CHAPTER 8 Digital Pedagogies for Primary School Science Education

GOALS

The goals for this chapter are to support you to:

- Describe categories of educational technologies that can be used to support primary school students to learn science
- Distinguish between techno-centric and pedagogical arguments for selecting digital resources and for rationalising the use of educational technologies for primary school science teaching and learning
- Appreciate the range of digital pedagogies and resources available to primary school teachers
- Describe and illustrate how social constructivist learning theory might inform selection and use of digital technologies in primary school science education

Australian Professional Standards for Teachers – Graduate level

- Standard 2: Know the content and how to teach it (Focus area 2.6)
- Standard 3: Plan for and implement effective teaching and learning (Focus area 3.4)

INTRODUCTION

New educational technologies have been regularly introduced and hailed as 'game changers' in schools. In the early 20th century, film and radio were introduced as resources in schools and now include mobile devices and associated applications (or *apps*), interactive white boards and other online facilities such as virtual field trips and collaborative writing platforms. Educational technologies have frequently been promoted as a panacea for student engagement but there has also been an alarming gap between claims about what using new technologies can achieve and clear evidence of enhanced teaching and learning. This chapter explores resources that primary school science teachers and children can use. It presents a theoretical framework that can inform the use of existing and emerging digital educational technologies, or what we refer to as *learning technologies*. Throughout this chapter, we refer to specific examples of technologies including apps and websites. It is important to note that these are current examples of high-quality resources and new ones are constantly in development. Key online resources are superscripted in the text and listed at the end of the chapter.

THE LEARNING TECHNOLOGIES LANDSCAPE

Learning technologies may include hardware such as laptops and game consoles, peripherals such as wearable devices and software such as educational games and simulations. A wide range of discipline-specific and generic educational software and apps can be used to support children's science learning. Science-specific applications include data collection apps, visualisations, animations and participatory simulations, which might actively immerse children in realistic scientist roles or support rich experiences of authentic, community-based science projects. For example, *nQuire* allows upper primary school science learners to join a scientific mission that might involve a science experiment or data gathering using a mobