o Contribution frequency and quality |
| 2 | Participant characteristics | o Participant age, gender, culture<br>o Experience levels<br>o Roles: in real life/virtual context<br>o Interests, values, attitudes |
| 3 | Purpose | o Social purpose – e.g., professional, recreational, social, transactional, communal<br>o Goal of interaction – e.g., play, learn, create, read |
| 4 | Topic | o Topic/s of exchanges<br>o Topic of group interest |
| 5 | Tone | o Formal/informal<br>o Attitude/mood conveyed (dis/satisfied)<br>o Humorous/serious<br>o Positive/neutral/negative |
| 6 | Activity | o Play a game, complete a task, visualise, problem-solve |
| 7 | Norms | o Social<br>o Cultural<br>o Language<br>o Community |
| 8 | Language code | o Written language conventions<br>o Spoken language conventions<br>o Genres and text types<br>o Syntax<br>o Vocabulary and orthography<br>o Fonts, font sizes, graphics |
| 9 | Visual grammar | o 2D and 3D imagery<br>o Visual reading pathways<br>o Narrative and conceptual depictions<br>o Viewer positions<br>o Representation and interaction<br>o Modality and validity<br>o Compositional meanings<br>o Colour (value, saturation, hue, purity, modulation, transparency, luminosity, and differentiation) |

## *The medium: AR, VR, and MR*

VR, AR, and MR technologies are characterised by a number of technological facets that condition the range and nature of social relations (see Table 7.2), and these interact with the previously outlined social situation factors.

The extent to which the medium depends on *virtual reality* alone, or *mixes the virtual with the real*, influences the social practice. For example, a fully immersive,

**TABLE 7.2** Medium facets – VR, AR, and MR technologies

| | |
|---|---|
| 1 | Virtual reality/mixed reality |
| 2 | Synchronous/asynchronous |
| 3 | Single user/multiplayer |
| 4 | Online/offline |
| 5 | Presence (the extent of presence is influenced by interactivity and realism) |
| 6 | GPS Location tracking/no tracking (AR only) |
| 7 | 3D/2D |
| 8 | Moving image/still image |
| 9 | Sensors (e.g. head tracking, eye tracking, haptic, body movement, locomotion) |
| 10 | Wearable/non-wearable technology (e.g. phone vs. smartglasses, data gloves) |
| 11 | Channels/modes – visual, audio, haptic, vibration, olfaction, taste, texture |
| 12 | Ephemerality/permanence |
| 13 | Pseudonymity |
| 14 | Voice/chat/messaging |
| 15 | Distribution/reproducibility |
| 16 | Materiality/immateriality (e.g. physical book with augmented reality content) |

virtual experience blocks any view of the real world (Pottle, 2019), rendering the virtual content more visually and sensorially focal than the backgrounded action of others in the real world, such as teachers or peer observers. In contrast, augmented and mixed reality often supports interaction with both virtual and real objects or environments, so that participants in the real world are visible. For example, a user wearing HoloLens 2 smartglasses (MR) typically sees everything in their immediate, real environment, while also seeing a virtual layer of projected characters, screens, menus, and objects that are visible only to the wearer (see Figure 7.3).

**FIGURE 7.3** Student making 3D Holograms to illustrate an MR story. Ethical consent was provided for the use of all facial images in the book

Whether the communication is *synchronous* (same time) or *asynchronous* (different times) is an important factor in virtual, augmented, and mixed reality because it concerns whether or not any interactions will occur simultaneously with others who are geographically remote, but virtually connected. For example, used in the context of multiplayer gaming, a VR headset can be used to enhance the gaming experience while the user interacts with other players verbally and socially at the same time (e.g. *Vivecraft* – multiplayer *Minecraft* VR). This medium creates a very different discourse than a virtual experience that is recorded and shared to be played back or recorded with other synchronously engaged participants to be replayed by others at a later time (asynchronous).

Virtual, augmented, and mixed reality media offer *single user* or *multiplayer modes* (two or more). The affordances of each mode influence the range and nature of interaction, the facility for collaboration, or pursuit of mutual goals, all of which will influence the social practice. For example, students can play *Minecraft* in VR with other students who are wearing a VR headset in another location, collaborating in real time to build, explore, or conduct virtual transactions in the game (https://www.minecraft.net/en-us/vr).

Synchronous voice communication can be used to play together if connected using VOIP (voice over internet protocol – calls over the internet), such as with *Discord*, a free voice, video, and text application (https://discord.com/). Often, VR games are conducted in single user mode, without the ability to collaborate with another user. Of course, users who are playing a virtual game in the same room can take turns using the headset, while participating and observing the action on the computer screen.

*Online* and *offline* applications of VR, AR, and MR differ in terms of how interactions occur with the technology, most critically because the functionality of various social applications may be dependent on internet connectivity. For example, an offline VR game, like *Vive Spray 2*, will involve interaction with downloaded computer-generated content, such as spray painting a virtual subway station with graffiti art – a solitary artistic and creative game – rather than involving interactions with other players (https://store.steampowered.com/app/614830/ViveSpray_2/). Contrastingly, Google Earth VR involves online connectivity to the internet to view geographically locations around the globe in a more immersive way than on a screen. *Wooorld* now allows users to explore the world in VR with friends located elsewhere (https://www.wooorld.io/).

The extent to which virtual, mixed, and augmented reality technologies support the users' psychological sense of *presence*, of actually being there (Heeter, 1992), is an important facet of the medium that conditions the social practice. A sense of presence is the general feeling and mental orientation that one is having a real experience, which may or may not be experienced as real sensorially. Interactivity and realism are two key factors that contribute to this sense of presence (Von Der Pütten et al., 2012). Interactivity, the responsiveness of digital technology to the user's input, can influence the sense of presence. For example, playing a VR game creates a stronger sense of presence than simply observing a game (Vorderer et al., 2009). Realism can include factors such as the resolution of the graphics, whether the events are in first-person or third-person view (Hoffmann et al., 2010), the realism of the player's virtual form, and the degree to which virtual objects behave as they would in the real world (Blascovich et al., 2002).

*Location-based or geo-based AR* uses a GPS, digital compass, and accelerometer to detect or tag precise locations, including the user's position. For example, the entertainment industry has utilised location-based AR gaming in popular applications, *Minecraft Earth* and *Pokémon Go*, which involve placing virtual objects in precise real-world locations, with potentials for viewing and interaction by others who traverse the same public spaces (and within the particular privacy and authorisation settings of the game). While the social purpose for location-based AR applications varies significantly (e.g. educational, commercial, productivity, entertainment), this facet of the medium conditions the types of interactions possible among users, with virtual content anchored to particular geolocations that are accessible by physical proximity in the real world. For example, *Wonderscope* uses AR to enhance reading experiences for kids (https://wonderscope.com/), where stories like *Clio's Cosmic Quest* allow children to move around the physical world while interacting with Clio who talks audibly and directly to the viewer (see Figure 7.4). The child reads and interacts with words that appear on the screen to make choices in the narrative.

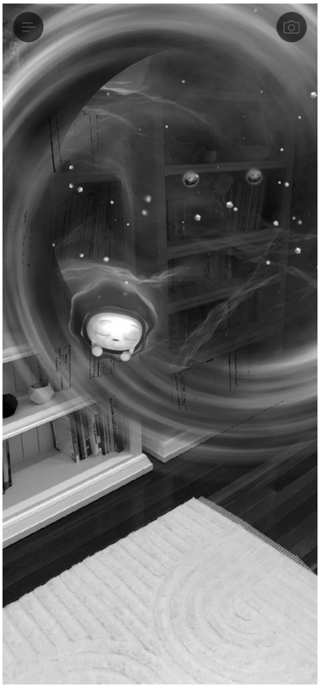

**FIGURE 7.4** Augmented reality story, Clio's Cosmic Quest in the Wonderscope app produced by Within Unlimited Inc., overlaying virtual objects on the real world

Whether the virtual or mixed reality environment is presented using *2D or 3D* visual representations or a combination of both, will influence the social practice because three-dimensionality often invites different reading paths to two-dimensional displays. For example, three-dimensional scenes in immersive VR can involve the user walking to different areas within a play space. Viewing virtual objects in a 360-degree space involves moving the body and head to explore and shift one's gaze around objects, to see the front, sides, and back. In contrast, viewing a two-dimensional image can occur from a single vantage point from the front (Kress & van Leeuwen, 2020). While most virtual and mixed reality environments involve some three-dimensional elements, the quality of the graphic displays vary, and two-dimensional representation is not uncommon, such as 3D virtual scenes or objects that can be translated and shared online in a 2D format. There are very different meanings for social interactions that are conditioned by a sense of presence (Mills & Brown, 2021), different forms of sensory engagement and physical movement within the text (Mills et al., 2022), and various spatial orientations within a three-dimensional virtual or mixed reality environment.

Social practices using virtual, augmented, and mixed reality technologies may involve *still or moving imagery*, or combinations of these, which conditions the potential meanings. Moving texts, such as those that appear in filmic media, video, television, and many contemporary video games, are sometimes referred to as kineikonic texts. The systems of signification in kineikonic texts, such as image (including dramatic action, gestures, facial expression, etc.), narration, music, or even silence, are combined in multimodal ways to create meaning within the spatial and temporal frames of filming and editing (Burn, 2013; Mills, 2011). The representational, interactive, and compositional meanings of kineikonic or moving image texts have been analysed elsewhere by social semioticians who note that action and transactions are realised by movement, rather than vectors, as occurs in still images (Kress & van Leeuwen, 2020).

The use of *sensors* is an important facet of virtual and mixed reality technologies which shapes the social practice. In the case of immersive VR technology with HMD, a positional tracking system uses infrared light-emitting base stations to communicate with sensors worn by the user to create 360-degree, room-scale virtual immersion. The sensor-based tracking system enables a sensorial form of computer-human interaction that simulates embodied interactions in the real world (see Figure 7.5).

When used to explore historical and literary content, for instance, such embodied interaction with historical times and places has been observed to build the user's empathy with literary characters (Moran & Woodall, 2019). Mixed and augmented reality applications may use one or more motion-tracking systems, such as digital cameras or other optical sensor, GPS, radio-frequency identification (RFID), gyroscopes, solid-state compasses, or accelerometers. For example, in research of AR technology, users' social connectedness and non-verbal behaviour were influenced by the presence or absence of a headset in a group setting (Miller et al., 2019).

**FIGURE 7.5** Using HTC Vive VR sensors

The extent to which VR, AR, and MR activities involve the use of *wearable technology* influences the social meaning, and there is a growing variety of wearable devices, from AR smartglasses to VR HMD that block out views of the real world (Jensen & Konradsen, 2018). Other VR technologies are not wearable, such as immersive rooms, or smartphones that support AR. The social conditions of each vary in particular ways. For example, when a user wearing smartglasses concentrates their gaze on virtual information, people nearby are effectively 'looked past' and ignored.

Virtual, augmented, and mixed reality platforms combine multiple *channels* of communication, often referred to as modes (Kress, 2000). These media typically give priority to vision, which may include the visualisation of written words, images, spatial layouts or graphic formats, and gestural meanings. The visual channel may or may not be supported by eye-tracking technology and sensors to guide vision through head movement. Audio, such as background music, is typically supported by VR platforms, with headphones and microphones in the HMD, while AR apps for education, commercial use, or productivity, such as those that overlay 3D images through one's smartphone camera, may background (e.g. music, sound effects), foreground (e.g. virtual character speaking directly to the user), or exclude sound. Each offers different semiotic resources for communication, with each mode carrying a different functional load of the meaning.

VR technologies often track the user's body movements via a range of motion-sensing technologies, with movement being an important channel for making meaning. Other channels for simulated communication include tactility (user action), vibration (user receives), or airflow (user produces into a microphone) through various game controllers. Channels to simulate olfaction, taste, and texture have been developed to enhance narrative meanings in game play. For example, the taste of food has been simulated through electrodes on the tip of the tongue (Ranasinghe & Do, 2016), while the texture of eating food has been simulated through electrodes that stimulate the masseter muscle in the jaw (Niijima & Ogawa, 2016). Examples of how taste has been used to support meaning making across a range of media were discussed in Chapter 5. The trajectory of development in human–computer interaction is rapidly opening up a greater number of sensorial channels for simulated communication, experience, and interaction.

The degree to which virtual, augmented, or mixed reality practices are characterised by *temporality or permanence* may influence the social dimensions of the practice (Herring, 2007). For example, Snapchat, which overlays AR filters and art over selfies, automatically deletes digital content sent by someone after it is viewed rendering it temporal. Texts that are shared and permanently viewed by others on social media (e.g. Instagram) have a different social function than a transient or ephemeral text, such as taking an AR image to see how a potential purchase might look in a home.

In addition, the extent of user *anonymity* or *pseudonymity* is relevant to virtual and mixed reality technologies with direct implications for how one interacts, pretends, or edits one's digital persona (Herring, 2007). Immersive VR game play often involves the user selecting a player name that is different to one's real name or taking on a game persona using a pseudonym. Anonymity involves the absence of any revelation of personal information or identifiers. Research of other online interactions has shown that anonymity increases the frequency of self-disclosure (Kiesler et al., 1984), role play (Danet, 1998), and antisocial behaviour (Donath, 1999; Herring, 2007). This does not necessarily mean that the user cannot be identified to technology companies.

Virtual, augmented, and mixed reality technologies may include integrated facility for *messaging, chat*, or *voice call*, or require a separate program. This might occur in the context of a multiplayer game while using HMD with built-in microphone to talk to another player. *VRChat* is an example of a massive multiplayer online VR game where users appear as 3D models, and speak to one another socially in groups, or in separate two-person conversations, configuring the discourse in particular ways (VRChat, 2020).

Technology support for the *reproducibility* and *distribution* of digital content varies across VR, AR, and MR, which often enables users to save and share elements of their virtual experience. For instance, users may save images produced in an AR app to a smartphone's image library for easy distribution on social media. In contrast, VR video recordings, such as Google *Tilt brush*'s Tilt files, can be converted into an accessible format to be viewed by those without *Tilt brush* software (see Figure 7.6). Thus, the ease of distribution of augmented and virtual reality texts varies across platforms and applications, with differing emphasis on enjoying the social experience itself or sharing about the experience with others.

**FIGURE 7.6** Boats in Trojan War painted by a student using Google Tilt brush

The *materiality* or *immateriality* of virtual, augmented, and mixed reality texts, hardware, and software varies substantially, influencing the social conditions of their use. Immersive, VR technologies project a virtual environment or 'text' that is visible, but which is essentially immaterial, characterised by a lack of corporeality or tangibility. For example, Smartglass technologies have built-in processors, so that the relatively lightweight glasses can be worn in various social settings while on the move or around the classroom (Ibrahim & Ali, 2018). Many mixed and augmented reality technologies support hands-on interactions with both physical learning materials, such as tangible books with links to AR content, flashcards, and pencils, with virtual content displayed on a tablet or smartphone, which orientates the social interaction in particular ways (Fan et al., 2020).

The purpose of the current classification was to identify and systematise the key dimensions for VR, AR, and MR literacies that influence interactions with others and virtual texts. It is formulated on the understanding that digitally mediated literacies are shaped at the most elementary level by the social situation of use and the medium (Herring, 2007). Discourse norms will not be the same for different social purposes and virtual environments.

## Tensions for VR, AR, and MR literacies technologies

While VR, AR, and MR platforms are changing the nature of literacy and communication practices in definitive ways, particularly in commercial and recreational spaces, the full extent of these transformations is yet unseen. In 2018, the number of people who had used an AR application at least once a month in the USA was 59.5 million, forecast to exceed 95 million by 2022 (Vailsherry, 2021). AR applications have been associated with improved kinaesthetic, spatial and visualisation skills, critical thinking, and active involvement in learning – skills that are supportive of language and literacy practices (Altinpulluk, 2019). Likewise, VR technologies have become more common in education, with fully immersive meaning-making potentials that include virtual painting, manipulating three-dimensional models, reading interactively, and many other ways of using information and sign-making (Dooley et al., 2020; Mikelli & Dawkins, 2020; Rose, 2018).

The commonly cited constraints for language learning have included the tendency of these platforms to prioritise visual information (Mills, 2016), the limited and inflexible range of education content developed to date, and the difficulty for teachers to develop and adapt applications for their own purposes. Others have noted technical difficulties in classroom settings, such as unstable or imperfect tracking (Fan et al., 2020). Some AR and VR literacy applications are based on a narrow definition of literacy as phonological and word recognition skills, with many literacy games based on behaviouristic, stimulus-response quizzes and factual recall (Fan et al., 2020). Likewise, virtual and mixed reality technologies are subject to some of the common barriers to teacher take-up of any new technology in the curriculum, including insufficient professional development for teachers, teachers' lack of time, an overcrowded, and in the case of some VR and MR systems (e.g. HMD, smart glasses), expensive computer upgrades, maintenance, and space requirements (Chandra & Mills, 2014; Sirakaya & Sirakaya, 2020).

One of the foreseeable tensions for the use of extended reality technologies for language and literacy learning will be closer work between educators and technology developers to ensure that these platforms are suitable for curriculum use in large and small group learning contexts. This requires technology development research in which these new media are researched and adapted *in situ* for classroom use, with input from literacy educators and curriculum developers to guide the future of virtual, augmented, and mixed reality technology for positive educational change.

The necessary development of assessment tasks and rubrics to ensure that these technologies are not marginalised in the curriculum is anticipated to be an additional challenge, given that print-based literacy practices dominate standardised testing programs on a global scale. In addition, given the digital divide in-home computer and internet access (see Warschauer & Tate, 2018) – technologies that are needed to support many AR, VR, and MR applications – it is important for schools to provide access to these newer learning technologies for purposeful learning gains that will otherwise become the exclusive domain of the middle class. Within the context of current growth of extended reality technologies, AR applications that are supported by mobile phones have become one of the most widely accessible technologies to the masses (Sommerauer & Müller, 2014).

## Implications of VR, AR, and MR for literacy curriculum and pedagogy

While research of VR and MR applications for language in education currently only constitutes a small proportion of published work (Reisoğlu et al., 2017), there are clear potentials for using VR, AR, and MR for the literacy curriculum. Emerging potentials of these hybrid technologies have been identified for speaking and social learning, language code breaking, reading and comprehending texts, and creative digital text production. Spoken language learning is a vital foundation for literacy practice, so it is interesting that virtual and mixed reality technologies have been found to provide a supportive environment for speaking and social learning. For instance, some people with introverted personalities report feeling more comfortable in virtual social interaction compared to face-to-face social setting (Brennan, 2017). Additionally, researchers have found learning gains for children's AR-supported dramatic play (Han et al., 2015).

In relation to VR, AR, and MR technologies for literacy, there are numerous studies that demonstrate the potential for teaching language code breaking using games-based pedagogies (Fan et al., 2020). Most notably, a number of studies have explored AR technology games for teaching spelling (Pu & Zhong, 2018), word recognition, word and object matching (Barreira et al., 2012), sound and object matching (Fan et al., 2020), and other collecting games, usually in location-based educational AR applications (Hsu, 2017).

Extending beyond phonics and other early literacy skill development, emerging VR research has considered the potentials for creative digital text production. For example, Mills and Brown's (2021) research with open-ended design software, Google *Tilt brush*, was used with upper elementary students in generative ways to transmediate or shift meanings from conventional writing and drawing in two dimensions, to three-dimensional immersive textual creation across multiple modes. The lack of equivalence between sign systems (2D drawing to 3D VR painting) established an anomaly for the learners that led them to invent new ways to represent concepts three-dimensionally. Students used amplified haptics and locomotion to create 'surround images', with immersive effects, conjuring a sense of presence in their immersive digital designs that was distinct from conventional drawings and writing on paper (Mills & Brown, 2021).

Recent research has pointed to the potentials of VR, AR, and MR technologies for reading, comprehending, and making meaning from texts. For example, in classroom research by Moran and Woodall (2019), teachers used VR headsets to support the students' interpretation of the novel, *To Kill a Mockingbird*. The students were able to walk around a 360-degree virtual space to explore the historical context first-hand, which enabled the students to empathise with the experience of the characters. Further, students were able to think critically about narrative settings, time, and place in literature more broadly. Another example is AR interactive books, which contain overlaid virtual content, such as three-dimensional models, viewed through a mobile device (see Chapter 10). Interactive meaning-making activities based on the reading of an AR book can involve tasks such as organising events from the narrative in chronological sequence, supporting meaning making with books in interactive ways (Vate-U-Lan, 2011).

## Recommendations for research of VR, AR, and MR literacy practices

While virtual, augmented, and mixed reality technologies have generated new textual formats that combine visual, tactile, audio, and other channels that are only emergent in media and literacy research, technology developers are still exploring the simulation of touch, taste, and smell as human–computer interaction modalities, which are currently missing in most VR and AR technology platforms marketed on a mass scale. Technology researchers envisage a future in which the expansion of virtual, augmented, and mixed reality platforms for everyday users is more fully multisensory and immersive, stimulating more than vision and hearing in immersive virtual environments (Mills & Friend, 2021). Likewise, the expansion of communication channels in virtual and augmented simulations will contribute in some ways to the development of more inclusive digital environments for the deaf or blind, working against ableist assumptions that are complicit in technology development, and the Western, empiricist prioritising of the visual mode or observation as the main source of truth, and as a higher form of knowing (Mills et al., 2018).

Researchers who apply a human-centred approach to guide these technology developments similarly point to a lack of vocabulary or nomenclature to describe olfactory, tactile, and gustatory experiences in the same granularity as visual and audio elements to guide human–computer interaction development (Anjum, 2019). For example, the language of taste focuses on broad descriptors such as sweet, sour, and salty, yet if electrodes on the tongue are to simulate the varieties of human taste sensations, both the nomenclature and simulation technology will need to advance beyond three main experiences. In the future, it is anticipated that virtual, augmented, and mixed reality technologies will have higher *simulation fidelity*, that is, the extent to which the simulation mirrors interaction in the real world (Hamstra et al., 2014), with texts that require the use of an expanded sensorium that includes visual, auditory, tactile, gustatory, and olfactory features (see Chapter 5). Narrow, text-image-based conceptions of sign making will need to be expanded to account for odours and flavours that have been invested with meaning, such as the use of the aromas of incense in many religious traditions to denote the prayers of the faithful, or the flavour of cinnamon as a status symbol in the European Middle Ages.

Research on embodiment and learning demonstrates that the precise ways in which the body is mediated by digital tools actually matter to the mind, to memory, and to understanding, whether it be the way visual attention is more focused when writing by hand compared to keyboarding or how handwriting speed, an often taken-for-granted fine motor skill, is actually a strong predictor of students' ability to compose quality, lengthy texts (Haas & McGrath, 2018). It comes as no surprise then, that virtual, augmented, and mixed reality technologies, with their varied material and immaterial forms, hybrid sensorial interaction, motion-tracking, and location-based features, position the body in different ways that matter for the mind, for literacy, and for the representation of knowledge.

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# PART III
# Texts and digital semiotics

Technology is fundamental to the semiotic, or meaning-making, processes in which we engage through our creation and interpretation of texts expressed in various forms of media. The materiality of texts and the nature and extent of our bodily engagement in interpreting and producing them have always been related to the technologies for communicating meaning that are available in society. The semiotic affordances of different types of communication technologies favour or facilitate different kinds of meaning. Kress and van Leeuwen (2020, pp. 227–228) distinguish three classes of such technologies according to the ways in which they produce representations of meanings: (i) those articulated by the human hand, aided by handheld tools such as brushes, pencils, keyboard, mouse, etc; (ii) audio and visual recording such as digital photography and movie-making, "which allow more or less automated analogical representation"; and (iii) technologies which allow digitally synthesised models of the phenomena to be represented. As Kress and van Leeuwen (2020) point out, the boundaries between these categories are not clear cut. The chapters in this section evidence a range of combinatorial applications of these categories of technologies reflecting the changing materiality of texts, differing bodily engagement in their creation and interpretation, and the resultant expansion of semiotic choices in multimodal digital age texts.

In Chapter 8, we discuss the increasing prominence of infographics, particularly in public communication of health and environmental information but also in science and technology curricula in schools (Unsworth, 2020, 2021). Today, we readily recognise infographics as page or screen-sized image–language ensembles that usually include at least one image of various kinds such as photographs, diagrams, graphs, maps, cartoons, etc. separately or in combination, along with text in the form of image captions, 'call-outs', annotations within images,

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and interpolated text blocks. Such contemporary infographics combine hand articulated and recording communication technologies. Their communicative role entails the condensation of complex, detailed information as visual-verbal 'synoptic eyefuls' within the spatial confines of one page or screen. The effective bi-modal portrayal of meanings in this format requires not only astute and appealing design but also dextrous creation and manoeuvring of a variety of representational forms. Mapping the available designs for infographics provides a metalanguage describing the meaning-making options they afford, which can inform the development of critical infographic literacy. Chapter 8 outlines current approaches and future possibilities along this trajectory.

The earliest forms of animation involved devices such as a spinning cardboard disk of slightly different images that created the illusion of movement when viewed in a mirror. These animations relied entirely on hand-articulated technologies, but these were augmented in later forms of animation with recording technologies that enabled filmic animations. This sequential augmentation of different production technologies persists as stop-motion animation but has become increasingly inter-related in digital animation creation that integrates computer programming with multimodal animation authoring. In Chapter 9, we discuss primary and secondary school students' involvement in this form of animation creation through coding animated narratives. The physicality of this kind of multimodal digital text creation cannot be underestimated. The kinds of meanings that can be conveyed rely on students' dexterity in modifying digitally drawn avatars to represent different feelings or actions – or drawing their original avatars – as well as their physical construction of the computer program (in our examples by assembling on-screen virtual blocks representing computer codes). This coding results in the dynamic portrayal of the story. Recording technologies enable the student authors to incorporate their own or others' voices for the characters and to include original or selected sounds and music as part of the animation. In Chapter 9, we discuss existing pedagogic approaches to coding animated narratives and suggest a re-configuring of research and pedagogy at the intersection of coding and multimodal authoring as a basis for further advancing this aspect of literacy for digital futures.

Kress and van Leeuwen (2020 p. 228) indicated that synthesising communication technologies are not only tied to recording technologies oriented to the eye and ear, but in addition reintroduce hand articulation technologies through interfaces such as the keyboard and mouse, and increasingly through direct articulation of the body via spoken commands or responses to the computer, and through touchscreens and the manipulation of digital devices such as tablets. The materiality of contemporary and emerging digital interactive literature exemplifies these synthesising technologies, which are creating new dimensions of literary experience through new forms of literate practice and expanding the nature of bodily engagement in literary story worlds. Chapter 10 examines the nature of user bodily interactivity in works of digital interactive literature for children and adults that involves interacting with fictional entities through activity such as screen swiping or device shaking in animated picture books, and confronting the seeming corporeality of characters and materiality of settings in picture books, short stories, and novellas through various forms of virtual reality apps. A framework is developed that maps complex networks of options for interactivity to the multiple meaning-making dimensions of language and image to inform ongoing research and to derive future-oriented pedagogies that will address new ways of experiencing and interpreting digital multimodal literary narratives.

Core to developing literate competence, whatever communication technologies and representational modes are involved, is the negotiation of meaning. This negotiation entails an appreciation of the three simultaneously occurring, distinct and inter-related dimensions of meaning: ideational meaning referring to the representation of events, participants, and circumstances in experience; interpersonal meaning referring to the nature of relationships among participants; and textual meaning, pertaining to the relative information value and cohesion among the represented elements (Halliday, 1978). But negotiating meaning also entails understanding how these dimensions are communicated through various modes. This requires a metalanguage describing the options for the expression of meaning in the different modes and their multimodal combinations (Rose, 2020a, 2020b). Pervading this section is our contribution to advancing this evolving metalanguage as a resource for pedagogies seeking to develop literacy for digital futures.

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# 8

# INFOGRAPHICS AND SCIENTIFIC LITERACY

## Introduction – infographics in 21st-century literacies

The digital multimedia communication world of the 21st century, with its predominant information-based economy, is characterised by cultural and societal expectations of increased engagement with the readily accessible and ongoing proliferation of information in all walks of life. The promotion of ubiquitous popular consumption of information in these varied realms has led to an ever-increasing emphasis on visualisation, and the notion of communicating large amounts of often complex information as an 'eyeful' within single page or screen size information graphics. These infographics are image–language ensembles that usually include at least one image of various kinds such as photographs, diagrams, graphs, maps, cartoons, etc. separately or in combination, along with text in the form of image captions, 'call-outs', annotations within images, and interpolated text blocks (Unsworth, 2021). They have been characterised as having the capacity to grab readers' attention, and to condense, connect, and make accessible components of high volume, complex issues (Conner, 2017; Damman et al., 2018; Dunlap & Lowenthal, 2016).

Infographics have been shown to have aesthetic appeal to a broad general readership (Lima, 2011, 2014, 2017). They are also increasingly being used in professional journals such as the *British Medical Journal* (BMJ, 2021). The BMJ website states:

> Our infographics are a new initiative at the BMJ. We know that you, our readers, are increasingly time-pressured, so we aim for them to include some carefully selected information from an article, highlighting the key messages…. BMJ infographics are reviewed by the authors, our technical

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> and section editors and with some the peer reviewers before publication, and we're confident that they are accurate representations of the article.
>
> *(BMJ, 2021)*

But infographics are used extensively and are seen as increasingly important in communicating to the general public on websites and in the popular press, as well as in brochures and other publications by government and semi-government authorities and industry (Gebre, 2018; Lee & Kim, 2017; Naparin & Saad, 2017; Yarbrough, 2019).

While the occurrence of various forms of infographics can be traced back for centuries, there has been an upsurge and widespread proliferation of their use in the 21st century (Gebre, 2018; Yarbrough, 2019). Infographics are ubiquitous in communicating about a wide range of issues of personal, social, and global significance that warrant urgent attention. The importance of infographics in educating the general public has been evident in their widespread deployment by the World Health Organisation, and by national and state governments and health authorities during the COVID-19 pandemic and emphasised by intense research on their use (Cavazos et al., 2021; Domgaard & Park, 2021; Jacob, 2020; Li & Molder, 2021). Many infographics concerning health and environmental issues are focussed on developing a scientific understanding of complex concepts in highly condensed, single page formats that provide accurate information, and at the same time are visually appealing and understandable by a lay audience. The ubiquity of this compact, multimodal form of public education and the significance and urgency of the issues being addressed make infographic representation in scientific literacy pedagogy crucial on the agenda for educational research and classroom practice.

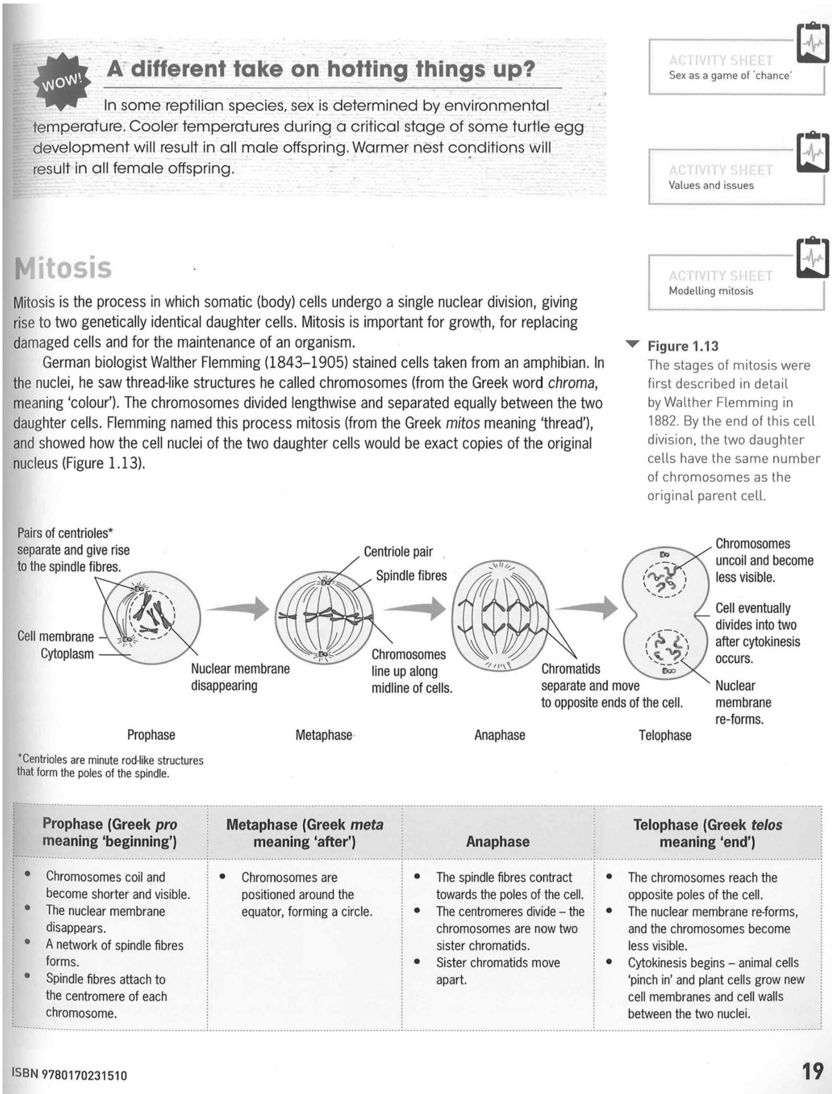
In this chapter, we firstly show examples of *infographics in science learning and assessment* that students need to negotiate in schools. We outline the distinctive inter-relationships of image and language in these highly condensed but tractable portrayals of complex ideas and indicate the requirements for students to create approximations to these kinds of infographic representations in assessment tasks. In the next section, we examine research into the *co-articulation of language and image in student-created infographic representations*. Here, we identify the need for this research to draw on a more comprehensive and consistent account of mechanisms for linking image and language, the variety of text formats used in conjunction with images, and the semiotic means by which meanings are condensed in the disciplinary discourse of science. In the following section, we provide a set of network-mapping options *for image–language integration and meaning aggregation in infographics*. From this mapping, we make some suggestions for *teaching–learning experiences to enhance infographic literacy development*, and we conclude the chapter with recommendations for researching infographic literacy for digital futures.

## Infographics in science learning and assessment

In contexts of schooling, the trend toward infographic style representation has been documented in science education with the increasing dominance of images as the rhetorical locus in 'trade' and textbooks (Bateman, 2008; Bezemer & Kress, 2010; Kress, 2005; Peterson, 2016). In some cases, this trend has progressed to the extent that traditional 'running text' has been elided in favour of image-based portrayals that include annotations, interpolated text blocks, and a caption (Danielsson & Selander, 2016; Martin & Rose, 2012; Unsworth, 2020a). Figure 8.1 shows a page from a Year 10 science textbook widely used in Australian Schools (Chidrawi et al., 2013, p. 19). Under the heading of "Mitosis" in Figure 8.1, there are two paragraphs of 'running text' and then the infographic is designated as "Figure 1.13". This consists of the caption, the annotated diagram of the cell at different stages of mitosis, and the table of dot points whose headings correspond to the stages of mitosis depicted and named in the diagram with each column of the table directly below the corresponding stage in the diagram.

The running text firstly defines mitosis as "the process in which somatic (body) cells undergo a single nuclear division, giving rise to two genetically identical daughter cells". The remainder of the running text indicates the importance of mitosis for growth, replacement of damaged cells, and maintenance of an organism, as well as historical information about the biologist Walther Flemming's discovery of the processes of mitosis. It is important to note that the brief traditional running text does not explain the process of mitosis, and the textbook relies entirely on the infographic for this explanation. This is also the case with other similar textbooks (Lofts, 2015, p. 28; Silvester, 2016, p. 10). Students need to read and interpret each of the diagrammatic representations and the changes from one representation to the next, coordinating this visual interpretation with the annotations in each case, and then they need to relate this to the table of dot points below, which provide additional information to that included in the diagram and annotations. This kind of complex multimodal interpretive reading practice which involves continuous inter-relating of multiple visual representations and interpolated annotation in the absence of traditional main running text, is also what is required in reading the kinds of infographics that are used in public education campaigns, such as that shown in Figure 8.2 disseminated by the National Oceanic and Atmospheric Administration of the US Department of Commerce (2021). Hence, developing this form of scientific literacy is important learning in school and beyond.

The importance of infographics in school education is also evident in their increasing inclusion in high stakes student assessment programs. Figure 8.3 is an example of an infographic from the Program for International Student Assessment (PISA) widely administered in over 80 countries every three years to 15-year-old students through the Organisation for Economic Co-operation



WOW!

**A different take on hotting things up?**

In some reptilian species, sex is determined by environmental temperature. Cooler temperatures during a critical stage of some turtle egg development will result in all male offspring. Warmer nest conditions will result in all female offspring.

ACTIVITY SHEET
Sex as a game of 'chance'

ACTIVITY SHEET
Values and issues

ACTIVITY SHEET
Modelling mitosis

## Mitosis

Mitosis is the process in which somatic (body) cells undergo a single nuclear division, giving rise to two genetically identical daughter cells. Mitosis is important for growth, for replacing damaged cells and for the maintenance of an organism.

German biologist Walther Flemming (1843–1905) stained cells taken from an amphibian. In the nuclei, he saw thread-like structures he called chromosomes (from the Greek word *chroma*, meaning 'colour'). The chromosomes divided lengthwise and separated equally between the two daughter cells. Flemming named this process mitosis (from the Greek *mitos* meaning 'thread'), and showed how the cell nuclei of the two daughter cells would be exact copies of the original nucleus (Figure 1.13).

**Figure 1.13**
The stages of mitosis were first described in detail by Walther Flemming in 1882. By the end of this cell division, the two daughter cells have the same number of chromosomes as the original parent cell.



| Prophase (Greek *pro* meaning 'beginning') | Metaphase (Greek *meta* meaning 'after') | Anaphase | Telophase (Greek *telos* meaning 'end') |
|---|---|---|---|
| • Chromosomes coil and become shorter and visible.<br>• The nuclear membrane disappears.<br>• A network of spindle fibres forms.<br>• Spindle fibres attach to the centromere of each chromosome. | • Chromosomes are positioned around the equator, forming a circle. | • The spindle fibres contract towards the poles of the cell.<br>• The centromeres divide – the chromosomes are now two sister chromatids.<br>• Sister chromatids move apart. | • The chromosomes reach the opposite poles of the cell.<br>• The nuclear membrane re-forms, and the chromosomes become less visible.<br>• Cytokinesis begins – animal cells 'pinch in' and plant cells grow new cell membranes and cell walls between the two nuclei. |

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**FIGURE 8.1** Infographic in a Year 10 science textbook
Chidrawi et al., 2013, p. 19

and Development (OECD, 2010, p. 100). Here, there are only two lines of traditional running text, but students need to coordinate their interpretation of the inter-relationships among four different kinds of visual representations, along with their associated annotations and interpolated text blocks.

Similar infographic formats are included in national high-stakes student assessments (see, for example, the final year high school public examinations

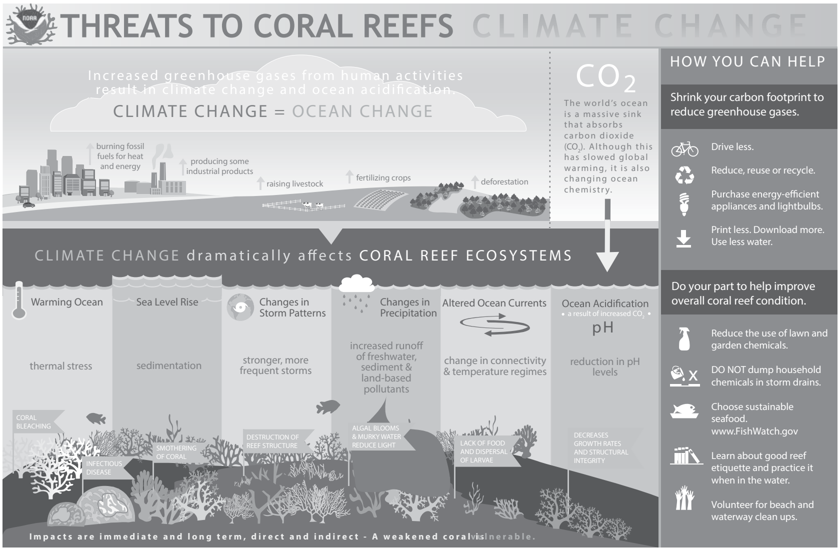


**FIGURE 8.2** Infographic from the National Oceanic and Atmospheric Administration of the US Department of Commerce
https://oceanservice.noaa.gov/facts/coralreef-climate.html

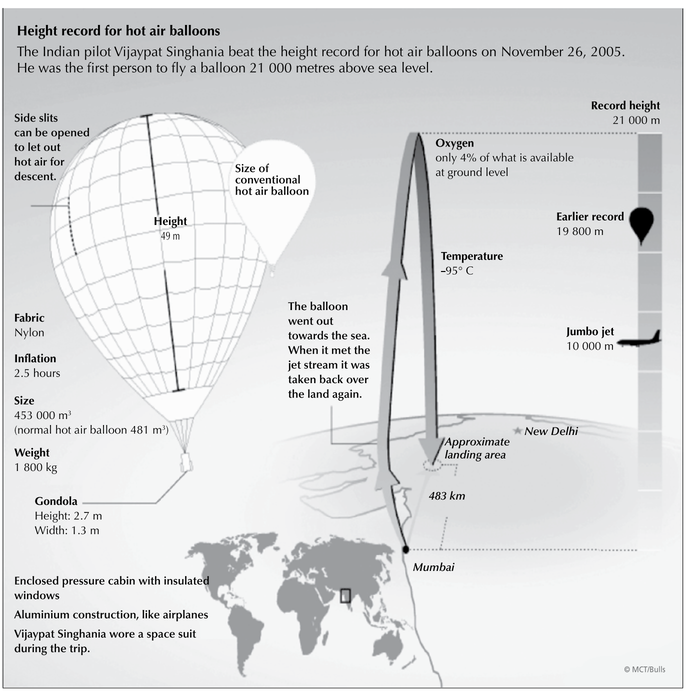


**FIGURE 8.3** Infographic used in the 2009 PISA test
OECD, 2010, p. 100

in biology under the New Zealand Qualifications Authority, 2021). But students are also required to create infographic representations in school assessment regimes. In senior high school science in Australian schools, students routinely complete assessment items based on those that appear in the public matriculation level examinations. As part of a study of multimodal literacy in senior high school, science infographic responses to such assessment tasks were examined (Unsworth, 2021). The following is an example of an assessment item from chemistry:

> When an experimenter adds 50g of solid sodium nitrate (NaNO3, an ionic salt) to 100ml room temperature water it will all readily dissolve. Explain how this occurs with reference to the bonding between particles. Use a diagram to aid your explanation.
>
> *(Unsworth, 2021, p. 10)*

The student response in Figure 8.4, created under examination conditions, includes similar multimodal meaning-making resources to those in the professionally published infographics. It shows the effective inter-relationship of two diagrammatic representations, along with articulated annotations of different kinds and two strategically positioned text blocks.

However, the response in Figure 8.4 was created by a higher achieving student, while many students in this and other studies in biology and chemistry were not able to optimally articulate images and language in multimodal representations (McDermott & Hand, 2013, 2016; Unsworth, 2021; Unsworth et al., 2022).

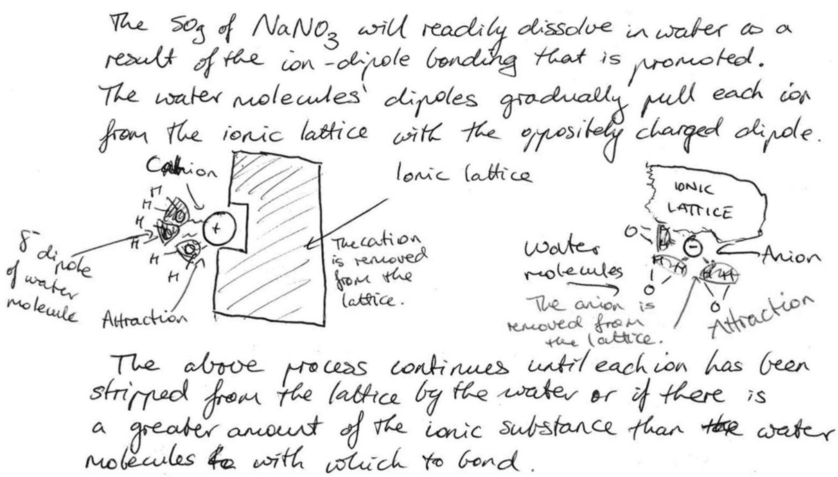


**FIGURE 8.4** Year 11 student-created infographic response to an examination question
Unsworth, 2021, p. 13

## Co-articulation of language and image in student-created infographic representations

In recent years there has been substantial research interest in enhancing science learning through student-created infographic representations (Davidson, 2014; Fowler, 2015; Fuhrmann et al., 2018; Gebre, 2018; Gebre & Polman, 2016; Hand et al., 2016; Polman & Gebre, 2015; Tytler et al., 2018; Walsh & McGowan, 2017). Some studies emphasised the heuristic value of infographics reporting high student motivation and positive impacts on assessment results. However, the few studies that included attention to students' co-articulation of language and image did not seem to be informed by any systematic and comprehensive account of approaches to establishing cohesive relations between language and image (Bateman, 2014; Unsworth & Cleirigh, 2009), or of the strategic use of converging or complementary meaning making through language and image.

The integral role of visualisations in science discourse and education has been long acknowledged (Gilbert & Treagust, 2009; Treagust et al., 2017; Treagust & Tsui, 2013), but infographics are a nascent genre in research on learning from and with visualisations. There has been limited attention to the multimodal rhetoric of infographics in research or classroom implementation. In view of the paucity of research literature to inform the design process about ways and means of reading and creating 'quality' infographics, research by Gebre and Polman (Gebre, 2018; Gebre & Polman, 2016; Polman & Gebre, 2015) engaged high school students in examining and critiquing published infographics. This was a precursor to the students generating their own infographics to communicate their investigations of self-selected topics, such as cloning, shark attacks, dangers of snake venom, and cauliflower ears, and in the latter study, the nutritional value of food from various fast-food chains, sports drinks, and the chemicals in fireworks (Gebre, 2018; Gebre & Polman, 2016; Polman & Gebre, 2015).

The students received feedback on their progressive infographic drafts from their peers and from volunteer qualified science professionals. From the examination of what students had learned about infographic creation through the feedback and the quality of the students' final versions, issues for progressing the incorporation of infographics into multimodal disciplinary literacy were revealed. These included the propensity of students to use predominantly iconic images, such as photographs and drawings, rather than schematic images, such as diagrams, charts, and graphs, and their difficulties in strategically integrating the use of images and language.

The inter-relating of language and images was referred to by Polman and Gebre as student management of "the interdependence of the visual and textual descriptions" (2015, p. 885). They analysed the distribution of meaning across the modes of language and images (which they called non-text representations). Non-text representations included iconic images, such as photographs or drawings, schematic images or diagrams, and charts or graphs. The message or meaning communicated about the topic by each representation was referred to by the researchers as a dimension of meaning. A dimensionality ratio for each infographic was calculated by dividing the number of dimensions conveyed by non-text representations by the number of non-text representations in the same infographic. A non-text representation might communicate one or several distinct dimensions of meaning, or zero dimensions if the information it conveys is already conveyed in the text or in other non-text representations.

Gebre and Polman believed that their dimensionality index showed the degree to which learners communicate "more with less" and do not overuse non-value-adding representations (2016, p. 2678). The researchers did not take into account any dimension of meaning that was conveyed via text alone. This severely limits insight into the functional complementarity that may be obtained between text and image in some infographics. The co-occurrence of the same dimensions of meaning in text and image is considered in this study to be undesirable, but this apparent redundancy may be strategic. For example, Figure 8.5 shows an infographic response by a Year 11 physics student to the task of explaining the operation of a simplified direct current electric motor (Unsworth et al., 2022). The first two sentences may be considered redundant with the visual depiction of these meanings in the diagram. However, the inclusion of these sentences enables the use of the text reference "This" in sentence three, to clarify agency in the causal relationship between the current flow and the rotation of the coil, which can only be conveyed in language. Condensing meaning in infographics is a complex process, the investigation of which clearly needs to be based on a more detailed and subtle account of intermodal cohesion (Unsworth, 2020a, 2021).

The approach taken by McDermott and Hand (2013, 2016) to investigating students' co-articulation of image and language in their multimodal responses to science tasks was adopted in a number of related studies reported in Hand, McDermott and Prain (2016). McDermott and Hand (2013, 2016) designed a one lesson intervention with high school chemistry students to build their awareness of ways to improve the integration of non-text modes in their multimodal representations, which they referred to as 'embeddedness'. Teachers were provided with a lesson plan outline, which drew attention to strategies for linking modes, such as "placing modes other than text near text that refers to them, complete textual descriptions of modes in the text, (and) captions added to modes other than text" (McDermott & Hand, 2013, p. 242). The lesson culminated with a joint student and teacher generated checklist for assessing the embeddedness of multimodal science representations. The researchers developed a scale that provided an average embeddedness score (AES). Each use of a non-text mode was awarded a point for any of the following characteristics: next to the text, referred to in the text, scientific accuracy, including a caption, completeness (amount of detail), and originality (created by the student and not adopted from another source). The AES was calculated by adding the scores

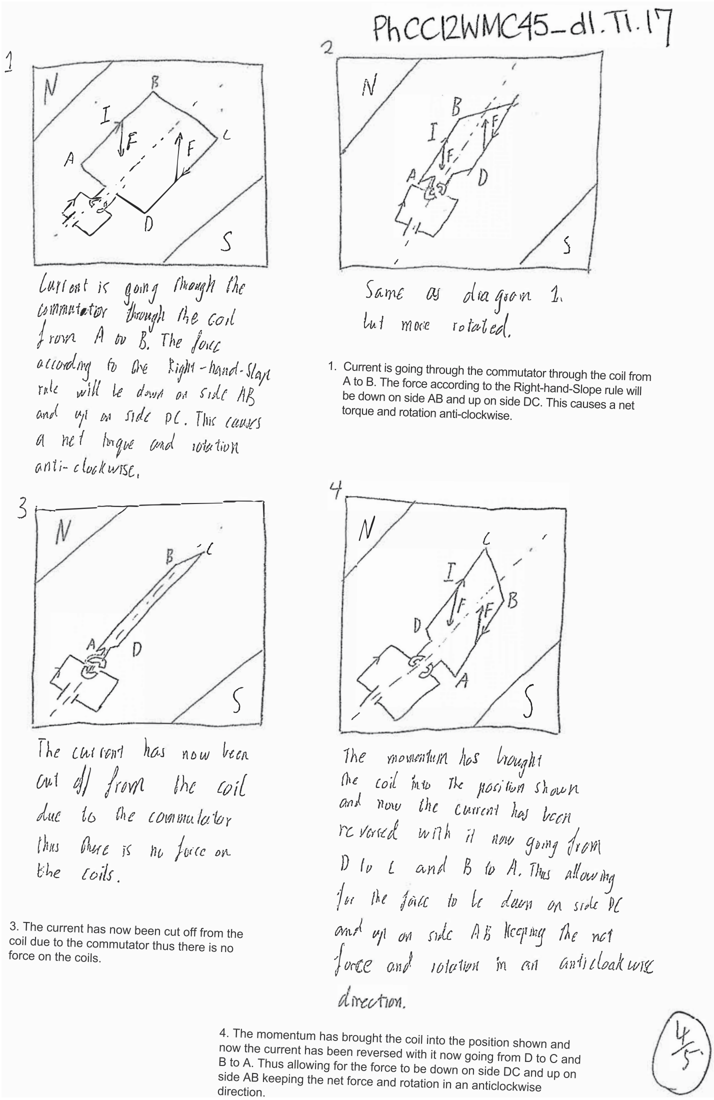


**FIGURE 8.5** Year 11 physics student infographic on the functioning of a direct current electric motor

for each modal representation and then dividing by the total number of modal representations.

The results of the studies provide evidence to support a strong positive relationship between what the researchers refer to as "high levels of embeddedness" and student achievement on tests of science understanding (McDermott &

Hand, 2013, p. 223). But the AES rubric addresses other factors that are not germane to the students' linking of different modes in their representations, such as originality (created by the student and not adopted from another source). The AES includes three inter-modal linking devices: next to the text, referred to in the text, and including a caption. A caption is frequently the titling or naming of an image, and it is not clear how this is a linking device. There is no mention of annotations to an image. Annotations may be naming labels, but they can also provide other information, such as indicating processes and cause-effect relationships among image elements. In referring to a modal representation being near text, it is not clear whether text refers to a 'main' text or to other forms of text segment typically embedded into infographic portrayals. There is also no mention of lines or arrows, which are frequently used to link image and text in these kinds of multimodal representations. From a semiotic perspective, the concept of intermodal linking addressed in research of this kind is confined to limited forms of textual meanings – physical linking through layout ('next to text') or reference (e.g. 'see Figure 8.1'), and the presence of a caption.

Some consideration of the co-articulation of image and language and the distribution of meaning across modes was addressed in a study of year nine students learning about osmosis (Fuhrmann et al., 2018). The students conducted an experiment using an egg, vinegar, sugar, and water to show that the membrane of the egg is semi-permeable, allowing water molecules to penetrate but not sugar molecules. The students were asked to construct a diagram along with a written explanation showing what happened to the egg membrane and to the water and sugar molecules, labelling the egg membrane and individual molecules, and showing the direction that the labelled components would move. The rubric for the assessment of the students' multimodal representations is indicated in the summary adaptation from the paper in Table 8.1.

Although the study did not include any preparatory teaching of the co-articulation of image and language, the communication Category D of the rubric in Table 8.1 certainly addresses this. Category D indicates that annotation of the drawing is an expectation, and further, that annotations are expected to describe the activity as well as to label entities. Acknowledgement of the complementary distribution of meaning across the modes of image and language is also partially evident, for example, in Category B where temporal progression can be represented graphically or verbally.

On the other hand, Category A suggests that scoring for the inclusion of micro-level representation can only occur via the image, whereas this might be included in language even if the image is represented at the macro level. One of the examples of student work from the Fuhrmann et al. (2018) study, includes a micro representation in the image as well as referring to molecules in an adjacent text segment. While the approach in this study deals more systematically with how image and language are co-articulated in multimodal representations, some

**TABLE 8.1** The 'model drawing rubric' with the score and examples

| *Category* | *Score* |
|---|---|
| A: Macro–micro level<br>Scores here indicate the extent to which the model represents both micro and macro levels of the experiment. | (0) No picture.<br>(1) Drawing contains a picture of an egg without further qualification.<br>(2) Drawing contains some or all the kinds of particles and other elements identified for the model (sugar and water as distinct substances) with focus on detail at the molecular level. |
| B: Temporal chaining<br>Score indicates whether students draw their model as a process or as a static state. | (0) No temporal chaining: Static state is indicated rather than a process.<br>(1) Provides either a graphic representation of a two-step process or some other explanation of the temporal progression. |
| C: Scientific explanation<br>These scores measure the formal scientific understanding of the observed phenomenon: The variables involved in the osmosis process and their interactions. | (0) No explanation.<br>(1) An incorrect explanation or an incomplete explanation that mentions only a single factor or uses concepts imprecisely.<br>(2) A more elaborate, scientifically complete explanation includes several sentences and uses all chemical concepts correctly |
| D: Communication<br>These scores indicate the extent of the model's design clarity and its capacity to communicate. | (0) No label or text in proximity to the drawing.<br>(1) Student includes a word, words or arrows in the drawing, indicating an understanding of the value of labelling and illustrative graphic elements in visual representations of scientific explanations.<br>(2) Student describes the movement of particles in a sentence or more and includes arrows and labels in drawings. |

commonly occurring realisations of inter-model cohesion are not incorporated such as the inclusion of reference to the image in the explanation (e.g. 'see Figure X'), or through numbering or 'lettering' of image elements included in the explanation text.

While many science education researchers recognise the increasing prominence of infographic communication in everyday life and its particular significance in science and science education, the conceptualising of image–language interrelationships in researching students' multimodal representation construction in science learning remains fragmentary, inconsistent, or absent. For example, in response to the limited uptake of student-generated multimodal representations in science pedagogy, a framework for evaluating explanatory diagrams in chemistry incorporated a rubric for classifying these student representations as non-explanations, macro-descriptions, mixed descriptions, associative explanations, simple scientific explanations, or complex scientific explanations (McLure et al., 2021). The descriptions of these classifications do not mention language at all. However, examination of the examples for each classification reveals that the lower-order non-explanations and mixed explanations include no verbal annotation at all, the associative explanation has minimal annotation, but the simple and complex scientific explanations include many more annotations. This suggests that the role of language and its interaction with the image(s) in determining the quality of students' infographic explanations warrants further investigation.

A review of learning from and learning with diagrams in science education noted that they include a variety of visual, symbolic, and verbal features that collectively contribute to the representation of an idea or event (Tippett, 2016). However, there was no discussion in the review about how to describe or teach the co-articulation of these different modes that comprise this collective representation. The recommendations from the review were confined to explicit teaching of the scientific conventions such as captions, labels, symbols, and the use of arrows. Advancing 21st-century multimodal literacy to incorporate infographics as a nascent but increasingly significant genre in communicating scientific knowledge in the school curriculum and in the broader community will require transdisciplinary attention to the multimodal rhetoric of the genre to inform research and development of enhanced multimodal disciplinary literacy pedagogy.

## Mapping options for image–language integration and meaning aggregation in infographics

Inspired by the work of Bateman (2008) and his colleagues (Bateman et al., 2017; Hiippala, 2016, 2020; Hiippala et al., 2021), recent and ongoing semiotic research analysing infographics in high school science textbooks has started to document the repertoire of options for ways in which images and language are deployed in these multimodal representations (Martin et al., in press; Martin & Unsworth, forthcoming; Unsworth, 2020a, 2021). As shown in Figure 8.6, infographics are made of two categories/modes – images and language. These can then be categorised further. The two sub-categories of language are co-text and annotations. The left-facing brace means that any one or all of the options to the right of the brace may occur in the infographic. The dotted line indicates that other, as yet unspecified image options may be included. The dash after the

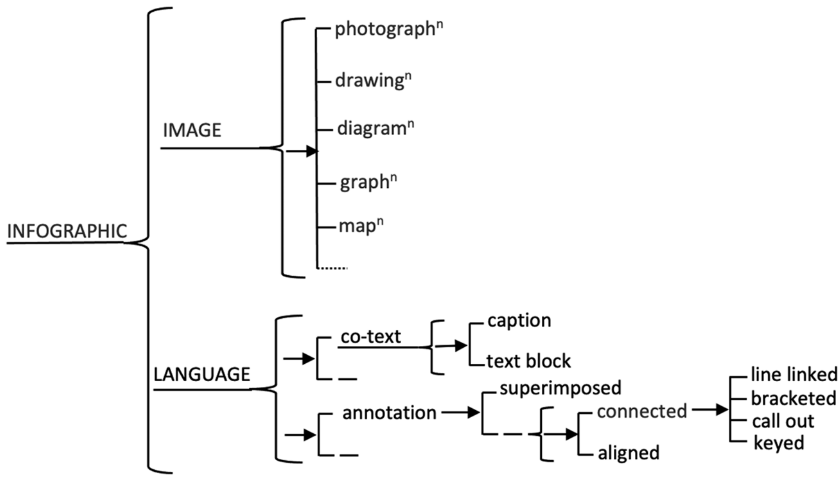


**FIGURE 8.6** Co-deployment options for image and language in infographics

line brackets means that the single option within that bracket may or may not be present.

The image components of infographics can consist of one or more of the several types of images, such as photographs, drawings, diagrams, and graphs, or a combination of the different image types. For example, the infographic in Figure 8.1 includes several connected diagrams, Figure 8.2 has two different drawings and Figure 8.3 has drawings, maps, and diagrams.

The language components of infographics can include co-text and/or annotations. The co-text, which relates to the image as a whole, can consist of a caption and/or one or more interpolated text blocks. An example of a caption referring to the image as a whole can be seen in Figure 8.1, where the caption is located to the top and right of the diagram of mitosis. A prominent interpolated text block is superimposed on the drawing of the sky in Figure 8.2, highlighted in Figure 8.7.

This text block also refers to the whole combination of the drawings of the land and the ocean. Annotations relate to specific parts of the image. The relationship of annotations to particular parts of the image can be specified in several ways. These include, for example, in Figure 8.1, by connecting lines linking annotations to the relevant parts of the cells, or by the close alignment

Increased greenhouse gases from human activities
result in climate change and ocean acidification.
CLIMATE CHANGE = OCEAN CHANGE

**FIGURE 8.7** Text block within Figure 8.2

*Source:* National Oceanic and Atmospheric Administration of the US Department of Commerce of annotations with the relevant image elements as shown in Figure 8.2, where 'deforestation', 'fertilising crops', 'raising livestock', etc. are aligned with the corresponding elements in the drawing. There are also other connecting devices such as call-outs, brackets, and keys.

The distinctive co-deployment of image and language resources in infographics serves to aggregate meanings in a multimodal construal of complex phenomena as a synoptic 'eyeful' within a single page format. To describe this condensation of meaning we need to relate the nature of the infographics as image–language ensembles to the ideational meanings that construe the represented phenomena in terms of the relevant field knowledge (An example of which was seen in Figure 8.6). Doran and Martin (2021) described the representation of phenomena in these multimodal assemblages in science texts from the perspective of field. They view field as a resource for construing phenomena as sequences of activities alongside the taxonomies of items involved in these sequences organised by both classification and composition, and their associated properties.

In language, activity is typically realised by verbs. For example, in explaining sound waves we may say:

> A vibrating object compresses the air particles next to it and these compressed air particles compress the air particles next to them and so on, so the compression wave travels away from the vibrating object.

Here, the activity sequence in the first sentence, which is expressed by the verb forms of "compress", is condensed in the second sentence into the noun form "compression wave". Even though the "compression wave" is grammatically a noun group, it is not actually naming a 'thing', but an activity sequence that is represented in language as if it were a thing. In this way, nominalisation is one significant linguistic resource for condensing meaning. The use of nominalisation in highly condensed discourse is also associated with the expression of logical relations in noun or verb form rather than their more common expression as conjunctions. So, for example, relations most frequently realised by conjunctions, like 'if' or 'so', may be realised by nouns like 'condition' and 'result' or verbal forms like 'depends on' or 'leads to'. Balancing condensation of meaning with accessibility by lay or novice readers involves careful articulation of the highly condensed nominalised disciplinary discourse with the verb and conjunction focussed, and more familiar, everyday/spoken grammatical forms. Language also has a range of specialised forms for realising part-whole taxonomic relations and classification taxonomies (Hao, 2020; Martin, 1992), but infographics more usually convey these kinds of field relations through images.

In their seminal work on the grammar of visual design, Kress and van Leeuwen (2006, 2020) distinguished between images that represent activity (which they called "narrative structures") and images that represent classificational taxonomies, as well as those that represent compositional (part-whole) taxonomies, which they referred to as "analytical structures". It is unclear in Kress and van

Leeuwen's (2006, 2020) approach whether images can contain, and accord the same status to, more than one of these types of structures (Doran, 2019). Kress and van Leeuwen (2006) do indicate that timelines seem to occupy an intermediate position between the narrative and the analytical, and that genealogies and evolutionary trees and graphs may blur the boundaries between the static and the dynamic (Kress & van Leeuwen, 2006, pp. 101–103). They also suggest that "embedding" can occur in diagrams and provide one example where a narrative structure is embedded within an analytical structure (p. 51). But certainly, the overwhelming emphasis in their work is on single structure images. However, Doran (2019) and Martin (2020) point out that infographic representations frequently simultaneously represent two or more of these aspects of field, and that the images combined with annotations and interpolated text blocks aggregate meaning multimodally in highly condensed synoptic portrayals.

The nature and extent to which activity, classification, composition, and properties are combined through images only, language only, or in combinations of image and language in an infographic, is referred to as aggregation. The system for aggregation in Figure 8.8 interfaces the options for inclusion of the technicality construing field – composition, classification, activity, and property – with two options for combining those meanings in infographics – accumulation and integration.

Accumulation refers to the aggregation of different types of meaning (composition, classification, activity and property) from two or more 'macro-groups' within an infographic, each consisting of an image +/− annotations and +/− interpolated text blocks. Integration refers to aggregation within a macro-group through: (a) incorporation of two or more of the dimensions of activity, classification, composition, and property within one image; (b) representation of different dimensions of meaning construing field in the image and in the annotations; and (c) depiction of activity as a verbal representation of an entity and a visual representation of an action process. Aggregation in infographics may involve either or both of the options of accumulation and integration to a greater or lesser extent, hence in Figure 8.8, these options are represented as a cline.

A highly condensed multimodal summative account of the biological functioning of inflammation is illustrated in the infographic from a senior high school biology text in Figure 8.9 (Greenwood et al., 2021). The prominent rhetorical

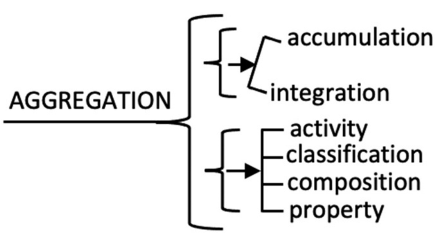


**FIGURE 8.8** Aggregating meaning in infographics

locus of this infographic is represented by the two salient diagrams. To the left, the diagram and annotations detail the infection, vasodilation, and phagocyte migration response. Connecting lines link most annotations to the relevant diagram segments, but bracketing is also used to indicate the tissue layers. Within this diagram, aggregation occurs through integration since the compositional relations among the entities are depicted visually and the activity of the inflammation process is communicated verbally through the annotations. Here, the language is overwhelmingly verb-focussed (although one nominalisation is given in parentheses – "vasodilation").

To the right, the second diagram is a 'blow-up' from the circled segment of the first diagram. Here again, aggregation is via integration as the composition is shown visually with labelling annotation and the activity of phagocytosis is communicated via the verb-focussed annotations. But aggregation also occurs via accumulation since it is the interaction of both diagrams that construes the

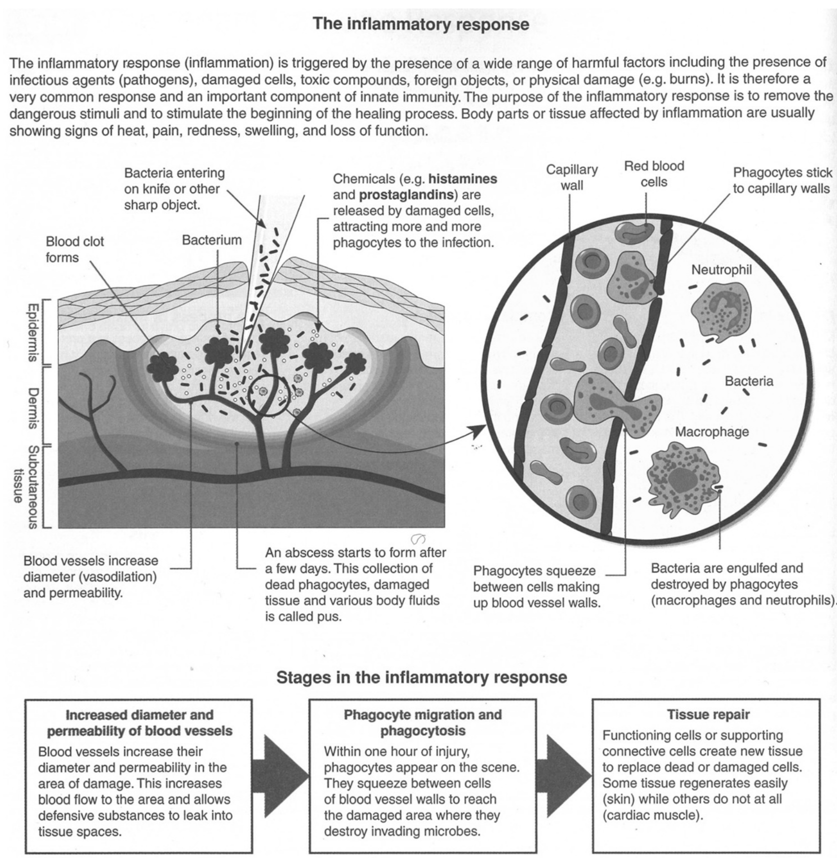


**FIGURE 8.9** Infographic: The inflammatory response
Greenwood et al., 2021, p. 124

overall process of inflammation. The ultimate condensation of meaning occurs with the text blocks below the images. Here, what has been succinctly multimodally detailed above, is synopsised verbally in the highly nominalised "Stages in the inflammatory response". And the stages are condensed as the headings of each text box and connected by sequence arrows.

As Martin (2020) points out, multimodal synopses in such infographics highlight the complex, compositional relations and the multi-tiered nature of the activity sequences that make up processes such as inflammation. High school science textbooks are replete with infographics depicting complex processes with two or more of the field dimensions of activity, classification composition, and property aggregated through integration by combining these dimensions multimodally within a diagram and/or through accumulation, requiring the articulation of meanings across two or more diagrams (or other types of images). This is clearly shown in Figures 8.1, 8.2, and 8.3. The multimodal condensation of meaning with progressive nominalisation that we saw in the synopsising of the stages of inflammation in Figure 8.9 can also be seen in the ultimate synoptic representation of the stages of mitosis (Prophase, Metaphase, Anaphase, and Telophase) in Figure 8.1.

Martin (2020) aptly encapsulates the utility and the challenges of such infographics as resources for learning in schools:

> Where well supported by reading and classroom discussion they can work effectively as summative aggregations of accumulated knowledge; where supportive reading and classroom interaction has not taken place they may well function as impenetrable obstacles to teaching/learning. There is certainly nothing transparent about the knowledge structure they encode.
>
> *(Martin, 2020, p. 138)*

Mapping the inter-modal semiotic options drawn upon in infographics to succinctly portray the construal of complex phenomena in a meaningfully accessible and appealing manner, can inform enhanced literacy pedagogies to support students in interpreting such texts and in constructing them to communicate what they have learned.

## Teaching–learning experiences to enhance infographic literacy development

We believe it is important for students to develop a meta-semiotic understanding of infographics, along with other representational genres they need to engage with. This means having explicit knowledge of the meaning-making resources of language and images to enable interrogation and discussion of how meanings are represented and could have been represented differently. This meta-semiotic knowledge provides students with a conscious repertoire of multimodal meaning-making strategies they can draw on in constructing multimodal representations such as infographics. Developing students' meta-semiotic understanding relies on teachers' knowledge of the 'grammars' of language and images as meaning-making resources, as well as an understanding of the options for their deployment in representational genres, such as infographics, as outlined in the approach to intermodal mapping discussed in the previous section. This kind of teacher pedagogic content knowledge makes it possible to develop with students a shared critical understanding of how meanings are made in multimodal representations (New London Group, 2000).

It is also important that this kind of meta-semiotically informed multimodal literacy development is integrated with, or infused into, the teaching and learning of the disciplinary knowledge in the relevant field – such as science (Unsworth et al., 2022). However, this does not occur incidentally and needs to be deliberatively integrated into pedagogic practice. Hence, we assume a pedagogic orientation which combines fostering student enquiry alongside teachers' guidance – through interaction in the context of shared experience (Martin & Rose, 2005). An effective pedagogic model for this involves teaching/learning cycles (Martin & Rose, 2008). These cycles unfold in a series of steps – building field knowledge, teacher-modelled deconstruction of sample texts, joint teacher–student text construction, and, ultimately, independent student construction (Rothery, 1994). Various reconceptualisations of the cycle have emphasised that it can be entered at different phases, with differing emphases on interpretation and production, and with phases being recycled according to the needs of the student group (Rose & Martin, 2012; Unsworth, 2001).

Within this orientation to multimodal literacy pedagogy, we outline a '5Cs' approach to developing students' critical interpretation and effective creation of infographics in the context of scientific literacy education.

1. *Contextualising* infographic interpretation/creation through direct and/or vicarious engagement with the materiality of the target phenomena, so that students' conceptual understanding is progressed through learning tasks based on direct experience and/or video, simulation, and illustration.
2. *Comprehending* meanings realised by unfamiliar visual representations and/or by linguistic forms of expression more characteristic of academic or disciplinary discourse than everyday language. Teachers 'talking out' (Lemke, 1989, 1990) the unfamiliar visual or verbal realisations of the different types of meanings can clarify the significance of all parts of the infographic – in dialogue with students. For example, the "pH levels" in Figure 8.2 and the somewhat subtle indication of the map 'blow-up' in Figure 8.3 may warrant such 'talking out' for some students.
3. *Connecting* meanings across different images and/or across images and text blocks, etc. may involve convergent or complementary meaning relations. For example, we noted the complementarity relationship between

the meanings conveyed via the diagrams and the corresponding columns in the table below them in Figure 8.1. Some students may read the macro-groups discretely without attending to how they may relate to each other. Students could be asked to identify commonalities and circle each one in a different colour (on reproductions of the page) to highlight this consolidation across macro-groups. They might then be asked how convergent the meanings are in each case, and how one of the realisations may elaborate, extend, or enhance the other. The next move might be to highlight the meanings in the diagrams that are not committed in the text blocks, etc.

4. *Comparing* infographics dealing with the same topic can help identify differences in the meaning of commitment in corresponding infographics. For example, Figure 8.1 could be compared with a corresponding infographic on the same topic in a different textbook (e.g. Lofts, 2015, p. 28; Silvester, 2016, p. 10). The centriole pairs in the original colour versions of the diagrams shown here in greyscale in Figure 8.1 are readily discernible due to the clarity of their depiction and their red colour contrasting with the blue of the cytoplasm. On the other hand, the centrioles in a corresponding infographic in a different textbook (i.e. Silvester, 2016) are extremely difficult to discern and do not seem to be present in the depiction of late prophase (when they are in fact present in this phase of mitosis). Further, in Figure 8.1, the small circle representing the centromere is clearly visible in joining the double strands of the chromosomes, whereas in the other textbook, the centromere is not distinctly discernible at all (Martin et al., in press).
5. *Constructing* multimodal responses to explanatory challenges has been shown to enhance the engagement and learning outcomes of science students in primary and junior high schools (Hubber & Tytler, 2017; Tytler et al., 2017, 2018, 2020). This approach has concentrated on students drawing to explore explanations of phenomena; in general, it has involved limited explicit teaching about and modelling of representational options and intermodal relations. However, as students move from junior to senior high school, they frequently need to construct succinct infographic representations in assessment contexts. Building this competence benefits from teacher modelling and joint construction of infographics with students to advance the effectiveness of students' independent constructions.

As well as the foregoing types of learning experiences, various other scaffolding learning experiences can be used. These include the teacher guiding students to reconstruct existing infographics based on a critique of the originals jointly developed by the teacher and the students, or similar teacher-guided student construction of composite infographics derived from others collected by the students. Teachers can integrate semiotic description as part of their pedagogic guidance enhancing students' metarepresentational competence in their interpretation and creation of infographics as well as their substantive subject area learning (Disessa, 2004; Kozma & Russell, 2005).

## Recommendations for researching infographics literacy for digital futures

Research in infographics and scientific literacy development will benefit from advancing a transdisciplinary approach that integrates perspectives from relevant disciplines, including science, health, and physical education, as well as social semiotics, literacy, and digital technologies. With the current impetus toward infographic representation in public and school-based science-related education, further developing contemporary research seeking to enhance student competence in interpreting and creating infographics is essential. This development needs to include semiotic perspectives on the rhetorical deployment of integrated image and language resources for condensing meaning into succinct multimodal page-based portrayals. There is also a need to extend insights from initial research into the positive impact of developing meta-semiotic competence to support student learning through multimodal infographic representations (Disessa, 2004; Kozma & Russell, 2005).

Additionally, educational research needs to rapidly prioritise substantially greater engagement with the strongly developing trajectory of digital infographics. A cursory internet search reveals an impressive array of animated science infographics (e.g. Lutz, 2021 – https://eleanorlutz.com/animated-science-infographics), which need to be acknowledged by schools as 21st-century digitally oriented students increasingly take to the internet as their personal learning resource. As students develop computer programming competencies from their early school years, they are using coding software such as *Scratch* (Massachusetts Institute of Technology, 2022) to code animated representations of their science learning (e.g. Goletti, 2018; Ko, 2019; Nikmah & Ellianawati, 2019; Robertson et al., 2021). It is imperative that research into infographic literacies for digital futures assumes transdisciplinary perspectives so that literacy pedagogy is informed by techno–social–semiotic–scientific epistemologies (Unsworth, 2020b).

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# 9

# ADVANCING ANIMATED STORY COMPOSITION THROUGH CODING

Viewing animated stories remains hugely popular with children and continues to attract a massive adult audience. The opportunity for children to create animated stories greatly increased with the advent of child-accessible digital animation software (Chandler, 2013; Chandler et al., 2010). Today, animation software for children is readily available, and some 2D and 3D applications, such as *Synfig, Opentoonz, Tupi*, and *Blender*, can be accessed *gratis* online. A significant futures-oriented development in animation authoring opportunities for children and teenagers (and older animators) has been the emergence of the 'programming as writing' movement (Breen, 2016; Burke et al., 2016; Hagge, 2021; Hassenfeld & Bers, 2020). This occurred with recognition of the importance of introducing computer programming concepts to young students as a fundamental competency, increasingly required in many dimensions of life in the computer-based, digitally connected, vocational, social, personal, and political environments of the 21st century.

The concept of programming as writing grew from the creation of object-based or block-based approaches to computer programming or coding, such as the *Alice* suite, culminating in *Storytelling Alice* (Kelleher et al., 2007; Pausch & Forlines, 2000), and the development of *Scratch* (Resnick et al., 2009). In *Scratch*, blocks are puzzle-piece shapes in software that are used to create computer programming code. The blocks connect to each other vertically like a jigsaw puzzle. There are ten categories of blocks (Motion, Looks, Sound, Event, Control, Sensing, Operators, Variables, List, and My Blocks), each with its own colour. The blocks enable users to program their selections or creations of characters or objects (called sprites in *Scratch*) and backgrounds, to generate the event sequences, dialogue, sound, and music that may comprise an animation.

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From very early initiatives in teaching school children to code with *Scratch*, creating animated stories has been the main focus of these innovative programs (Burke & Kafai, 2010). These initiatives were predominantly conducted outside of children's regular school classroom experience, and this has overwhelmingly remained the case for research on coding animated narratives to date. Since several countries have mandated the introduction of coding in school curricula, it is increasingly incorporated into science, technology, engineering, and maths (STEM), but relatively little uptake has occurred in humanities and English Language Arts (ELA) and other first language curricula (Rich et al., 2018; Whyte et al., 2019). However, outside of school, a growing number of child coding enthusiasts in online communities have generated a plethora of stories ranging from the brief and unimaginative, to intriguing and insightful micro-narratives, and extended and episodic animated movies (Burke et al., 2016; Hagge, 2018; Resnick & Rusk, 2020).

## Refocussing programming as writing for integration in language arts curricula

If digital animation as a prominent 21st-century literate practice is to be accessible to all students both as consumers and creators, it is important that language and literacy curricula introduce the expanded communicative potential of animation that coding affords. This is the aspiration of the 'programming as writing' and the 'coding as literacy' research agendas (Breen, 2016; Burke et al., 2016; Hagge, 2021; Hassenfeld & Bers, 2020), but for these agendas to achieve traction in schools, language arts teachers need to be given opportunities to develop their own competencies in coding. It is also essential that research investigating the melding of the teaching of coding and animated story creation is able to indicate how pedagogies for coding animated narratives can simultaneously address language arts curriculum goals for developing students' narrative interpretation and composition.

By far, the most popular block coding software for school-age students is *Scratch*, with over 21 million registered users predominantly between eight and sixteen years of age (Hagge, 2018; Resnick & Rusk, 2020). It is therefore not surprising that the vast majority of studies examining pedagogy development for coding animated stories have used *Scratch*. A key issue is how the trajectory of these studies is oriented toward enabling the integration of coding and animated story creation as part of the language arts curriculum. Research from 2010 to the present using *Scratch* for story creation with students from eight to fourteen years of age has occurred almost entirely outside of regular classroom teaching in after school clubs or elective programs (Burke, 2012; Burke & Kafai, 2010, 2012; Whyte et al., 2019, 2020). Researchers with expertise in *Scratch* conducted these programs with groups of about ten to twelve students once or twice a week over periods of six to seven weeks.

A detailed account of the highly scaffolded pedagogy was provided in the Burke and Kafai studies (Burke & Kafai, 2010, 2012) based on a well-known approach to ELA narrative composition pedagogy (Calkins, 1986). The main instructional stages are: pre-writing; drafting; revising; editing; and publishing. Each of the *Scratch* sessions opened with a mini lesson introducing an element of effective composition (such as characterisation, foreshadowing, setting a scene) tied to a coding procedure in *Scratch* (e.g. broadcast feature to establish dialogue, importing external images, using loops), and every mini lesson included one to three sample *Scratch* stories, exemplifying the storytelling element or genre (e.g. mystery, action/adventure) featured within the lesson. The sample stories also provided the opportunity to examine the coding scripts to understand how the targeted story elements were coded (Burke & Kafai, 2012).

These researchers emphasised the students' use of storyboards in preparing the stories as well as in drafting and revising. They fostered student collaboration by including gallery walks enabling students to share drafts and feedback provided by the instructor on draft stories. A highly scaffolded approach was also taken in the Whyte et al. studies (Whyte et al., 2019, 2020), albeit with less detail about the pedagogic procedures. They involved the students in a series of preparatory tasks that linked elements of story to the coding procedures required to produce them as *Scratch* animations, prior to the students coding a story independently. The second of these studies refined the pedagogy, emphasising the nature of narrative structuring and including more demonstrations of worked examples of preparatory tasks and of completed story structures.

Some regular classroom programs involving coding *Scratch* stories have been reported as brief descriptive outlines. For example, Hagge (2017) outlined a Year 6 program where students created a *Scratch* story to illustrate their understanding of important events and character responses in a novel they were studying. To prepare the students to create their story, the teacher presented examples of the kinds of digital stories he wanted them to create. In discussing each example with the students, they observed how the available tools in *Scratch* were used and examined the coding scripts to understand how the use of coding tools aligned with the design and content of each story. The teacher 'conferenced' with each student during the design and coding process to assess their progress in coding the story and to provide assistance, as required. The students presented their completed stories in class, discussing how character response was communicated, and later published their stories on the *Scratch* website. Greater specification of the pedagogy including references for the teacher's sample stories and some examples of the stories created by the students would better enable teachers to consider adopting the approach introduced in the study.

Pektaş and Sullivan (2021) interviewed two fourth-grade students who participated in a *Scratch* program in their regular ELA classroom. In this six-lesson unit of work, students were taught to identify character traits and behaviours associated with them, identify their own character traits, and create a *Scratch* story based on a few character traits. No further information is provided about the classroom program. The interviewed students were members of a group who composed a story called *Zombie Apocalypse* in which Earth is hit by a meteor containing zombies who then destroy the planet and zombify survivors. The interview deals only with the introduction to the story that the two interviewees were responsible for producing. This extends as far as the meteor hitting Earth; the planet being destroyed and the zombies about to spread all over the world. One part of the interview data deals with one student's coding of a sequence of blocks to simulate the glide block in *Scratch* to portray the meteor moving towards Earth as well as the background changes as the planet is destroyed and zombies appear.

The other aspect of the interview data related to the selection and modification of sprites, which is an important aspect of *Scratch* story creation. This interview data discussed the remixing of sprites by the other interviewee to create a character with protective clothing and also black skin similar to the interviewee. However, there is no account of this character's role in the story and no further discussion of the story as a whole or how it was coded. In fact, all of the studies mentioned would have benefitted from greater specification to enable ELA teachers to see how this multimodal composition context facilitates advancing students' understanding and implementation of narrative composition techniques such as rhetorical structuring, characterisation, point of view, etc.

Only one complete student *Scratch* story is accessible from the studies by Burke and his associates (Burke, 2012; Burke et al., 2016; Burke & Kafai, 2010, 2012). This is the *Crayfish* story created by one group of students aged 12–14 years (Burke & Kafai, 2012). An image of the six scenes of the story is included but no reference is provided to the story on the *Scratch* website. [None of the other stories referred to or partially described are accessible on the *Scratch* website.] In the *Crayfish* story, the single boy character is given a crayfish, who takes it home, puts water in the crayfish bowl, the crayfish exclaims in panic at the addition of fresh water, asks where the salt is, and dies. All scenes are distant views of the characters. The extremely basic orientation, complication, evaluation, resolution structure, lack of characterisation, simplistic point of view, etc. represent only the most minimal narrative compositional competence for a pre/early teenage student, yet the authors indicate that this 90-second story took the student more than ten hours to code. These studies report introductory programs for largely novice student coders and, of course, greater coding efficiency would be expected as students gain more experience, but we indicate in the subsequent sections of this chapter that there needs to be concomitant development in the quality of the students' multimodal authoring.

It is very clear from the published literature, and it is possible to determine from the website, that students of this age can certainly create sophisticated micro or extended animated narratives using *Scratch* (Resnick & Rusk, 2020). Researchers continue to pursue the explicit goal of the Burke and Kafai work to "leverage the professional knowledge of K-12 educators in traditional English/language arts classrooms to better integrate programming into core-content classroom activities" (Burke & Kafai, 2012, p. 433). There remains a need, however, for research into this integration to show more clearly how literacy curriculum authoring outcomes are advanced in the reported studies. Recent research using *Scratch* to investigate the integration of coding into the literacy curriculum through the creation of digital stories indicates that several students created stories with a complete narrative structure, but no examples of the stories are provided either in the research reports or by reference to the *Scratch* website (Whyte et al., 2019, 2020). In the following sections, we discuss key issues for enhancing the integration of coding and multimodal authoring pedagogy.

## Re-balancing programming as writing and multimodal authoring

Young *Scratch* enthusiasts, quite independent of any schooling connection, have created sophisticated stories, frequently in online collaboration with other Scratchers. In at least one project, they have substantially advanced their coding and story creation competence with the impetus of mentor feedback (Fields et al., 2014). While it is not possible to identify the age of Scratchers, an example of a readily accessible, highly sophisticated series of stories created by a young Scratcher named Taryn in collaboration with online peers is the *Colour Divide* (https://scratch.mit.edu/studios/1393192/). According to Resnick and Rusk (2020), Taryn was introduced to *Scratch* at her school in South Africa at age ten. At some later date, she collaborated with online Scratchers to create the *Colour Divide* series, which explores social issues in South Africa and the scars left by apartheid.

The *Colour Divide* stories are an exceptional animated narrative series, but we have also been able to identify quite sophisticated micro-narratives on the *Scratch* website and deduce the approximate age of the Scratcher. One example is *Can I Come In?* (https://scratch.mit.edu/projects/23367579) by FunnyAnimatorJimTV created in 2014. In 2016 FunnyAnimatorJimTV posted a youtube video on drawing in *Scratch* (https://www.youtube.com/watch?v=kmQvNoqIGbw) in which his speaking clearly indicates a boy's voice, which has not yet broken with the advent of adolescence, so he was pre-adolescent when he authored *Can I Come In?* This animation demonstrates the kind of narrative technique that ELA teachers would consider reflective of appropriate development of compositional competence for this age level. While the story is just under 90 seconds, and the external event sequence is quite simple, the engaging impact of the story lies in the subtle and sophisticated characterisation that foregrounds the interiority of the two characters through their verbal and bodily responses.

The story begins with Matt knocking on George's door to which George responds that he will be "out in a minute". An on-screen audience message then indicates that six minutes and twelve seconds have passed, and Matt is still waiting outside. He asks if he and George are going to have a play date as arranged, to which George replies that this can go ahead as soon as his television program is finished. Matt inquires how long that will be, and George indicates a few minutes. The next on-screen audience message indicates that eight and a half hours have passed. George, at last, opens his door into a night scene and sees a note on the floor from Matt. Matt's note reminds George that George was the one who wanted the play date. The note expresses exasperation about why George won't tire of watching television, while indicating that Matt had to go home. George muses about whether Matt may want to come over the next day for his sushi construction tutorial.

The narrative techniques in *Can I Come In?* draw attention to potential shifts in research and pedagogy that may facilitate more widespread and effective development of coding as multimodal authoring within schools. The effective minimalist 'stick figure' drawings of the story characters and similarly simple settings enable the story to communicate the essence of the message. This counters any potential preoccupation with avatar choice or selection of elaborate settings that are peripheral to the story themes. At the same time, the story emphasises the importance of communicating attitudinal meanings of positive or negative affect – un/happiness, dis/satisfaction, and in/security – in establishing the inner life of characters, as well as portraying their actions in external reality. The range of different attitudinal expressions by the Matt character is shown in Figure 9.1.

Studies investigating the integration of teaching coding and story creation using *Scratch* do not mention the portrayal of characters' attitudinal responses (Burke et al., 2016; Burke & Kafai, 2010, 2012; Hagge, 2017; Pektaş & Sullivan, 2021; Whyte et al., 2019, 2020). These studies attend to story structure, such as motivating events, attempts to resolve, consequences and resolution of the narrative, and a concern with characterisation, though there is no mention of the characters' evaluation of events, or the prosodic nature of this evaluation realised by characters' attitudinal responses as the plot unfolds. This aspect of narrative technique is commonly required knowledge for students in senior elementary and junior high school in countries such as the US in the Common Core Standards for English Language Arts (National Governors Association Center

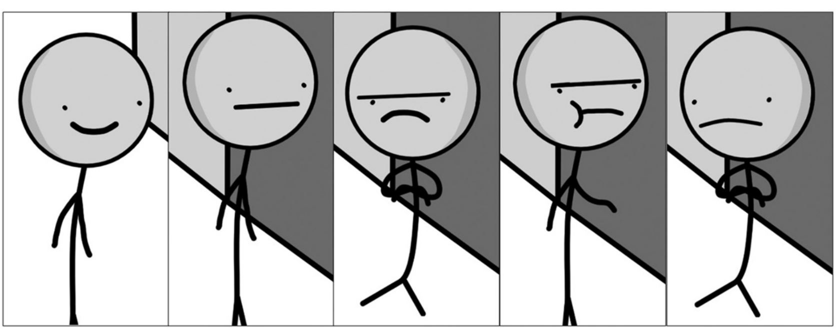

**FIGURE 9.1** Matt's attitudinal expressions

for Best Practices, 2010, p. 36, 44) and in the Australian Curriculum for English (ACARA, 2018, content descriptions ACELT 1616, ACELA 1518). Such requirements can be readily addressed using *Scratch* and warrant explicit attention in research and pedagogy seeking to advance coding of animated narratives within ELA.

The *Can I Come In?* story also highlights the multimodal authoring competencies that complement coding capacity in creating an engaging narrative. The effective selection and synchronisation of sound and music contributes to the effectiveness of this story. For example, the music accompanying the first five seconds on-screen audience message indicating the passage of six minutes and twelve seconds in the story, is quite a lively melody. On the other hand, the accompanying music for the nine-second on-screen message indicating the passing of eight and a half hours is very much slower and lower in tone. The story also incorporates background sounds of George's television show, and night sounds of frogs as George finally emerges to see Matt's note. As indicated in Figure 9.1, the author knows how to use depictions of facial expression and gesture to communicate attitude, but there is also evidence of his capacity to use focalisation to position viewers as if they were characters in the story. This occurs as George expresses surprise at seeing the note on the floor, and then the viewer is positioned as George reading the note (Figure 9.2).

Multimodal authoring competencies including knowledge of the semiotics of body movement, gesture, posture, facial expression, interpersonal positioning, sound, music, voice quality, colour, and knowledge of story structure options as well as the communication of engaging, personally, and socially significant experience – are all crucial to composing effective digital animated narratives. However, it is coding, in conjunction with the astute selection, modification, and/or composition of particular story-apposite sprites, that has greatly extended

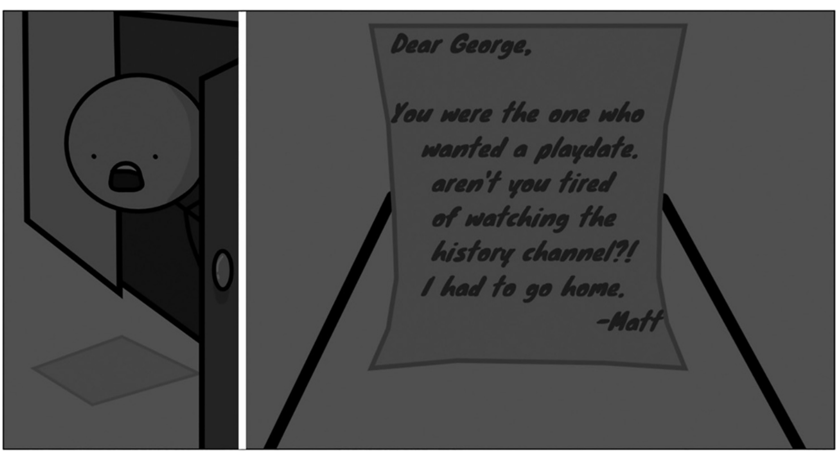


**FIGURE 9.2** Viewer as character

authorial freedom to enable students to create their own entirely original digital animated stories. Clicking on the *Scratch* 'See inside' tab for the *Can I Come In?* story (https://scratch.mit.edu/projects/23367579) enabling an inspection of the block coding that constructs the story will readily indicate the advanced coding capacity of this author.

The management of sprites in this story is very sophisticated. Rather than the usual animating of an entire character, this author separates the coding of facial expression and arm movement. The character's mouth and arms are isolated as discrete entities separated from the body, as can be seen in the repertoire of sprites at the bottom right of Figure 9.3. Each of these sprites has multiple 'costumes' (versions). The mouth sprite in row one, shown enlarged in the centre of the Figure, has 23 different costumes, some of which are visible in the column on the left in Figure 9.3. Selections from these costumes can be coded to appear in rapid succession, which results in visually depicted changes in the character's facial expression. Other 'mouth costumes' can be selected and coded to appear in rapid succession, resulting in a visual simulation of talking approximating lip-synch with the spoken dialogue. Similarly, multiple costumes of the arm sprite can be coded to appear successively to produce the visual depiction of fluidic movement of the character's arm in actions, such as knocking on the door.

Representing changes in facial expression, posture, and gesture in the *Can I Come In?* story by creating discrete sprites with multiple costumes for the mouth


**FIGURE 9.3** Separating coding of facial expression and arm movement from animating the entire character

and arms and coding them to appear on the base representation of the character's face required quite sophisticated coding competence, which may take most novice Scratchers some time to acquire. However, novice Scratchers could closely approximate the representation of these changes in facial expression, gesture, and posture by creating multiple costumes for the character as a whole entity and coding the story to change selections from these whole character costumes in rapid succession. Each of the panels in Figure 9.1 could be separate costumes for this character. Coding the costume in the second panel to appear rapidly following that in panel one would result in the visual depiction of a fluid change in the character's expression. In this way, changes in facial expression and gesture could appear in a fairly similar manner to those in the *Can I Come In?* story. Learning to code this costume sequencing and making it appear at the appropriate time in the story is well within the scope of early coding development for novice Scratchers.

Many other techniques for engaging multimodal storytelling can be utilised that require only very basic coding to implement. For example, a close-up view of a character can be achieved by creating a copy of the sprite as a separate costume, enlarging, and then cropping to show the enlarged head and shoulders only. This can be coded to follow a mid or distant view of the character in the story, which would require a simultaneous change in the background to be consistent with the close-up, all of which can be managed with basic coding. A simpler example enlarging the entire sprite is shown in Figure 9.4 from a story created by 13-year-old students in a regular English classroom, who had been learning to code stories for about seven weeks. The rabbit is a *Scratch* sprite, but none of its costumes includes a mouth. The students modified the sprite to create an additional costume with a mouth configuration consistent with the shout of surprise.

Positioning the viewer as a character in the story is an effective way of engaging the audience and fostering empathy for the character, as occurs at the end of *Can I Come In?* when George is reading the note (Figure 9.2). This requires only the single sprite of the note with George's (line) arms extending from it, and a small amount of basic coding.

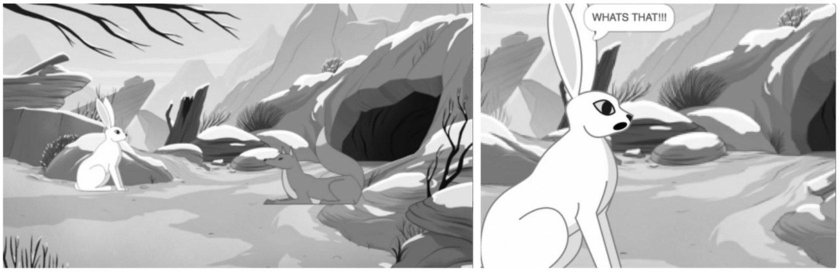


**FIGURE 9.4** Modifying a sprite and using a close-up view

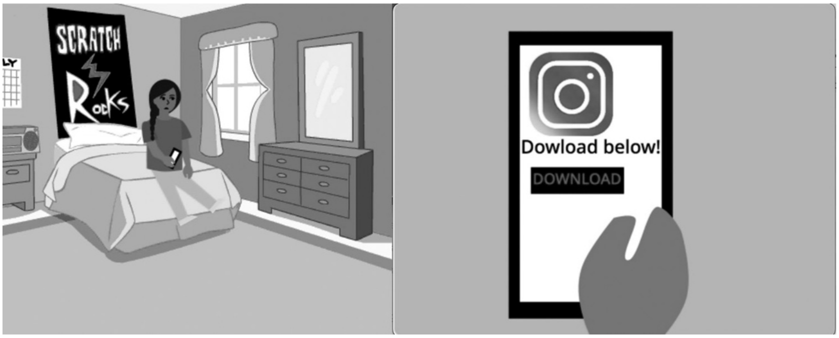


**FIGURE 9.5** How one student changed the point of view

Figure 9.5 indicates how another 13-year-old student, in the same class that had been learning to code for about seven weeks, incorporated this kind of shift in point of view. In this case, the background in the second frame should have been changed to be the same as the floor in the first frame, to make the shift in point of view appear more contextualised within the story world.

Similarly, other multimodal authoring techniques, such as the incorporation of sound, music, and spoken dialogue, are easily managed from a coding perspective. Re-balancing attention to coding and developing students' digital multimodal narrative authoring is an important consideration in investigating approaches to integrating coding and literacy in ELA.

## Challenges in integrating coding animated narratives as multimodal authoring in ELA

Research seeking to further the integration of computing and literacy through teaching students to code animated stories remains very much in its infancy. Progressing this agenda faces a range of challenges, including extending literacy teachers' coding competencies and their knowledge of the multimodal semiotics underlying animation creation, as well as assessment regimes in language arts and literacy curricula that continue to privilege the composition of monomodal texts. Added to these are the pedagogic challenges of catering for the diversity of learning needs among students in regular classrooms. While some of these challenges are gradually being addressed, some may be accepted as enduring and others seen as insurmountable, one highly tractable challenge is in the hands of researchers. Investigations designed to promote the integration of coding and literacy pedagogy need to be able to show how this will facilitate and enhance the kinds of multimodal literacy outcomes expected in ELA curricula.

The available literature investigating the integration of coding and literacy in ELA classrooms indicates that more attention to multimodal literacy outcomes is needed. In the studies to date, most students could learn enough basic coding to generate a very simple story over about seven weeks, while fewer mastered more advanced coding, which might have been more efficient and reduced coding time. An important issue is whether and how those very simple stories, within the constraints of a novice's basic coding competencies, might be enhanced to approximate the narrative qualities of some of the stories on the *Scratch* website created by enthusiast peers, which are more aligned with curriculum expectations for narrative composition. This would provide a basis for pursuing sustained cross-curricular collaboration between language arts and digital technology teachers for further integration of coding and literacy, and the inter-related learning development for students.

Our examination of animated narratives of literary quality created by school-age *Scratch* enthusiasts, and those of novice coders in a regular ELA classroom, indicates the need to prioritise the contextualising of coding initiatives in ELA within the development of students' interpretation and composition of multimodal literary narrative. ELA curricula for students in the transition years across the upper elementary/primary and junior secondary school include a focus on students learning about narrative techniques. This involves the representation characters' attitudinal responses to events in stories and the construction of point of view as key factors in audience (non)alignment with characters, which influences audience engagement with the story, and its thematic interpretation.

The Australian English curriculum for Year 6 requires students to explore "theme, characterisation, text structure, plot development, tone, vocabulary, sense of voice, narrative point of view, favoured grammatical structures and visual techniques…" (Australian Curriculum English Literacy (ACELT) content description 1616) and to identify narrative strategies that "offer insights into characters' feelings, so building empathy with their points of view…" (Australian Curriculum English Language (ACELA) content description 1518) (ACARA, 2018). Communicating evaluative meanings of affect, ethics, character, and capacity has been shown to be indexical of high-quality narrative writing by elementary and high school students (Macken-Horarik, 2003; Macken-Horarik & Sandiford, 2016; Ngo, 2016; Rothery & Stenglin, 2000). The representation of this interiority of characters does not appear in the studies of students coding stories with *Scratch*, yet it could be readily incorporated in even the simplest of stories.

In the *Crayfish* story discussed earlier, the same distant view of the one boy sprite is used throughout. An alternative representation might have been a close-up of the boy's face with a smile emphasising his joy at receiving the crayfish. His subsequent appearance could have shown a changed facial expression when he realised the crayfish needed water. At the end of the story, the boy could be shown with a sad face and the crayfish dead at the bottom of the bowl. Empathy for the boy could have been increased if the depiction of the boy arriving home with the crayfish, showed only the boy's arms extending out from the screen holding the crayfish tank directly in front, in a manner similar to Figure 9.2 – showing

George holding the note from Matt. This would have positioned viewers to have the point of view of the boy.

While students and teachers are familiar with the everyday expression of attitudinal meanings through frequently used language, facial expression, and perhaps also through gesture, posture and movement, it cannot be assumed that they routinely draw on systematic knowledge of these meaning-making resources in interpreting and creating multimodal texts. Similarly, while teachers and students have experienced the use of close up, social, and remote depictions of characters as well as high and low angle vertical views, it cannot be assumed that they are attentive to the effects of these forms of representations in their interpretation or creation of multimodal narratives. Teachers and students need to be familiar with the ways in which images position viewers to have different points of view including – (i) as observers of story events, (ii) as if they were characters in the story, or (iii) as viewing events along with the viewpoint of particular characters (O'Brien, 2014).

Research has provided systematic accounts of nuanced linguistic resources for communicating different kinds of attitudinal meanings (Droga & Humphrey, 2003; Martin & White, 2005) and how such meanings can be conveyed in images (Economou, 2012, 2013; Martin, 2008; Tian, 2011; Unsworth, 2015). Research has also shown how to depict interaction and point of view in pictorial narratives (Kress & van Leeuwen, 2020; Painter et al., 2013; Unsworth, 2013a, 2013b). Studies conducted in primary schools have shown that when teachers are alerted to accessible and succinct descriptions of these meaning-making resources they can very effectively enable their students to successfully deploy these visual and verbal resources for constructing characters' emotional responses, and to incorporate variation in point of view in the students' creation of digital comics and iPad animations (Mills et al., 2020; Mills & Unsworth, 2018; Unsworth & Mills, 2020).

As well as contextualising the creation of *Scratch* stories in relation to curricular expectations for narrative composition, integrating coding and literacy in ELA needs to take into account the relatively recent advent of multimodal literacy in the curriculum in many countries such as in the Common Core State Standards for English Language Arts & Literacy in the US (National Governors Association Center for Best Practices, 2010), and English curricula in Australia (ACARA, 2010) and (Singapore Ministry of Education, Singapore, 2010). However, these curricula tend to emphasise the interpretation of multimodal texts, rather than the creation of such texts. While multimodal digital compositions such as comic creation and the use of animation software for children have occurred in some classrooms (Chandler, 2013; Chandler et al., 2010, 2012; Unsworth & Thomas, 2014), many teachers' experience of story creation is monomodal, and the inclusion of images in student-created stories tends to be largely eliminated after the early years of schooling.

In many regular ELA classrooms, *Scratch* story creation initiatives will need to include support for teachers to provide explicit teaching of cinematic techniques and story creation as screenwriting competencies that have been successfully implemented in classrooms using digital comic maker and animation software (Mills et al., 2020; Unsworth & Mills, 2020). Learning to create animated movies coordinating visual storytelling, scripting, and the incorporation of music and sound through coding, is a challenging form of multimodal composition that will require detailed pedagogic scaffolding for the majority of students.

The importance of such well-developed pedagogic scaffolding for novice coders to create their animated stories is clearly reflected in existing studies. As previously indicated, the studies by Burke and colleagues (2010, 2012) included an examination of the coding of model stories, mini lessons on aspects of story creation, use of storyboards, student collaboration, and instructor feedback. Similarly, the approach by Whyte et al. (2019, 2020) was based on a continuum of preparatory learning activities conducted prior to students' independent story creation. These learning activities ranged from teacher 'directed' to student 'explored' and included teacher demonstration of worked examples and completed story structures. However, these researchers have recognised that the skewing of the scaffolding towards building confidence and competence in coding, while supporting rudimentary aspects of multimodal narrative authoring, is not sustainable if coding and literacy are to be integrated into ELA education. Burke et al. indicated that "there is also very much the need to explore (and make more explicit) the intersection between coding and narrative composition…" since their projects "largely held storytelling and coding apart as separate entities – each integral to and serving the same end goal – but introduced separately, nonetheless" (2012, p. 438). Correspondingly, Whyte and colleagues have indicated further development of their initiatives as necessarily working with teachers to determine how their perceptions of "…programming as a curriculum activity, and the role of multimodality in the literacy classroom could influence the co-design and implementation of these activities" (2020, p. 1323).

## Implications for a pedagogy of coding animated narratives in ELA

From the perspective of integrating coding and literacy in ELA, contextualisation of pedagogic practices within students' developing knowledge of narrative technique is essential. While some *Scratch* stories by experienced student coders, such as *The Colour Divide* have episodes of about 15-minutes duration, most *Scratch* stories are about 90 seconds or less. Composing *Scratch* animations of this short duration is important to maintain the amount of coding required at a manageable level for novice coders to complete a story within a feasible timeframe. An important initial contextualising strategy, therefore, is raising both teachers' and students' awareness and appreciation of the micro-narrative genre, and particularly the extensive popular cultural engagement with ultra-short, animated movies.

It is motivationally important to alert students to the significance of events, such as the annual Academy Award, or Oscar, for the Best Animated Short Film that began in 1932, and the plethora of Australian award-winning short animated movies can be viewed on the National Film and Sound Archive website (https://www.nfsa.gov.au/collection/curated/australian-award-winning-animated-short-films). Many high-quality animated movies of less than three minutes' duration can also be readily accessed via YouTube, such as the moving *Ticket without a Seat* (https://www.youtube.com/watch?v=_o2kL_kbosg) or the highly amusing and moving *Joy Story* (https://www.youtube.com/watch?v=vT7FsWg1t28). Using resources such as these micro-narrative animations, groups of students within a class can be invited to identify the most enjoyable story they can find. These can then be shared and, through discussion, teachers can guide collaborative analyses to reveal their story design. Stories can be analysed to understand how they are constructed to captivate audience interest through the multimodal representation of events, as well as characters' feelings. These are emphasised through filmic techniques, such as close-up views of characters, and sometimes by strategically positioning viewers as if they are viewing the story events as, or along with, a story character.

In developing their knowledge of narrative authoring technique, a key curricular focus for students in the transition years from primary to junior high school is the portrayal of characters' evaluative responses to story events from different points of view. Incorporating this in pedagogy for coding animated stories is necessary to establish the credibility of coding as a viable and advantageous digital literacy resource in ELA education for students of this age. A clear corollary in introducing *Scratch* is giving more attention to the role of sprite selection, modification, remixing, importation, and/or creation. However, it is also important to ensure that students focus on the features of sprites that are integral to communicating the significant ideas in the story. This can be emphasised by drawing attention to the effectiveness of minimalist depictions of characters, such as in the *Can I Come In?* story. Students can view well-known animations which also use minimalist depictions, such as the popular contemporary Australian television series, *Bluey* (https://iview.abc.net.au/show/bluey), or movies such as the Marjane Satrapi animated adaptation of her graphic novel *Persepolis* (Satrapi, 2008; Satrapi & Paronnaud, 2008) (https://www.youtube.com/watch?v=3PXHeKuBzPY). Students' critical viewing of animated narratives is an important resource in their learning to create their own animated stories.

The integration of coding and literacy in ELA that is accessible to all students will benefit from establishing a repertoire of pedagogic practices for developing low-, mid-, and high-level coding as authoring competencies. Such a repertoire would facilitate the kind of sustained long-term learning progression that would support students in the early and emergent stages of coding experience and extend those who are more advanced. For early stages, there is a plethora of tutorial activities on the *Scratch* website, but also elsewhere online such as on YouTube. For students who need additional support, these can be supplemented by learning activities gradually being accumulated through teacher experience.

In a recent study, a teacher introducing *Scratch* to bi-lingual Spanish-American sixth-grade students asked them to compare a segment from a familiar *telenovela* (soap opera) to a *Scratch* story version (Ascenzi-Moreno et al., 2020). First, the students acted out the scene using a playscript and then watched a *Scratch* animation depicting the same scene. They were then asked to match the script used by the telenovela actors with the *Scratch* code blocks. The first step was using the colours of the coding blocks for different functions (e.g. speaking, moving) to colour code the script according to the type of action. The second step was to draw a line from the relevant section of the script to the corresponding code blocks. Some, such as speaking (purple blocks) and sounds (pink blocks), were easy to connect, but some of the events (yellow) and motions (blue) were more challenging. Through this enjoyable drama and follow-up activity, the students were familiarising themselves with the connections among text, code, and the physical and communicative activity they represented.

Emergent coders with some experience can be asked to look at a story like *Can I Come In?* without access to the code, and then to generate their own versions of the story – or a segment of it – with relevant sprites, costumes, and code. This would build confidence and fluency in coding at their current level of competence. The kinds of extending tasks for advanced learners might be examining the code for *Can I Come In?* to determine how the changes in facial expression were managed when the facial features were discrete sprites detached from the blank base face of the sprite, and then attempting to incorporate this approach in their own stories. Further extension options are becoming available through analysis of the strategies of advanced Scratchers (Hagge, 2018, 2021). An expanded repertoire of learning experiences along such lines would always need to be strategically drawn upon to support the students' commitment to creating a personally meaningful narrative experience.

## Re-configuring research in classroom integration of coding and literacy

The potential of integrating coding into ELA education not only offers a productive response to international imperatives for developing students' coding and computational thinking as a core competency across curriculum areas, but it also offers a more enjoyable and agentive role for students in engaging creatively with digital animation as an increasingly popular form of multimodal literate practice. Studies introducing story coding with *Scratch* to date have drawn on a few examples of stories coded by the school-age participants. The significant disparity between these stories and those created independently by school-age peers who are coding enthusiasts, reflects the kinds of development that are needed in research and practical pedagogy to realise the potential of integrating coding in ELA education so that students' achievements in coding and narrative authoring align with curriculum expectations. Advancing animated story composition through coding in school curricula could benefit from transdisciplinary research that involves joint participation by researchers in computing and literacy and language arts education, and design-based research (DBR) that includes teachers as research partners (Anderson & Shattuck, 2012).

Transdisciplinary research is very different from 'inter'- or 'multidisciplinary' research (Halliday, 2003 [1990]). The latter implies research within disciplines while building bridges between them, and/or assembling the research efforts into a 'collection'; transdisciplinary research seeks to transcend disciplinary boundaries to achieve the integrated focus necessary for investigating pedagogies at the intersection of coding and narrative composition. This means that researchers need to commit to intensive critical engagement in discourses beyond the discipline(s) that they were trained in, have become their principal career focus, and through which their prestige is established (Unsworth, 2008). We believe commitment to a transdisciplinary approach is a priority in building credible curriculum proposals and pedagogic approaches that will persuade literacy teachers to invest in the transdisciplinary professional learning that will enable them to optimise coding as an important dimension of multimodal literacy in ELA.

Assuming a transdisciplinary approach, bringing the achievement of novices in animated story creation and coding competence to a level commensurate with relevant curriculum requirements could be effectively advanced by a DBR approach that extends well beyond the seven-week interventions of existing studies. The purpose of DBR is to build theory and to improve practice within authentic education environments (Anderson & Shattuck, 2012; Reimann, 2011). It involves teachers and researchers partnering in response to a commonly agreed issue of significance to produce iterative cycles of intervention, planning, and implementation within specific education contexts. Teachers and researchers work collaboratively to build understanding of the learning context, and to select and/or design interventions based on professional and research literature, theory, and practice. During the iterative cycles of DBR, the data that are collected and analysed after each intervention are used to refine and improve the next. This kind of longitudinally oriented, transdisciplinary informed, DBR approach would enable the same cohort of students to participate in successive cycles of coding animated narratives.

The initial cycle in introducing *Scratch* might deal with developing and/or consolidating students' multimodal authoring in terms of their visual representation of characters' attitudes, constructing varying points of view for audience engagement in observing, visually interacting with and aligning with or adopting characters' perspectives. This entails exploration of *Scratch* sprites, their existing costumes, affordances of their construction for modification, drawing in *Scratch* to modify facial expressions, importing or drawing new sprites, and informal exploration of some of the *Scratch* coding functions to animate selected sprites to complete various actions. At the same time, teachers could show examples of *Scratch* stories, highlighting multimodal authoring techniques and informally indicating how the *Scratch* blocks enable them, as well as modelling the creation of short within-story sequences.

The second cycle might involve consolidating students' knowledge of and capacity to deploy basic function blocks in *Scratch*, and teacher/student collaborative story building with high-level teacher scaffolding, followed by teacher modelling of original story creation. After this, students may work in pairs or small groups to generate their own stories with teacher guidance and support using storyboards to plan in detail. The emphasis in the initial story creation phase would be on creating an optimally engaging story within a modest repertoire of coding competence.

After the first round of stories have been coded, they might be shared and examined for potential refinement, both in terms of alternative and more efficient coding options to achieve the same story features, or editing the story to include more complex events, character actions and responses and/or construction of the audience into the story through visual point of view options and/or interactive fiction (see Chapter 10). Follow up story composition may involve more independent work by students individually, in authoring teams and as part of online communities. Learning progressions along these lines might well extend over at least one semester or over a full year.

The potential of integrating coding and literacy is evidenced by the impressive literary quality of coded animated narratives created by school-age children very largely independently of their school experience. Popular block coding platforms, like *Scratch*, have been instrumental in allowing early entry by these children into the changing literacies of the digital communicative world of the 21st century. Dissemination of these opportunities to the broad and diverse populace of school systems entails multitudinous complex challenges. Among them, the issues facing further educational research and development of curriculum and pedagogy for integrating coding and literacy call for the de-siloing of disciplinary endeavours so that new epistemologies based on transdisciplinary commitment can emerge. This de-siloing is essential to underpin the pedagogic practices needed for the universal preparation of children to engage productively with coding as a literate practice among the constantly evolving multiple forms of literacy for digital futures.

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# 10

# DIGITAL INTERACTIVE LITERATURE

## Introduction

The integration of literature and new technologies continues to evolve, maintaining the longstanding trajectory of literary adaptation and innovation with the ever-changing development of film and communication technologies. As digital technology has become a defining aspect of contemporary global society, we experience the ongoing recontextualisation of classic and contemporary literature afforded by digital technology development, as well as new literature specifically created to leverage those technological affordances. Students growing up in these digital communication environments have an increasing range of different kinds of digital interactive literature (DIL) available to them, including the same stories – such as the Harry Potter story world (Rowling, 2017) – not only as books and movies, but also as multiple video games, and even now as augmented reality games – such as *Harry Potter: Wizards Unite* (Warner Brothers and Niantic, 2020). At the same time, students can experience new interactive narratives created with and for virtual reality and augmented reality applications.

The literacy competencies entailed in engaging with and critically appreciating these multiple interactive digital formats will need to continue to evolve. For teachers to maintain a socially responsible literacy pedagogy in this context, frameworks will be required for examining how multiple options for digital interactivity are related to the interpretive possibilities of the stories. To develop such frameworks, we first need to specify the modes through which interactivity can occur, such as visual, verbal and bodily modes, and the available options within each. From this cartography of interactivity potential, we can map the choices or combinations thereof that create different types of interactivity. Then we can examine how different types of interactivity contribute to story meaning,

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enabling a critical appreciation of the overall co-patterning of different types of interactivity and its role in prompting interpretive engagement in the story.

To pursue this agenda, we adapt the approach of systemic functional linguistics (SFL) and semiotics, in which complex interacting networks of options for meaning making within representational modes (such as language and image) are mapped and instances of meaning making are described in terms of the choices made from such networks (Halliday, 2013). In this chapter we, therefore, propose a framework, drawing on the SFL or 'system network' approach (Martin, 1987), to map the available options in three core *dimensions* of interactivity (*imagic, bodily*, and *verbal*) and their narrative functions as *peripheral* or *integral* to the story.

## Networking dimensions of interactivity and narrative function

The main systems for mapping the dimensions of interactivity to their narrative functions are shown in small caps in Figure 10.1.

The superordinate system of INTERACTIVITY encompasses the main contributing systems (DIMENSIONS and NARRATIVE FUNCTIONS) in a left-facing brace. The brace indicates that as one proceeds from left to right through the network to describe a particular instance of interactivity, it is obligatory to select further

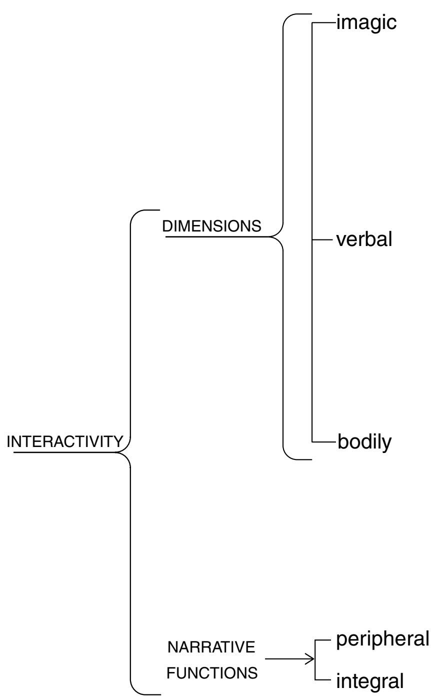


**FIGURE 10.1** A network base for mapping interactivity in digital literature

options from *both* main systems. Within DIMENSIONS, the initial options are *imagic, bodily*, and *verbal*, which are located as discrete options on a straight-line bracket. Such a bracket means that only one of these options can be selected, however, the combination of the left-facing brace and the straight-line bracket means that one or more of the options can be selected simultaneously. Hence, both *imagic* and *bodily* can be selected to account for digital narratives where imagic and bodily interactivity co-occur. In describing a particular instance of interactivity, one must select from the features of the DIMENSIONS and the NARRATIVE FUNCTIONS systems. The NARRATIVE FUNCTIONS features of *integral* and *peripheral* are dichotomous choices, as indicated by the straight-line bracket. So in one instance, the combination of imagic and bodily interactivity might be peripheral to the narrative, while in another instance it may be integral.

## Imagic, bodily, and verbal interactivity

### *Imagic interactivity*

Further *imagic* options include *format, dimensionality, view*, and *mobility* (Figure 10.2). The format may be *virtual reality* (to be discussed in the section titled 'Interactivity in virtual reality story apps') or an *illustration*. Dimensionality in virtual reality is necessarily 3D, and 2D in illustrations. What the audience sees in the representation we refer to as *view*. In 2D illustrations, the view is *fixed* to that chosen by the illustrator, but in 3D virtual reality, the view is *navigable* by the user. Clearly, the options within *format, dimensionality*, and *view* do not freely combine. For *illustration*, the dimensionality is necessarily 2D and the *view* fixed, whereas for virtual reality dimensionality is 3D and the *view* may be navigable. In the final imagic option *mobility*, there are three further sub-options. The first is whether image elements are manipulable by the user – and if so, whether this is free manipulation or constrained within pre-set parameters, such as a character being

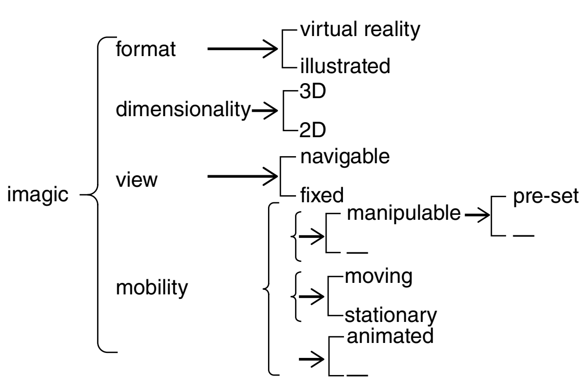


**FIGURE 10.2** Options facilitating imagic interactivity

movable in a set pattern. In Figure 10.2, the dash option in the square bracket with *manipulable* indicates the 'not manipulable' option, and, similarly, the dash in the *pre-set* bracket indicates 'not pre-set'. The second sub-option is whether the image elements are *moving* or *stationary*, and the third is whether they are *animated* or not. For example, a character may be stationary, but animation keeps the eyes blinking.

The left-facing brace following 'imagic' means an option from each of *format, dimensionality, view*, and *mobility* must be selected. Similarly, the left-facing brace following 'mobility' means that choices must be made from each of the three subsequent sub-systems. For the first two of these the combined brace and square bracket means that either or both options can be selected. For example, within any scene, some image elements may be manipulable and others not, and some may be moving and others not.

Characters in 2D and 3D can invoke interaction through, for example, a direct frontal gaze at the audience, a frontal view of arms outstretched directly toward the audience as a greeting, through the construction of the audience's point of view as if they were a character in the story, or through an 'over-the-shoulder' positioning of the audience to see along with the character. The represented physicality of 3D characters is suggestive of their, at least potential, interactant role with the audience, while inanimate 3D objects suggest they can be handled, circumnavigated, climbed upon, etc. In addition, the ability of the audience to navigate to different views within a 3D environment is a form of interaction with a particular setting. Animation such as eye movement, head nodding, hand waving and so on, can invoke audience interaction. The movement (displacement) of participants invokes interaction through 'tracking' by the audience.

## Bodily interactivity

Audience *bodily* interactivity involves various kinds of *touch* on the screen or *manoeuvre* of the device. These are sometimes *cued* by *verbal* and/or *visual* on-screen notifications. Verbal interactivity can also be a discrete system, which can be *oral* or in *print*. These options and their further sub-options are added to our system of DIMENSIONS of interactivity in Figure 10.3.

In DIL where the imagic format is illustrated, there is usually limited interactivity. This is common in interactive versions of classic children's literature such as *Alice for the iPad* (Carroll, 2016), which is a re-versioning of *Alice's Adventures in Wonderland* by Lewis Carroll (1865). The iPad version maintains the original text and illustrations. All images are 2D with the audience view fixed. There are two ways the reader can interact with the images. Firstly, characters as *stationary* images, are *manipulable* by *touch* (*tap* or *drag*) but within *pre-set* parameters. For example, a tap on the character results in the caterpillar moving its hookah to its mouth and back in a repetitive pattern, the Duchess's baby rocking and crying, and the Mad Hatter's head bobbing back and forth. When the image of Alice

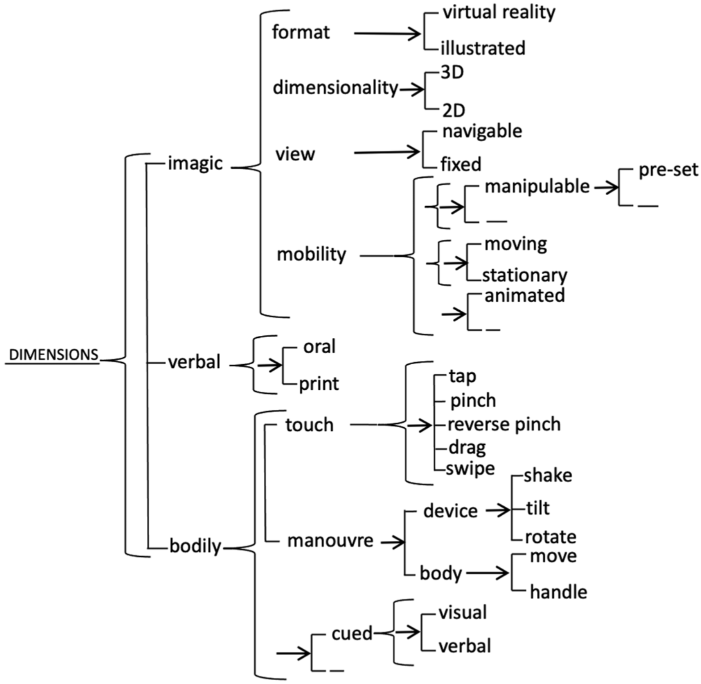


**FIGURE 10.3** Dimensions of interactivity

automatically shrinks, it is possible to *drag* to restore Alice to her original size. Secondly, objects can be *dragged* anywhere on the screen, such as the 'Drink Me' bottle that shrunk Alice, Alice's comfits (lollies), little cakes, mushrooms, the Queen of Hearts' crown, and the playing cards that float over the screen.

Similar limited imagic interactivity is possible in digital interactive versions of classic children's picture books such as *Jemima Puddle-Duck* (Potter, 2013), which is a re-versioning of Beatrix Potter (1908) story. In this app, *animation* involves the characters blinking, and while most are stationary and manipulable within pre-set parameters, there is an occasion where Jemima is moving (flying) and can be dragged all over the screen. These are also the most common forms of imagic interactivity in many contemporary children's interactive story apps. Some include other touch techniques such as swipe, pinch (pulling the thumb and forefinger together) and reverse pinch (Naji, 2021).

Interactivity can also occur through manoeuvring the device (*shake, tilt* or *rotate*). For example, in *The Cloud Factory* (Stokes, 2016), the user is invited to *rotate* the iPad 90 degrees to pour milk from a bottle into the bowl of ingredients for cloud making and later to *shake* the iPad to mix the ingredients. On-screen cues to the bodily interactivity are frequently provided, such as the question mark inside a yellow disk at the bottom of the screen in *The Cloud Factory* (Stokes, 2016). If the viewer does not take action a white hand points to the disk

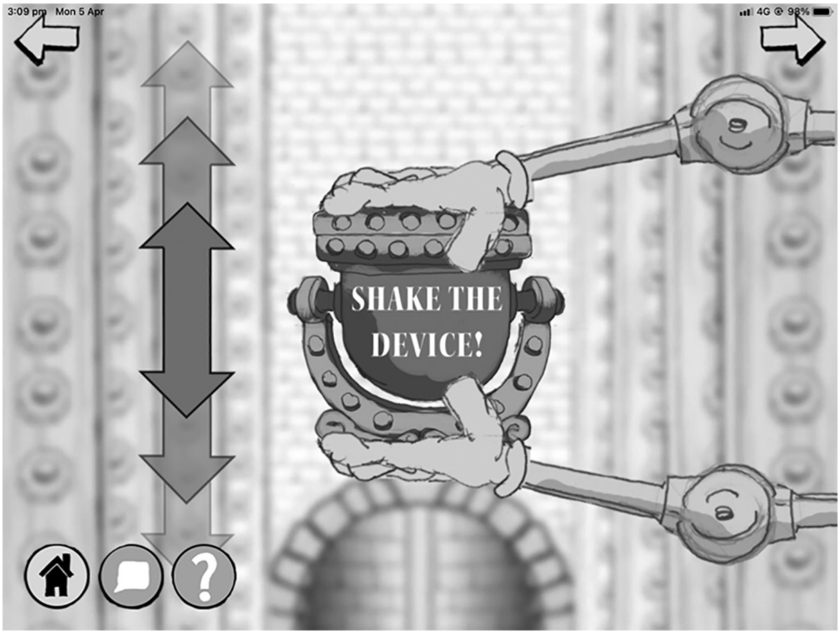


**FIGURE 10.4** On-screen notification for bodily interactivity
Stokes, 2016

and the words "PUSH HERE FOR HELP" appear. Upon doing so, a verbal and visual cue to the bodily action required appears (Figure 10.4). Similar cues occur in other apps such as the on-screen "HINT" in '*The Heart and the Bottle*' (Jeffers, 2010). But not all opportunities for bodily action are cued. In *The Cloud Factory*, for example, the use of swipe to remove the cow from the first screen is not cued and in *Alice for the iPad* and *Jemima Puddle-Duck*, there are no cues to use various touch techniques.

*The Thief of Wishes* (Markowska, 2017) is a children's story with principally stationary images that include some limited animations such as characters' eye movements, arm movements, etc. and background animations such as leaves floating onto water. Apart from this, the interactivity consists of on-screen 'choose your own adventure' verbal text interpolations offering usually two options for advancing the story. Many contemporary digital interactive novels for older children are verbal only. *The Hero of Kendrickstone* (Wang, 2015) is an interactive fantasy novel of the 'choose your own adventure' type with no images or sound. At frequent intervals, readers are presented with three or four options from which to choose to advance the story. Examples of other verbal only stories include *Sixth Grade Detective* (Hughes, 2016), an interactive novel for early teenagers and *Running Away* (Ardeshir, 2019) in the format of an interactive social media chat dialogue.

## Interactivity in virtual reality story apps

There are two main types of virtual reality (VR): non-immersive and immersive (Çoban, 2021; Freina & Ott, 2015; Lee et al., 2020). Non-immersive VR (NVR) is a desktop-based technology that simulates a 3D virtual environment and provides the user with some degree of *telepresence* (Steuer, 1992, p. 76), defined as a mediated perception of 'being there' in that virtual environment. In NVR, although the images look three dimensional, they are rendered on a 2D flat or curved screen, so the user retains the perception that s/he is separated from the virtual environment.

Immersive virtual reality (IVR) involves wearing a head-mounted display (HMD) over the user's eyes, which tracks user position and projects stereo images for each eye corresponding to where the user is looking in the virtual environment, so that users perceive themselves as located within the virtual environment (Jensen & Konradsen, 2018; Pottle, 2019). The HMD obviates any perception of the immediate material environment, so the user experiences an all-round perception of physical presence in the virtual environment (Slater & Sanchez-Vives, 2016).

NVR is experienced with many modern videogames and virtual worlds such as *Second Life*, as well as VR versions of literature such as *Sherlock Moviebook* (Doyle, 2014), a rendering of the Sherlock Holmes story, *The Red-Headed League* (Doyle, 1892), and for young children, the Bookful rendering of *The Tale of Peter Rabbit* (https://bookful.app/books/the-tale-of-peter-rabbit/) from the original by Beatrix Potter (1987). These stories exemplify very different approaches to NVR in digital narrative technique. In the *Sherlock Moviebook* story, Jabez Wilson comes to Sherlock Holmes claiming he has been wronged by a mysterious league of red-headed men, which was founded by an eccentric red-headed millionaire who wished to provide for other red-headed men by offering them easy jobs for high pay. Wilson acquired one such job, copying out the encyclopedia for four pounds a week. However, after some months, a sign on the office door announced that the league had been disbanded. Wilson was encouraged to apply for the job by his very efficient new assistant, Vincent Spaulding, who was happy to work for half wages. Wilson reveals that Spaulding spent hours in Wilson's cellar each day, developing his photographs. Holmes determines that when ostensibly developing photographs, Spaulding was tunnelling under the shop to get access to a nearby bank vault and that the job with the red-headed league was a ruse to get Wilson away from the shop until the tunnelling was completed.

The story is portrayed on screen as an illustrated novel with images and text on each page. Rotating the iPad displays the images in full screen with audio reading of the story. Swiping upwards reveals thumbnails of each page to enable re-reading/viewing at any stage in the story. Some images are user-navigable NVR environments while others are NVR movies, which are not manipulable by the user, and other illustrations are simply stationary images. Swiping on the NVR representations enables horizontal and vertical navigation around the three-dimensional virtual environment. For example, the view of Wilson initially recounting his experience to Holmes shows them in lounge chairs opposite each other but swiping enables the user's gaze to shift around so that nearly all of Holmes's room can be viewed.

The animation of the 3D characters in NVR enhances the user's experience of telepresence. For example, when Wilson sneezes after taking snuff, images of droplets of saliva appear over the screen. Touch in NVR also enhances telepresence. For example, when Holmes and his colleagues enter disused passages to the bank vault, swiping not only moves the audience around the disused room, but also results in wiping dust off one of the boxes stored therein (p. 24). Hence, the NVR movie segments and the 2D stationary images contribute significantly to user interactivity.

The Bookful version of the Peter Rabbit story (https://bookful.app/) typifies a minimalist deployment of NVR. This story is also portrayed on the screen in book format and as the user swipes to turn pages the 2D illustrations convert to 3D animations. While the NVR is 3D, the user view is fixed with the single view of the virtual environment maintained throughout the story. The animated characters repetitively perform the same activities until the page is turned. For example, the rabbit's hop, jump, etc. and Mr McGregor on his knees rhythmically and repetitively bends over his garden. Apart from swiping to turn pages, there is no bodily interaction with the story.

These types of NVR we refer to as *contained* NVR, since they are experienced entirely within the screen-based environment of the tablet or smartphone device. However, another form of NVR is augmented reality (AR). As discussed in Chapter 7, AR technologies overlay virtual content, such as animations and representations of natural or artificial artefacts or texts, over real-world environments, so the user of AR is simultaneously interacting with elements of the real world enhanced by computer-generated perceptual information. AR displays can be rendered on devices resembling eyeglasses but are more commonly accessed with apps using the cameras of smartphones and tablets.

The apps are cued to activate the AR displays by signals which may be embedded in books, and in some cases are projected from the device onto an AR receptor such as the 'Merge Cube' (https://mergeedu.com/cube). This is an inexpensive holographic object which is placed in front of the device and rotated to display the AR depictions. The AR activation signals may also be physically present in selected real-world environments, or they may be activated by the Global Positioning System (GPS) on the device. We can now extend the *format* system to include more detailed options for imagic interactivity (Figure 10.5).

Adaptations of literary classics such as Robert Louis Stevenson's *Strange Case of Dr Jekyll and Mr Hyde, Frankenstein* by Mary Shelley, and T.S. Eliot's '*The Waste*

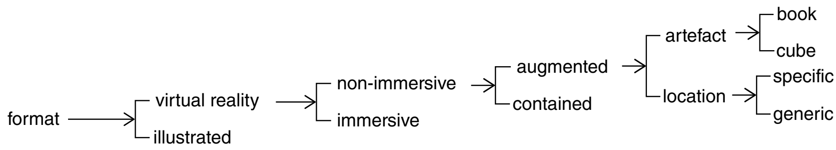


**FIGURE 10.5** Non-immersive virtual reality contexts for digital interactive literature

*Land'* (Eliot, 2011; Hugli & Kovacovsky, 2010; Morris, 2012), as well as Penguin Books' and Zappar's interactive versions of *Moby Dick, Great Expectations*, and others (Farr, 2012), have afforded some status to AR books, in the context of DIL (Karhio, 2021; Weedon et al., 2014). Many classic works of children's literature have been re-versioned with AR apps such as the multiple versions of *Alice's Adventures in Wonderland* (Carroll, 2017, 2018). The paper versions of the books have the illustrations cued to respond to AR apps on a smartphone or tablet, which then portray 3D animated depictions of the characters enacting set routines. For example, in the version published by Ranok (Carroll, 2018), the characters do not speak but we see Alice follow the white rabbit down the rabbit hole, drink from the bottle which alters her size and swap places around the Mad Hatter's tea party, etc. Many such classic children's stories follow this AR format, for example, *The Little Mermaid* (Andersen, 2016) and *Little Red Riding Hood* (Lambert & Butcher, 2018). Contemporary books for children, such as *Toy Story* (Kent, 2019) and graphic novels for teenagers and young adults such as *Chosen Kin* (Sparks, 2020) also adopt this AR format. Some AR stories, although they will work on the smartphone or tablet alone, are specifically designed for use with the Merge Cube e.g. *57° North* (Mighty Coconut, 2019) and *Little Red Riding Hood* (PleIQ, 2018).

The more nuanced deployment of AR as an integral dimension of digital literary technique occurs in the experimental literary creation, *Sherwood Rise* (Weedon et al., 2014). This is a derivation from the Robin Hood legend set in the years around 2010 in a housing estate in the suburban wastelands of London. The privileged elites are pursuing their exploitation of the poor and a band of hackers led by a beautiful young woman, Robin, hack newspapers to reveal the corruption. The story is told over four days using the mobile phone AR app, emails and four newspapers, which are in three different versions. The AR characters interact with the user via email. Which version of the paper the user receives depends on how s/he has responded to the efforts of Robin and the 'Merry Men' in championing the causes of the poor, so the reader becomes part of an illegal group of outlaws, becomes implicated and takes sides. The development of the positions taken by the user affects how they progress with the story.

The finessing of AR techniques to build interactivity in literary narrative continues to develop with ongoing research such as the innovative AR picture book for adults, *Saints of Paradox* (Tavares, 2019). The main character, Elza, is an elderly woman who mourns the death of her lover, Euclides, who disappeared during the 1964 Brazilian coup d'etat. For 50 years, she has been immersed in grief. She initially searched for her lover but has since retreated into a deeply religious existence, bordering on obsession and madness. She watches an antiquated television that repetitively plays propaganda from the 1960s. She becomes fixated on the day that her lover disappeared. One day, she accidentally breaks a photograph of Euclides, which triggers her vision of the place where he had been imprisoned. She sees him dance, but suddenly he is shot.

The book consists of ten richly elaborate pictures. When the pages are scanned, the user can select narrations for each picture from one of three different Saints: The Mother of Benevolence, the Father of Pragmatism, or the Father of Orthodoxy. Each saint has a distinctive monologue, soundscape, video, and animated interpretation that plays out over the printed picture, the AR depiction for each narrator changing the printed picture to form its own distinctive remaking of the image and hence divergent interpretation of the scene. Hence, the user interacting with and responding to AR depictions is contributing to the instantiation of the particular narration that is derivable from the potential narrative progressions. The vision of her lover from her youth has a dramatic impact on Elza and the story ends in three different ways, depending on how each saint interprets the sequence of events.

AR in DIL is not only anchored to artefacts, but can also be anchored in *locations*, which can be *specific* or *generic* (wherever the user happens to be). For example, the 2017 winner of the New Media Writing Prize, *The Cartographer's Confession* (Attlee, 2017) is a fictional narrative set in specific locations in London. It tells the story of Thomas Andersen, whose Norwegian mother Ellen brought him to London in 1945 as a small child in a suitcase. Since Thomas's father was German, Ellen had her head shaved in Norway. London was a bewildering labyrinthine city that neither of them could fathom, resulting in a life of anxiety and trauma. To survive and make sense of their environment Thomas began charting the city through the location of places they became attached to. From this beginning, Thomas later became a cartographer. The AR story unfolds as users walk around three city locations. More story material becomes available as the users move between the three sites where the story takes place. The storying is via voice, video, text, historical photographs of 1940s London, new illustrations, sound, and music (Parezanović, 2019).

In *Silent Streets: Mockingbird* (Cobbett, 2018) the AR location is generic. This is a mystery adventure in the tradition of Sherlock Holmes set in Newport in Victorian times in which a detective has to find the killer of a local boxing champion. Augmented reality depictions are shown in the user's own environment and can range from inspecting various 'clues' on an AR depicted writing table to examining an AR depicted corpse in a morgue. The story follows a 'choose your own adventure' format, where user choices affect the progress and conclusion of the story. There are many other similar AR adventure stories such as *Anomaly: Clandestine* (Zenfri, 2015), which involves the user defending his/her own environment against invading aliens. For young children examples of generically located AR DIL are typified by those available via the *Wonderscope* app (https://wonderscope.com/). Some are derivations from traditional tales such as *Little Red – The Inventor* (Bora, 2018). In this twist on the traditional *Red Riding Hood* tale, the app user works with Little Red to overcome her initial deception by the wolf and to assist in eventually saving her grandma and capturing the wolf. The app prompts the user to find a well-lit and flat location in the user's environment on which the AR world is depicted. The story employs voice activation to involve the user interacting orally with Little Red and hot spots to enable the user to assist Little Red in finding and activating crucial objects, helping her in completing difficult puzzles, and providing encouragement when she becomes disheartened. The AR affordances are deployed powerfully to achieve the kind of user interactivity that promotes empathy with the depicted characters.

In IVR stories, experienced via HMDs, the concept of the book or even the digital visual facsimile of a book is completely discarded as in the IVR version of *Wolves in the Walls* (Fable Studio, 2019) or almost completely discarded as in the IVR story of *Tara's Locket* (Big Motive, 2017). *Tara's Locket*, nevertheless, is described as "an illustrated storybook adventure in a stunning virtual world.... inspired by the landscapes, stories and folklore of Ireland's dramatic Atlantic coast" (https://www.wearvr.com/apps/taras-locket-a-vr-story-for-children).

Intended for children (four to eight years), the story involves the user in Tara's adventures of bringing her family safely back together from their perilous experience working in their fishing boat. The virtual world is set up so that users can explore the 3D environments without bodily navigating through virtual space. The creators "designed Tara's world to be explored simply by looking around and designed the interactions to be triggered by the user's area of attention" (https://www.bigmotive.com/blog/taras-story-a-childrens-book-brought-to-life-in-vr/). The story is progressed through interactivity cued by visually presented 'hints', that draw attention to outlined participants which, once selected, become full 3D story components.

The creators of *Tara's Locket* were very much aware of the role of literary picture books in introducing children to active reading and growing facility in interpreting text, so this aspect of the book format was maintained:

> Conscious also of the fact that our users want to interact and not just watch, we created the interludes around flowing sentences that reveal themselves as the user follows the text and guides them to the conclusion. For users too young to read the words this 'flowing sentence' model is useful in reinforcing some very simple literacy fundamentals, such as reading from left to right. As a rule of thumb, VR is best when it relies on the least amount of text, but it can work to enhance the experience when used sparingly to change the pace and progress the narrative.
>
> *(https://www.bigmotive.com/blog/taras-story-a-childrens-book-brought-to-life-in-vr/)*

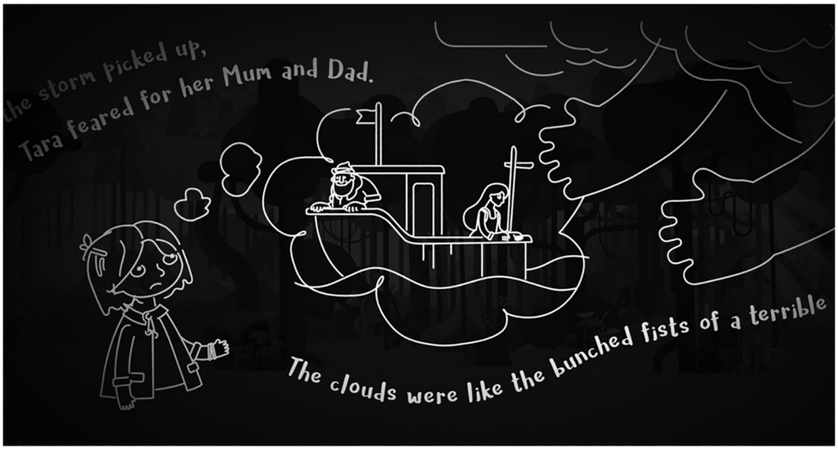


**FIGURE 10.6** Flowing sentence interludes in *Tara's Locket*
https://www.bigmotive.com/blog/taras-story-a-childrens-book-brought-to-life-in-vr/

This aspect of the IVR story is indicated in Figure 10.6.

The IVR experience of *Wolves in the Walls* (Fable Studio, 2019) is based on the award-winning picture book of the same name (Gaiman, 2003). In this story for young people 13 years and older, young Lucy hears the sounds of wolves in the walls of the family home. Her family dismisses these claims suggesting that harmless creatures that often inhabit the walls of old houses are responsible. Lucy's claims prove to be correct and her resolution for the dilemma this causes for the family constitutes a highly engaging, open-ended literary experience. Users can join Lucy in exploring the very detailed 3D representation of the family home and its contents. Users who have touch controllers can manipulate these to hold a camera passed to the user by Lucy to collect evidence of the wolves' presence. This means the user can also retract photos from the polaroid camera and pass them to Lucy, take a magnifying glass from Lucy to inspect the photos, and moving around the attic and looking under furniture, the user can pick up fallen photos. Users can also accept a crayon from Lucy to write their names in the story credits. The user is both a participant and an observer as the story progresses.

Through dialogic and visual interaction with Lucy, users experience moving through the rooms of the house, hearing the household sounds (including those of the wolves), bending under tables, etc., and experience their presence in the story world as they support and assist Lucy. The IVR experience of interactivity in *Wolves in the Walls* involves the manoeuvrability of the user's body as well as the ability to handle and manipulate objects, while the visual interactivity with 3D depictions affords navigable views, open-ended manipulation of objects, and interaction with animated moving participants. This kind of multi-sensory immersive active participation in the story world provides a very distinctive basis for interpretive responses to such narratives.

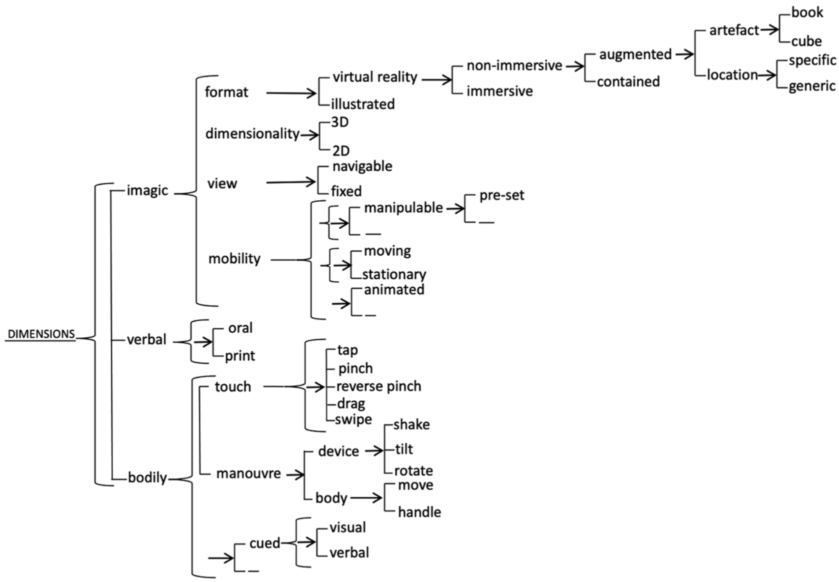


**FIGURE 10.7** Dimensions of interactivity with non-immersive virtual reality contexts expanded

We can now complete our mapping of options within the DIMENSIONS system for interactivity as shown in Figure 10.7.

## Narrative functions of interactivity

We now consider the contribution of the patterns of choices from the DIMENSIONS of interactivity to their NARRATIVE FUNCTIONS. The initial consideration is whether a particular instance of interactivity is *peripheral* or *integral* to the story (Figure 10.8).

In *Alice for the iPad* (Carroll, 2016) many instances of interactivity – such as tapping resulting in Mad Hatter's head bobbing or the Duchess's baby rocking and crying – are peripheral, as is the tapping in *Jemima Puddle-Duck* (Potter, 2013), which results in quacking or the noises of other animals. This is a prominent form of interactivity in digital interactive versions of picture books and illustrated stories for children. A recent study found that "Most of the AR interactions that

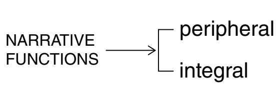


**FIGURE 10.8** Interactivity as peripheral or integral to the story

were found in this study consisted of taps and pokes of AR elements on the page resulting in squeals and other noises" (Green et al., 2019, p. 372). However, this study did find some interactivity integral to the stories. For example, in *TJ and the Beanstalk* (Pai, 2017) the user assists in cutting down the beanstalk by swiping in AR and in *The Adventures Suit* (Zappar, 2015) the picture book shows the little boy in reality in his dress-up suits that he imagines transport him on a variety of adventures, while the AR shows the boy on the imagined trips (Green et al., 2019, p. 371). *The Heart and the Bottle* (Jeffers, 2010) has similar examples of interactivity that are integral to the story (Zhao & Unsworth, 2017) and we have noted further examples in previous sections such as rotating the device to pour the milk in *The Cloud Factory* (Stokes, 2016).

We now examine three ways in which the various kinds of interactivity can be integral to the story:

- *procedural* – activating the functionality of the app;
- *elaborative* – reinforcing the development of plot or characterisation;
- *transformative* – influencing the nature of the progress and outcome of the story;

as shown in Figure 10.9.

Firstly, in our system of NARRATIVE FUNCTIONS (Figure 10.9) we need to acknowledge the integral role of procedural interactivity. This has been referred to as 'extra-text' interactivity (Zhao & Unsworth, 2017, p. 92) because it activates aspects of the functionality of the app rather than elements of the story. Procedural interactivity includes swiping to turn 'pages', hot spots that activate thumbnails of all pages enabling the user to jump to different parts of the story, and sometimes other features such as a microphone icon as a hot spot that activates a 'read aloud' function.

Interactivity that is *integral* to the story is also commonly *elaborative*. Such interactivity may *reinforce* or *extend* the *plot* or *characterisation* (Figure 10.10).

The *reinforce* function for the *plot* occurs when the interactivity rehearses what has already been conveyed by the images and/or the language. For example, in *The Cloud Factory* (Stokes, 2016) the grandfather says, "Now dear, we need to shake the mixture" and the cued interactivity of shaking the iPad reinforces this part of the process. The *reinforce* function for *characterisation* occurs in *The*

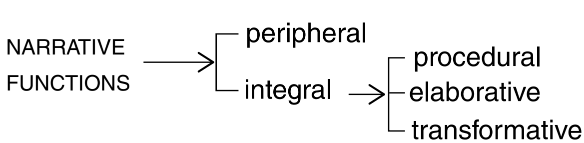


**FIGURE 10.9** Integral interactivity

*Marvellous Machines* (Grimm & Fortuna, 2016) when the main character is giving a tour of his fantastical robot collection:

> While the book pages describe each of the robot's behaviours, the AR brings the robots to life. For example, one of the robots, The Twinkle-Toe-Sprinkle, is described on the pages as a robot that will 'splash you all over' (p. 13). In the AR, the full extent of the robot's spraying and spattering abilities are demonstrated.
>
> *(Green et al., 2019, pp. 370–371)*

The *extend* function of interactivity with respect to the *plot* is exemplified in two key scenes in *Sherlock Moviebook* (Doyle, 2014). The first is when Holmes is outside Wilson's shop tapping on the pavement with his cane (Figure 10.11). The text says nothing about where on the pavement Holmes was tapping ("having thumped vigorously upon the pavement with his stick two or three times, he went up to the door and knocked" (p.12)). But swiping and tapping on the screen activates Holmes's cane tapping both behind and in front of him thus extending the text and providing a clue to the later revealed purpose of the tapping as testing the possibility of Spaulding's secret tunnelling under the pavement. The second example of the *extend* function occurs in the subsequent scene, where swiping up on the screen reveals the clue of the dirty knees of Spaulding's trousers not mentioned in the text and not visible in the image until swiped upwards. The *extend* function for *characterisation* is exemplified in the scene following Wilson's departure from Holmes's apartment. The text mentions Holmes smoking his pipe while considering the case but swiping the 3D image of the apartment reveals other aspects of Holmes's character, which are not visible in the initial image depiction, such as the violin on his lounge chair and the steel syringe on his desk.

Similar examples of the extend function can be found in other DIL. *The Heart and the Bottle* (Jeffers, 2010), for example, follows a little girl's journey through grief at the death of her grandfather. She was very close to her grandfather who often read her books about the curiosities of life as they both sat in his favourite chair. The pages depicting their loving relationship are filled with vibrant warm colours. One of the many instances of interactivity that extend characterisation occurs when the little girl enters the room with her grandfather's empty chair. Swiping over this page colours the scene with a deep dark blue overlay.

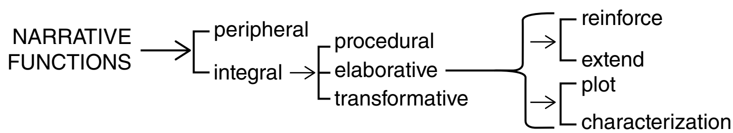


**FIGURE 10.10** Elaborative interactivity

Sherlock Holmes stopped in front of it with his head on one side and looked it all over, with his eyes shining brightly between puckered lids. Then he walked slowly up the street, and then down again to the corner, still looking keenly at the houses. Finally he returned to the pawnbroker's, and, having thumped vigorously upon the pavement with his stick two or three times, he went up to the door and knocked.

12

**FIGURE 10.11** Interactivity extending plot
Doyle, 2014, p. 12

From our network of options for interactivity in DIL (Figure 10.12), we can now characterise each instance of interactivity by coding the choices it represents from the right-most options for each system in the network.

This helps to indicate to what extent and how the design of interactivity from the options within each system contributes to the interpretive possibilities of the

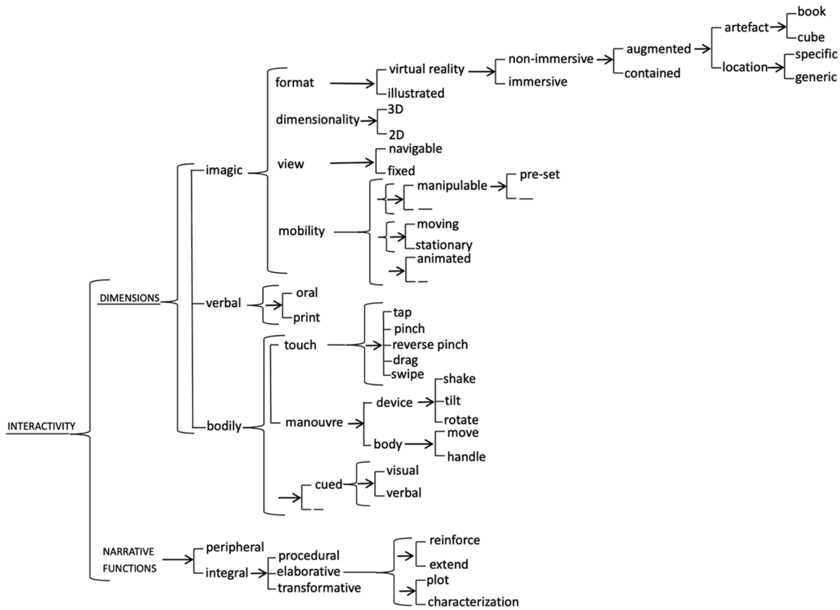


**FIGURE 10.12** Mapping interactivity in digital interactive literature

story. To illustrate this, we return to the *Sherlock Moviebook* interactivity instance of Holmes tapping on the pavement outside Wilson's shop (Figure 10.11) and indicate each of the options taken up in the representation of this incident in Figure 10.13. In this NVR story, the 3D images are central to the forms of interactivity, but in contrast to most other 3D depictions in the story, in this incident, the user's view is fixed and no amount of swiping or tilting will enable any other view. This constraint is strategic in focussing the interactivity on engaging the user in the elaboration of the plot. Swiping above Holmes's hands has no effect but swiping behind and in front of him below his hands activates his cane tapping on the pavement. If the user does not activate the tapping, the visual cue appears as shown in Figure 10.11. Only through the interactivity is this clue to the mystery accessible to the user. This shows the potential of interactivity design as integral to the interpretive possibilities of the story.

A key issue in the ongoing innovation in DIL is *integral* interactivity that is *transformative* of the story – the extent to which user input determines the nature of the story (Weedon et al., 2014). In the AR story *Sherwood Rise* (http://davemiller.org/2019/12/12/sherwood-rise/), we noted earlier that the manner and extent to which the user's actions/choices in the AR sections respond to the efforts of the character Robin and the 'Merry Men' to ameliorate the conditions of the poor influences the way the story progresses. The user's actions/choices are recorded in a database that calculates a score and this determines which of three versions of the story newspaper the user receives each day (Weedon et al., 2014, p. 118).

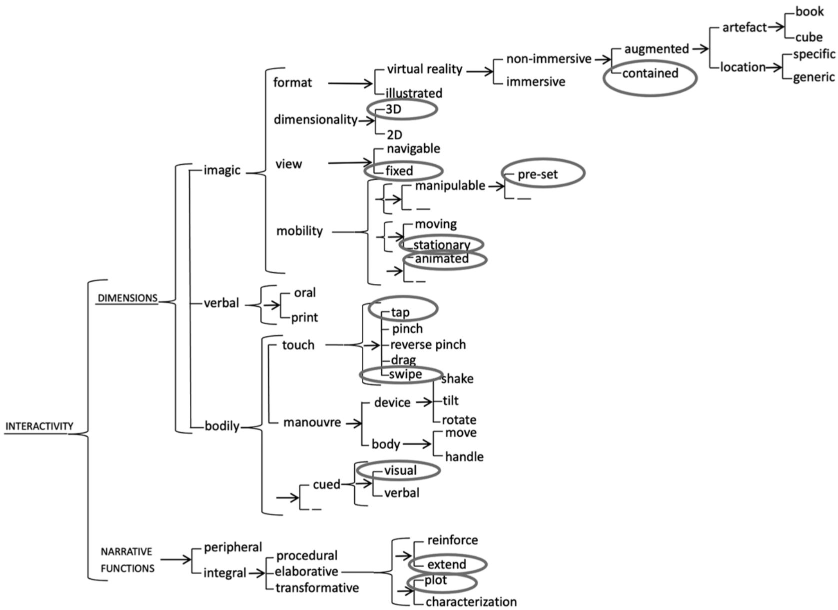


**FIGURE 10.13** Dimensions of interactivity and narrative functions

In such stories the scope of possibilities for user influence on the story outcome is finite, but a seminal and probably the most open-ended example is the user participatory AR drama *Façade* (Mateas & Stern, 2003).

In *Façade*, the user assumes the identity of a friend invited to the apartment of a young couple, Grace and Trip, who are experiencing marital difficulties. The user necessarily becomes dialogically embroiled in the antagonistic exchanges. There are now several versions of this drama: a desktop version with keyboard and mouse input, and an alternative desktop version with voice input, as well as an IVR version (Dow et al., 2007). Any conversational initiatives of Grace or Trip towards the user can be responded to in any way the user wishes, and to whatever the user says, Grace or Trip will make a coherent response, so that extended conversations can occur. The nature of the conversation determines the outcome of the overall exchange and influences the outcome concerning the relationship between Grace and Trip. The user, Grace, and Trip can continuously move anywhere, use objects, speak, and gesture at any time. Users can experience the drama several times to explore how their contributions to the conversational exchanges might be varied to achieve different outcomes. The DIL available to date does not include user transformative contributions that are as open-ended as this. However, *Façade* indicates the trajectory of this kind of development, and along with the innovative transformative options in *Saints of Paradox* (Tavares, 2019) anticipates new forms of transformative interactivity in future DIL.

The transformative aspect of most currently available DIL occurs as 'choose your own adventure' interpolations of on-screen text offering two or more choices to advance the story. Whether the imagic context is *illustrated* as in *The Thief of Wishes* (Markowska, 2017) or *augmented* reality as in *Silent Streets: Mockingbird* (Cobbett, 2018), the story pathway choices are shown verbally and selected by touch. However, this form of transformative interactivity occurs mostly in text only (or text with background images) in contemporary stories such as *The Hero of Kendrickstone* (Wang, 2015), *The Sixth Grade Detective* (Hughes, 2016), and *Running Away* (Ardeshir, 2019) and in adaptations of classic literature such as Mary Shelley's (2003/1831) *Frankenstein* re-versioned as DIL by Dave Morris (2012). The transformative multiple pathway/hypertext options in the Morris (2012) re-versioning have been hailed as demonstrating innovative and sophisticated new narrative techniques consistent with the complex themes of the original paper media version (Mills, 2018).

## Cultural challenges: interfacing digital interactivity and literary engagement

Our analysis has highlighted the multiple forms of interactivity in the many different formats of digital narratives that are now readily accessible online. While DIL is proliferating, what is at issue is the kind of engagement with literature that is afforded. There remains a chasm separating the integral role of interactivity in the innovative artifice of story-world creation and cueing of interpretive audience responses in the relatively small number of experimental literary narratives such as *Sherwood Rise, Saints of Paradise, The Cartographer's Confession*, and *Façade*, and the very large number of adaptations of classic literature as well as contemporary digital interactive stories for children and youth where interactivity is simply *procedural* or *peripheral* to the thematic concerns of the story, such as in *Toy Story* (Kent, 2019) and *Alice for the iPad* (Carroll, 2016).

In many digital stories and adaptations of literature for child and youth audiences, where the interactivity is actually *integral* to the narrative experience, it is a combination of the *procedural* and *elaborative* interactivity that is largely confined to the *reinforce* function, which rehearses what has already been conveyed by the images and/or the language (Figure 10.10), as we discussed in relation to *The Cloud Factory* (Stokes, 2016) and *The Marvellous Machines* (Grimm & Fortuna, 2016). Some stories, such as *Silent Streets: Mockingbird* (Cobbett, 2018) and classic story adaptations such as *Little Red – The Inventor* (Bora, 2018), are more oriented to the *extend* function – where interactivity augments elements of the plot or aspects of characterisation, both of which we have illustrated in our analysis of the *Sherlock Moviebook* (Doyle, 2014) segment. Core among the challenges for further enhancing DIL as culturally valued activity then, is synthesising multimodal literary authorship and the affordances of new digital technologies so that digital interactivity increasingly serves key roles in creating the interpretive possibilities of literary narratives.

## Implications for curriculum and pedagogy

DIL is essential in school curricula that are oriented to the global trajectory of digital futures in multimedia communication and creative expression of contemporary and traditional stories. The iterative re-telling of some of the most enduring, entertaining and culturally and personally significant works of classic literature for adults and for children in concert with ever-changing new technologies would be reason enough for the embracing of DIL in futures-oriented curricula. Such re-tellings, leveraging the affordances of new technologies, offer innovative, engaging and often challenging re-interpretations of the original and subsequent versions of these narratives, as well as emerging innovative digital narrative forms, all contributing to the ongoing vibrancy of literary experience. The societal significance of this curricular attention is further supported by the increasing uptake of digital interactive fiction as evidenced by the projected global growth in the interactive children's book market of USD755.13 million during 2020–2024 (https://www.businesswire.com/news/home/20201013006054/en/).

Curriculum approaches need to foster a discerning appreciation of interactivity, which can function in a variety of ways from peripheral amusement to integral roles in reinforcing and extending aspects of the narrative. The framework we have proposed could guide curriculum recommendations for DIL, and also inform the design of classroom learning experiences that focus on the meaning-making role of interactivity. Students could be asked to examine a selection of instances of interactivity and determine what difference it would make if any of these interactivity experiences were deleted. This might also take the form of asking to what extent and how interactivity revealed the kind of person a particular character was – and how that interpretation of the character would be different without the interactivity. Students could be asked to indicate where other kinds of interactivity might have been included to illuminate aspects of the story, such as a zoom in to show the reaction on a character's face to certain events, or a zoom out to reveal a detail of the setting that influenced a particular action of the character. Further work might probe how the combination of dimensions of interactivity functioned to influence the story (as in our discussion of the *Sherlock Moviebook* excerpt) and lead to student suggestions for efficacious alternative combinations.

## Recommendations for research

Transdisciplinary research across fields of digital technology, narratology, semiotics, and literature continues to explore further possibilities for audience participation in DIL, especially in relation to interactivity that is transformative of the story development and outcome. While there is also a burgeoning field of research exploring a critical poetics of electronic literature (Heckman &

O'Sullivan, 2018; Mills, 2018; O'Sullivan, 2019), further research is needed on a pedagogically accessible critical poetics of DIL as a basis for developing learning experiences that promote engaged, discerning, reflective, and creative responses among students. As an initial move, research is needed to build a corpus of studies explicating the nature of interactivity and its narrative functions in a range of digital literature for audiences from early childhood to youth, to inform educators' selection of stories and their design of learning experiences.

A transdisciplinary approach to this research incorporating researchers in literature for children and youth, multimodal semiotics, digital technology, and literature and literacy education can provide complementary perspectives to the exploratory framework outlined here mapping the core dimensions of interactivity and their intersection with narrative function. Immediate implementation could provide more detailed and comprehensive explication of literary oriented interactivity exemplified in some of the digital literature we have discussed. While we have briefly addressed IVR stories, much more investigation is needed into the nature and role of the bodily and sensory literacies entailed in different forms of interactivity in these stories and their role in the story experiencers' interpretive responses. This kind of explication of the distinctive narrative techniques of DIL drawing on the affordances of new technologies will facilitate delineation of emerging digital literacy and literary competencies that will support socially responsible digital literacy pedagogy into the future.

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# 11

# CONCLUSION: MULTIMATERIAL LITERACIES FOR DIGITAL FUTURES

This concluding chapter provides a forward-focused perspective of literacy, technology, media, and visual communication curriculum in the context of anticipated changes in an AI and automation era, and the increasing sophistication of smart technologies. It discusses potential ways to prepare instructional leaders, teachers, and students for the uncertainties of the future in the context of multimaterial literacies – literacy practices that are not only characterised by multiple modes, but also by radically different possibilities for the material production of texts. It points to a framework for reconceptualising and evaluating technologies and identifying new knowledge and skills that students need for success to navigate digital worlds. New skills will be needed to thrive in flexible, next-generation social practices in an area of artificial intelligence-driven media and learning that engages the body and mind differently than compared to the past. Pedagogical recommendations are provided for incorporating new forms of embodied cognitive engagement with multimaterial texts and neoteric ways of reading and thinking to engage students in materially diverse ways. The heterogeneity of multimaterial textual forms in the context of digital media development presents new challenges, opportunities, and directions for literacy curriculum and research transformation.

Among many changes, it is certain that the future of literacy practices will continue to shape and be shaped by technological shifts, such as artificial intelligence (AI), that have transformed society, and which are impacting virtually all industries this century (Holmes et al., 2019). For example, a decade ago we did not have the same opportunities as we have today to use virtual, augmented, and extended reality technologies to teach about narratives, or to represent ideas virtually in three-dimensional (3D) simulations. Some of these developments, particularly augmented reality (AR) technologies, have been buoyed by the

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widespread accessibility of mobile phones and the social web (see Chapter 7). Extended reality technologies, also called XR, are those that extend from virtual reality and augmented reality – innovations that have yet to materialise in what is expected to be a rapidly developing area this decade, given that these platforms have not reached their peak in development (Mills, 2022).

A useful way to think about new digital practices for literacy is the extent to which new practices are simply a modest substitute for a conventional literacy practice, such as reading a digital versus analogue clock display, or whether literacy practices are genuinely and radically transformed. The SAMR model, originally designed for assessing computer-based technological tools by Puentedura (2003), could be considered as a framework to evaluate new literacy practices in digital contexts of use. For example, some technologies, like Dictionary.com, function as an almost direct substitute for the print version of dictionary use, since the practice of consulting this app from one's phone is similar to carrying a conventional pocket dictionary (see Figure 11.1).

Then there are technologies that augment print literacy practice, but with functional improvements, such as e-books that are lightweight, interactive, searchable, shareable, and have compact storage. Next, there is modification – tech that allows for significant literacy task redesign – such as mixed reality (MR) 3D models, representing concepts in a virtual reality environment, or designing and programming a dancing robot. Finally, we can look to redefinition – where digital technology allows for the creation of new literacy practices that were previously inconceivable. These categories – substitution, augmentation, modification, and redefinition – are not inflexible categories, but can be conceived as a continuum of practices that have greater or lesser resemblance to conventional forms of literacy.

Educators need to understand how changes to information-based societies, and the expansion of technological developments for communication, have given rise to new media skill sets that will be essential for the productivity of nations. It is predicted that in the next two decades, half of the current occupations in countries of the OECD will experience dramatic digital disruption, while new occupations that are currently unimagined will emerge (PwC, 2015).

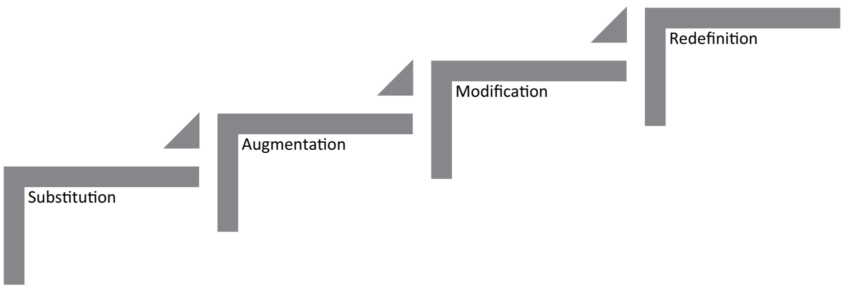


**FIGURE 11.1** SAMR model
Adapted from Puentedura (2003)

These changes will involve new digital media practices that require distinct forms of embodied cognition with new material and technological networks. These will involve multimodal and multimaterial texts in social contexts that differ in fundamental ways to the past. While literacy, media, and technology educators have demonstrated great agility in response to digital change in the past, the rate of change is speeding up, and competition in global economies is heightened for schools, post-compulsory education, and workforce readiness.

The undeniable influence of digital and global communication environments has been recognised since the end of the last century (New London Group, 2000), which is important in rethinking literacy practices in schools and society. Most online spaces require students' proficiency with multimodal literacy practices, where students use new platforms to combine words, images, sound, body movement, and spatial configurations in new ways to shift meanings across modes and media (Mills & Brown, 2021). Creativity remains a key facet of future skill sets, which can be exemplified, for example, in computer-aided design or CAD (Harris & de Bruin, 2018). 3D printing involves multimodal making of tangible signs that count as a form of hybrid literacy. For example, a 3D-printed festive tree ornament is a material sign that communicates or stands for cultural meanings that can potentially be understood by others. Creative multimodal designing associated with additive manufacturing and rapid prototyping technologies is now taught in education contexts, including 3D printing, screen printing, and laser cutting (Ford & Minshall, 2019).

## Materiality of representation: emerging directions

Significantly, the materiality of textual practices has undergone dramatic shifts in recent decades, not just the visual displays. As we have argued throughout this volume, the materiality of the medium matters to literacy practices, whether of writing with a pen on paper, typing on a computer keyboard, swiping a touchscreen, or painting in the air using VR game controllers. Recently, social semiotic theorists have acknowledged in their third edition of Reading Images: The Grammar of Visual Design (Kress & van Leeuwen, 2021), that their visual image analysis across many of the chapters of their volume has tended to "abstract away" the diverse material aspects of the images, whether of paintings, photographs, web pages, drawings, collages, menus, billboards, and so on (p. 224). In so doing, they suggest that they followed a Renaissance tradition associated with artistic practices of da Vinci and Michelangelo, in which the material aspects of a painting were considered a secondary concern, left to the assistant, while the artists' conception of a depicted artwork was most essential. However, in their subsequent chapters and editions, they have given special attention to the material dimensions of visual production, such as the embodied performances of singers, dancers, and actors, which they see as equally important to the design of the music score or a play script in meaning making.

Today, the materiality of texts is changing as schools introduce teaching and learning using additive manufacturing and 3D printing applications that involve modelling data associated with fabrication industries. Rapid prototyping technologies, 3D hubs, and fablabs have been used in schools to inspire creativity (Ford & Minshall, 2019; Kostakis et al., 2015), often leading to learning outcomes and diverse material forms of three-dimensional, multimodal designs that are to be interpreted as signs imbued with meaning. There is a need for new multimodal literacy curriculum and teaching resources that simplify the incorporation of low-cost additive manufacturing and 3D printing to support students' knowledge in these advancing areas of technology change, to induct students into the tangible media that will figure in life and work in the new digital age (Trust & Maloy, 2017).

While material shifts from reading and writing mostly on paper to mostly on screen began decades ago, digital communication environments continue to change in hybrid ways. For example, the materiality of texts popularised in the late 1990s and early 2000s were often displayed using a desktop computer – instant messaging, chat rooms, email, internet searches, web pages, and PC-based video games. By the 2010s, the widespread accessibility of mobile phones and tablet technologies, including handheld touchscreens, provided further impetus for the changing materiality of textual practices that could occur anywhere, anytime, and which involved different forms of haptic engagement and social contexts (e.g. texts displayed on a phone used on a public bus). At the same time, Web 2.0 became important as everyday users could easily share moving image texts via social media and video sharing sites, while multiplayer games provided real-time interaction in connected game spaces.

More recently, the materiality of virtual reality headsets has made three-dimensional narrative representation accessible, such as watching 360-degree films, virtually spray-painting murals in simulated urban spaces, and playing virtual reality games (see Figure 11.2).

Literacy educators should be aware that in the next ten years, virtual, augmented, and mixed reality technologies are predicted to reach a peak growth stage of affordability and accessibility, offering new potential for learning and 3D meaning making in narrative and non-narrative textual formats. Virtual reality technologies provide a digitally simulated environment, with the user wearing a head-mounted display for full immersion. As discussed in Chapter 7, MR merges virtual and real in interactive ways (e.g. Microsoft Hololens; Mills, 2022), while AR overlays virtual content in real locations, typically viewed through an internet browser, and often supported by smartphones (see Figure 11.3).

Literacy teachers in the future will gain proficiency with these technologies that are able to give simulated experiences of places in the real world, past or present, that can enliven historical fiction, and which are not possible to explore in real life (see Chapter 4). These technologies are particularly useful for exploring or creating three-dimensional representations, and for supporting abstract

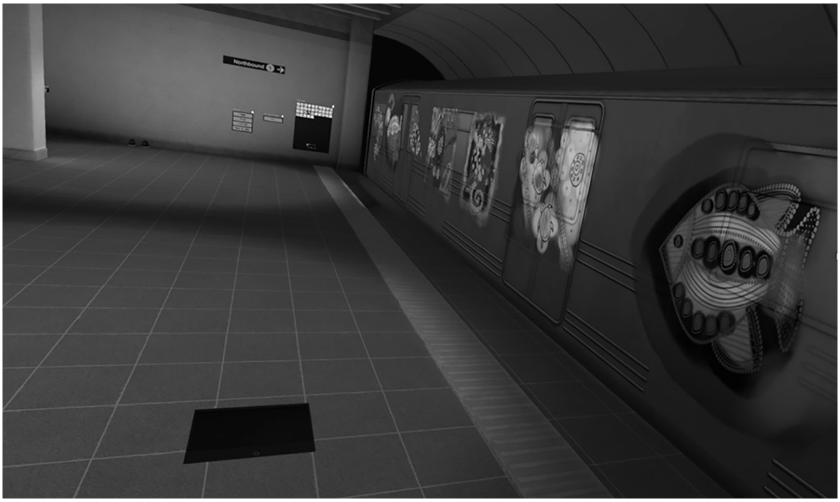


**FIGURE 11.2** VR community subway mural painted by 11-year-olds in the game *Vive Spray 2*

**FIGURE 11.3** AR dinosaur photographed by Year 6 student with Google browser and tablet

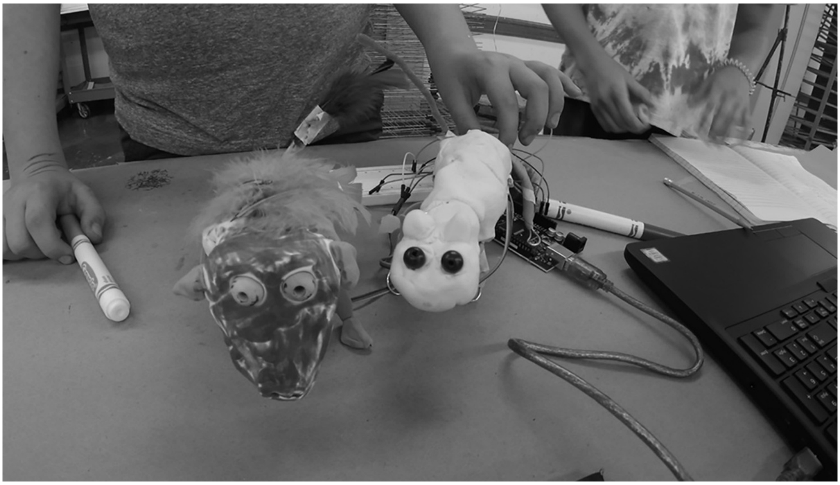

**FIGURE 11.4** Mixed media e-sculpture using Arduino kits at Toledo Museum of Art

thinking and communicating concepts in experiential ways (Fernandez, 2017). An exponential rise in the use of these extended reality technologies is anticipated to influence all levels of education (Mills & Brown, 2021).

Material representational forms that were traditionally associated with science, technology, engineering, and mathematics (STEM), will have increasing intersection with digital communication, such as robotics (Chalmers, 2018), e-textile making, electronic sculpturing (e-sculptures), and computer coding (Popat & Starkey, 2019; See Figure 11.4).

For example, students' ability to use programming languages is another form of multimodal writing and textual design, both in terms of the coding language and the meaning imbued in the final project. Traditional boundaries between subjects, such as mathematics, English, and technology, may persist; however, increasingly students will need skills that are transferable between these conventional disciplinary patterns as they encounter real-world texts in their everyday lives. Teachers need to embrace interdisciplinary approaches to pedagogy that support learners in thinking that involves boundary crossing, core concepts, inter-domain knowledge, and conceptual frameworks that can be readily applied to unfamiliar problems and texts (Harris & de Bruin, 2018; Kim, 2016b).

## Mind and materiality of reading: emerging directions

The materiality of reading is also changing as students read words from environmental print, mobile (cell) phones, e-books, tablets, handheld computer games, smartwatches, and other technologies that play a role in text comprehension. As young people engage in their digital futures there will be exciting opportunities for reading, comprehension, and meaning making that may well rearrange the structures of the mind and how students think (Wolf, 2018). Cognitive functions, such as literacy, are based on networks of connections that become circuits for learning. These miraculous circuits are orchestrated in response to experiences as they interplay with neurons to reorganise structure, functions, or connections to modify the strength and efficiency of synaptic transmission (Markram et al., 2011; Nagel, 2014). This plasticity is ongoing in response to repeated activities and learning. While initial neural circuits related to decoding letters and learning to read print appear basic, a key question might be: "To what extent does the future hold for such circuitry in readers engaged in multisensory stimulation through vision, olfactory cues, sensations of haptics related to touch, and aesthetics as they increasingly shift to screens?"

As young children are encultured into their digital futures at an exceedingly early age, toddlers may well grow up with a smartphone as a pacifier (Chang et al., 2018). The materiality of experience and the role of the mind in cognition changes in relation to such experiences (see Chapter 2). Plasticity of processing related to the use of touchscreen phones may well be associated with cortical reorganisation due to increased tactile stimulation (Gindrat et al., 2015). Common, daily activity such as screen or smartphone use may change the brain due to its plasticity. We already know that the mind adapts when a particular part of the body is used frequently (Markram et al., 2011). For instance, people who use touchscreens have greater activity in brain areas associated with the fingertips (Gindrat et al., 2015).

With increasing amounts of time spent reading digitally, understanding how screen-based reading behaviours may be changing our minds and nuances in experiences afforded by decoding texts across multiple devices is imperative. Future directions in literacy point to increasing challenges in making meaning of texts in metamorphosed digital spaces, but also potential changes to our cognitive capacities and educational needs. Reading behaviours such as 'stacking' multiple devices for conducting unrelated tasks, and 'meshing' as readers simultaneously communicate content being viewed, along with fragmented engagement in digital materials epitomised by the use of the acronym TL;DR (too long; didn't read) are changing how readers comprehend while presenting new challenges for contemporary curriculum and pedagogy.

As the tendency for skimming increases, young people may seek out sources that seem the simplest, most familiar, and least cognitively challenging (Wolf, 2018). It may be that this strategy leads to accepting 'fake news' and false assertions without any examination or analytical processing. Technological advances will continue to increase exposure to misinformation that circulates rapidly on mobile devices (Herrero-Diz et al., 2020). Rather than decoding to evaluate information online, young people are more likely to believe and share content if it connects with their interests, regardless of its truthfulness, and if they are attracted to the appearance of newsworthy information, regardless of the nature of the content. Moved by the power of attraction of conspicuous, emotional, or outrageous language to camouflage hoaxes, rumours, or false assumptions that are offered under the guise of reliable information, young people can be seduced by provocative or suggestive content, contributing to the distribution, and sometimes virality, of false, erroneous, or unverified information (Middaugh, 2019).

Billions of dollars invested in AI algorithms by companies in the future may also increase the spread of biased information to promote sites, and to adapt content to personal, political, and consumer dispositions (Epstein & Robertson, 2015). These algorithms are no longer static but are ever-evolving. Education is vital in teaching students how to decode, and effectively discern the truth when they seek information online (Goldberg, 2017). Future-focused systems and educational communities will need to be innovative in how they respond to shifts in communication and prepare students for their literate futures. Such an agenda will necessitate the need for the transformation of teaching workforce skill sets as they prepare students. Sophisticated reading comprehension that involves evaluation, dialogic discussion, and evidence-informed debates, are all practices that will need to be fostered in critically literate individuals.

The sophistication of reading narratives, procedural texts, and endless amounts of conflicting materials on screens will evolve in the future, and so too will the demands in translating information into knowledge (see Chapter 3). Internet-based and hypertextual reading involves strategies that have no counterpart in traditional offline reading, and which require navigating reading paths in a shifting problem space (Leu et al., 2015). While everyday activities on devices, such as reading on screens, may be changing the nature of the mind, the rise of digital distraction does not necessarily translate to increased abilities to decode for meaning making. Plasticity is then a strength and a potential challenge, as digital modes requiring processing of volumes of information very quickly will diminish from more in-depth processing (Wolf, 2018). It is these slower processes related to deep learning that will become more cognitively challenging for students in the future. The visual dynamics on offer, along with exciting hotspots, and hyperlinks to games, videos, targeted marketing, and consumable items, demands support for readers as they learn to navigate the materiality of the reading experience.

If new circuits in the brain are to be created to facilitate sophisticated decoding in digital spaces, the role of education is more important than ever. As the ubiquity of technology continues to transcend information-based societies and expand modes of communication, what constitutes reading in the future may well need to be redefined. These shifts to fragmented engagement in digital spaces call for rethinking how to support slower processes that contribute to very important critical, analytical, and empathetic cognition. Epistemic engagement is undeniable in the context of the rapid circulation of multimodal texts, as higher-order thinking skills are critical for evaluating, interpreting, and making inferences for future-focused critical literacy. For instance, while the internet can potentially foster epistemic thinking as readers choose what to read, when to read, and navigate their personal pathways to explore and evaluate intertextual sources in a non-linear space, such engagement can also result in limited thinking processing (see Chapter 3).

Online reading needs to be supported by other cognitive skills such as cybersafe skills and relatedly, internet cognition: that is, accurate conceptions of the internet (Edwards et al., 2018). Children are increasingly accessing the internet at younger ages; a social phenomenon made more ubiquitous through mobile devices and touchscreen technologies. Consequently, there is a heightened need for cybersafety skills for the young. Likewise, researchers have identified that children need more advanced conceptions about the internet itself, also called internet cognition, which forms the basis for the development of cybersafe concepts in early childhood (Edwards et al., 2018). At the same time, research has shown that the overarching focus on risk and safety in schools has sometimes reduced opportunities for media learning, with the need for more supportive facilitation of online practice within schools. Schools need to optimise learners' online access to information, while skilling young users to engage safely and critically with the internet (Harrison, 2018; Third & Collin, 2016).

## Digital gaming futures and literacy practices

Increasing demands on the literate mind in the future are not just limited to digital reading devices or World Wide Web internet spaces – digital gaming platforms also offer spaces that not only demand critical literacy, but also foster opportunities for developing epistemic thinking related to decoding, evaluating, and making meaning (see Chapter 4). While VR and AI technologies are shaping the future of digital games, cloud gaming services offering unlimited opportunities for anyone with Wi-Fi, will also change lives. The future will see mobile, PC, and consoles merging in gaming experiences. Internet streaming will be the unifying technology that allows access to all the content people want on any screen over the next ten years. Once again, the internet has the potential to change the lives and digital literate practices, as stable connections will provide avenues for cloud streaming to a multitude of devices. 5G, ultra-wide band fibre, and satellite services will enable technologies that quickly make this a reality.

The role of gaming in learning in the future is now beyond debate (see Chapter 4). Unravelling the effects of playing video games on brain and cognition is continuing to be identified, such as understanding how video games can be used as tools to shape critical thinking and improve cognitive performance for education-related applications (Dale et al., 2020). The challenge, however, for literacy advocates of the future, is to see gaming through the eyes of avid players. Perhaps spending time engaging in popular games such as *Minecraft* or *Fortnite* may foster an appreciation of exciting experiences in high-fidelity immersive spaces that capture players across generations. Appreciation for the affordances of evolving VR extensions that bring to life wrap-around display screens, augmented sensorial experiences, and advanced AI technologies that are powered to respond to player feedback, may also be critical. Evolving technologies in gaming will require educators to make haste and keep up. Player cognitive flexibility and decision making will be at the core of innovative technology-related transformations, as machine learning, AI, and natural language interfaces accelerate game design. Imagine wearables that enable better AR game play experiences that take over from a mouse and keyboard as the primary input device so you can play paintball in a live arena. What about engaging in a virtual game world where you can have a conversation with a character that knows you and your backstory?

The evolving nature of gaming will undoubtedly transform opportunities for literacy engagement and the myriad of learning opportunities. As young people engage in increasingly complex and demanding cognitive, linguistic, and socio-cultural practices generated by game play, there are important implications for literacy teachers (Beavis et al., 2015). Supporting players to develop the skills to decode, evaluate, and make decisions in collective spaces of self-generated ideas afforded by gaming needs to be considered in the reconceptualisation of knowledge goals that go beyond the technological or pedagogical to envisage how video games can facilitate critical literacies. Re-calibrating literacy involves an epistemological shift that moves beyond acquisition of facts that are right or wrong, towards opportunities for self-generated ideas in digital spaces as people learn to make meaning in immersive virtual worlds. In globalised and digitally connected gaming and communication environments, such as when using multiplayer games, VR chat, and paratextual gaming forums (e.g. Reddit), students need advanced digital citizenship skills (Rapanta et al., 2021; Third & Collin, 2016). They also require transcultural skills for online gaming interactions with those from cultural perspectives that are different to their own (Kim, 2016a), with an awareness of different audiences in the online presentation of self.

## Influence of AI and machine learning on textual practices: algorithm-driven media

In algorithm-driven media environments, students will also need critical understanding, backed with technical knowledge, of how algorithm-based media subtly influences their online browsing and use of social media feeds, which is driven by artificial intelligence. AI and machine learning are predicted to be key influences on communication practices in the next five decades (Valtonen et al., 2019), with students requiring basic understandings of how these technologies function to both automate simple tasks for efficiency, while discerning how such technologies serve the interests of those who design artificial intelligence and machine learning for their own commercial gain (see Chapter 3).

Literacy educators can benefit from understanding the mechanisms of algorithm-based media, surveillance technologies, deep learning, social media attention engineering, algorithm-based content curation, and predictive analytics to be able to guide students in agentive uses of digital and SMART devices – Self-Monitoring, Analysis, and Reporting Technology (Holmes et al., 2018). Examples of smart technologies include devices that allow you to secure a home, order food, adjust the lighting of a room, switch off devices when not in use, or even control the brewing time for coffee making via smartphone and Wi-Fi. Smart technologies need to be used critically, because the use of autonomous and interconnected devices is associated with new security risks and vulnerabilities, with the need for new habits to protect data, property, and privacy – skill sets associated with critical datafication literacy (Pangrazio & Selwyn, 2021).

To illustrate some of the areas of transformation in literacy practised with digital media, consider the critical skills required by learners to understand the complexities of algorithm-based media with which we engage every day. In digital media environments that have rapidly changed, algorithms and automation are now involved with a host of processes inside the 'black box' from tracking users' actions and data mining, to profiling, behavioural engineering, targeted advertisements based on predictive analytics, filtering information, delivery, and content generation (Kramer et al., 2014). Media is used to influence political judgements and emotions, and to spread misinformation, while AI technologies of the second machine age include image and speech recognition, machine translation, and radical technologies that are based on neural networks and machine-learning algorithms – not on traditional coding and programming by computer scientists (Brynjolfsson & McAfee, 2014; Valtonen et al., 2019).

Algorithms are used to filter media content, feeds, and online advertising, suppressing, or drawing attention to content that is consistent with the user's preferences, online affiliations, and historical patterns of use (Kramer et al., 2014). These algorithms are well-hidden secrets of large technology companies and social media sites, and with infinite data input, it is impossible to trace how automated results are produced. Attention and behavioural engineering are used to bring users back to websites or apps, engage for longer, or make purchases, while research has demonstrated how social media news feeds can personalise content and manipulate emotions without the users' awareness (Tufekci, 2015).

Students today need to be taught how predictive analytics are used to build rich profiles of users, who are then targeted with content and advertising. Educators can help students to see how seemingly innocuous data, such as social media feeds, search results, and YouTube recommendations, can be manipulated by predictive analytics based on past online activities creating what have been called "echo chambers" – where users' personal views are amplified and reverberated in endless cycles to reinforce rather than to challenge beliefs, irrespective of accuracy (Valtonen et al., 2019). These echo chambers have been found to create political and attitudinal polarisation, influencing public perception for a long time even after fabrications are proven false and reinforcing homogenous online networks (Lazer et al., 2018).

A key implication for literacy and digital media practices in an age of machine learning is that students and teachers now need knowledge and tools to critique these mechanisms and consequences of algorithm-driven media. This includes understanding the ethical consequences of these everyday AI-based applications including the decreased privacy associated with their use. Educational systems are not yet equipped to address these understandings in interdisciplinary curricula, teacher education, and professional development, nor have many governments and organisations developed advanced educational policies to guide informed and ethical purchasing, use, and governance of AI in K-12 schooling and beyond.

## The future of text semiotics in multimaterial textual environments

The ongoing emergence of new forms of digital communication media requires a recognition that language (involving words) is one of many modes to represent meaning. Likewise, text semiotics must accommodate the contemporary and future multimaterial forms of literate practice. Two fundamental and interrelated semiotic concepts are central to this realisation. The first is the concept of 'affordances' – the distinct potentials and limitations of the various modes of representing meaning (Kress, 2005, p. 339). The second related concept is 'transduction', which involves relating the representation of a phenomenon in one mode, such as an image, to its representation in another mode, such as speech or writing (Kress, 2010, p. 125).

The 'affordances' of different modes derive from the materiality of their resources for representation. Kress (2005) explains this by focussing on the functional specialisation for meaning representation of speech and writing on the one hand, and images on the other hand. He describes the possibilities for organising meaning in speech and writing as based on the logic of time, whereas for images, this is based on the logic of space. In speech, one sound necessarily comes after another, and in spoken and written language, one word comes after another, one clause after another, so time and sequence are the inherent principles for making meaning. However, in images, all meaning-making elements are simultaneously present, and it is their spatial arrangement, relative size, colour, and other features, that are the basis for making various kinds of meanings.

Accordingly, the resources of language are most apposite to the representation of sequential relations and categorical distinctions, while the resources of images are most apposite to the representation of spatial relations, and those of degree, quantity, proportionality, and other topological relations (Lemke, 1998, p. 87). These specialised affordances of language and image have received a good deal of attention in semiotics and literacy research (Bateman, 2014). With the broadening of literacy to encompass multiple modes of meaning making, a key agenda is to similarly theorise the underlying logics and representational affordances of additional modes and their deployment in new media contexts such as various forms of virtual reality.

Transduction relates the representation of a phenomenon in one mode to its representation in another mode, such as from words to images. This invariably involves changes in meaning, which may occur as greater commitment to aspects of meaning and diminished commitment to other aspects (Kress, 2010; Painter & Martin, 2012). Because the semiotic affordances of the representational resources of the various modes differ from one mode to another, the representation of a phenomenon in any mode is inevitably partial (Bezemer & Kress, 2016; Kress, 2010). Hence, transduction from one mode to another can never mediate a full understanding of phenomena, which may only be approximated by a multimodal ensemble of representations leveraging the affordances of different semiotic systems to optimise understanding (Volkwyn et al., 2019).

The productive role of transduction in multimodal learning experiences across disciplines, from science to the arts and communication studies, is being actively investigated by educational researchers (Mills & Brown, 2021; Svensson et al., 2020). The trajectory of this research may be enhanced through transdisciplinary approaches drawing on explicit articulation of the semiotic affordances of multiple modes of meaning making to explicate the strategic convergence and complementarity of various modes in communicating different facets of meaning in what is being multimodally represented. Semiotic studies continue to extend accounts of the representational affordances of an increasing range of modes, including sound and music (van Leeuwen, 1999), three-dimensional static representations, such as sculpture and architecture (O'Toole, 1994, 2004), movement (Mills & Brown, 2021), gesture, and other forms of paralanguage (Martin & Zappavigna, 2019). However, new media not only integrate familiar modes of meaning making, but also create new modes, the semiotic affordances of which are yet to be established.

While significant advances have been made in systemic functional semiotic research into the meaning-making resources of static images (Kress & van Leeuwen, 2021, film (Bateman & Schmidt, 2012), and animation (He, 2020; He & van Leeuwen, 2019), and in static 3D representations (O'Toole, 1994), the affordances of static and moving image in virtual reality media need further exploration. In immersive virtual reality contexts, for example, point of view options of the viewer as context participant and as context observer appear to be conflated. Hence, point of view in immersive virtual reality can be variable in accordance with changes in the gaze of the participant. This facilitates participant access to multiple points of view in relation to the represented phenomena. At the same time, the participant role may obviate the synoptic encompassing viewpoint of an external observer of the phenomena. Further exploration of many other such semiotic dimensions of new and emerging multimodal digital media will increase understanding and strategic negotiation of the multimodal and intermodal meaning making of the continually evolving literacy for digital futures.

## Implications for future curriculum and pedagogy

Given these anticipated changes to the materiality of the medium for reading, writing, and the multimodal grammars of new texts, educators need to rethink the shape of literacy pedagogy and curriculum. Some of the key implications for next-generation literacy and media education are considered here to account for hybrid reading, representation, and textual grammars, amidst the intensification and reconfiguration of capitalism and globalisation, within an AI and automation era.

Reading in digital spaces is an important part of daily life for many students in classrooms across the globe as they engage in learning across disciplines. Increasing demands to facilitate remote learning, hybrid models of learning, and online academic assessment raises the significance of teaching skills to read, decode, and evaluate information in a range of digital spaces and should be a high priority for educators. Although we are still learning about the differences between digital reading and print-based reading, we know there are fundamental changes in the materiality of reading experiences and associated embodied cognition that demand specific skills to be taught in order to excel (Afflerbach & Cho, 2010; Leu & Maykel, 2016). Importantly, specific skills to focus attention, engage in deep reading, and make meaning needs to be scaffolded by adults with expertise. This is particularly true if readers are to be supported with immersions in multimedia websites, e-books, digital e-readers like Kobo and Amazon Kindle, social media, or video games. As innovations in technology will likely increase access to exciting spaces for learning, educators will need to support readers to make meaning of the information with which they engage. It is this meaning making that is at considerable risk of being lost in curricula that do not engage with pedagogies to enable new and evolving literacy practices for comprehension.

Future-focused literacy and media education will need to consider a curriculum that supports advances in technology-enabled critical reading, with an understanding that technology does not necessarily translate into, or equal, learner achievement. Educators will need to evaluate the right technology to incorporate to enhance learning and stay relevant. Rapid changes necessitate targeted professional development to facilitate innovative pedagogies. This is critical given that a major challenge for students is the diversity of accessible information that will in turn influence approaches to reading, thinking, and ultimately, critical literacy.

Understanding the plasticity of the mind and how new experiences may be changing how people think is critical, as is providing learning instruction that explicitly addresses fragmented engagement with reading on digital devices. Whatever the platform, deep reading, cognitive processes, and critical thinking associated with meaning making can be supported as teachers scaffold planning of reading pathways, choice of digital resources, focus of attention to the task, prioritising reading goals, mapping, and monitoring pathways, and supporting flexible critical thinking for evaluating information.

As digital communication media continue to evolve, so will the nature of the meaning making that is involved in engaging with multimodal and digital media texts. These changes in meaning-making processes result from additions to, and re-alignments among, the multiplicity of modes, such as sound, music, movement, gesture, image, and words. The distinctive materiality of their representational resources, such as the style of brush strokes, or the texture of an e-sculpture, contributes different facets of meaning associated with the phenomena. In interpreting and creating multimodal texts, communicators need to be alert to what meanings are and could be contributed by different modes. This means knowing how different modes make meanings – their meaning-making resources. This is what the New London Group (NLG) referred to as Available Designs – the 'grammars' of the various semiotic systems (New London Group, 2000).

Past logocentric perspectives on literacy focussed on spoken and written language alone, but they recognised three important co-occurring aspects of the relationship between language and learning: learning language, learning through language, and learning about language (Halliday, 2004). The latter aspect involves learning what the grammar and discourse features of language are, and how they are deployed to construct meaning. This is still a significant component of the language and literacy curriculum, but as digital multimodal literacy pervades the culture, the clear implication for future curriculum and pedagogy is the importance of learning what are the meaning-making resources of multiple modes (learning language), how to apply these modal meanings in learning (learning through language), and how meaning-making resources converge or complement each other to construct the overall meanings of the multimodal texts (learning about language).

It is this third function, learning 'about' multimodal literacy – developing explicit knowledge about Available Designs, including how the representational resources of different modes make meaning, that is crucial to students developing their critical interpretation and creative and strategic construction of multimodal and digital texts. Therefore, the NLG argued that students and teachers need a shared metalanguage that describes meaning in the various realms of the auditory, visual, spatial, olfactory, and multiple other modes, that are increasingly incorporated into digital multimodal texts. The development of this educationally accessible metalanguage initiated by the NLG is an ongoing enterprise that will assume greater significance in future curriculum development and pedagogic innovation.

Developing this kind of meta-semiotic competence beyond knowledge about language systems (Disessa, 2004), has primarily attended to the resources of static image representation, and to a lesser extent, the resources of moving images (Unsworth, 2001; Unsworth & Mills, 2020). But a key agenda for optimising multimodal and digital literacy development will be curricular and pedagogic attention to the grammars or Available Designs of multiple modes, as well as conceptualising these to account for the materiality of meaning-making resources distinctive to new media formats, such as virtual reality. Getting 'meta' will be a key element of curricular and pedagogic initiatives addressing literacy for digital futures.

## Concluding thoughts: mind, body, and text

Returning to the central premises of this volume, we have aimed to demonstrate the usefulness of bringing together three lenses on future-focused literacy studies: (i) the mind and materiality of reading, (ii) the body and the materiality of representation, and (iii) a social semiotic view of multimodal texts. In so doing, we have productively attended to some of the formerly under-theorised dimensions of literacies and digital media practices that have been seen in dichotomous or mutually exclusive ways, in anticipation of the significant areas of textual transformation in the emergence of Industry 4.0 and the AI and automation era.

For example, social semiotic approaches to multimodality have sometimes been critiqued for their emphasis on signifying resources and systems or modes over the particularities of the technologies or media – the surfaces and substances of production (e.g. paint, clay, canvas, computer screen, stylus, keyboard). Similarly, multimodal semiotics has been less concerned with the actions of the meaning makers (e.g. brush movements, finger taps, footsteps) than the representational system of modes (Kress & van Leeuwen, 2021).

On the other hand, theorists of embodiment and the materiality of writing and media are rarely concerned with systematising the features of representations or interested in mapping networks of semiotic choices or resources, since this has generally been seen as the purview of applied linguists and semioticians. Thus, the current volume – *Literacy for Digital Futures: Mind, Body, Text* – has sought to account in a novel way for inescapable modifications to both modes and media, where the materiality of the medium matters. It theorises literacy practices with technologies in terms of the dynamic relations between the text user and embodied action in reconfigured and globalised communication environments.

Increasingly recognised as a leading area of research in the future, embodied cognition points to the central role of sensorimotor experiences in the world as the basis for the development of language and communication skills (Gibbs, 2005). Extending a sensory or embodied approach to literacies and digital media practices (Mills, 2016), we have demonstrated throughout the book how reading and representation depend not on the mind and abstract thinking alone, but on proprioception and bodily engagement in textual practices and media with new material affordances. Rather than simply arguing that hands and bodies move in tangibly different ways with new media than in the past (a mere tap on a screen vs. pressure applied to a pencil), we have sought to engage more deeply with the implications for embodied cognition.

If moving one's hands or body in particular ways matters to how information is perceived and remembered, then changes to the materiality of new media will inevitably open up yet unknown effects on literate minds. Perhaps even more importantly, if abstract thought indeed makes use of sensorimotor actions that are then fully internalised and operate covertly as simulations of one's experiences in the physical world (see Wilson, 2002), then so-called 'lower' sensorimotor engagements with new digital media practices are certainly not arbitrary. Rather, embodied action with new media has profound implications for all literate activities, both directly in observable physical interaction with texts, and perhaps most powerfully, in the abstract and less visible dimensions of reading and writing that we have previously attributed to the mind.

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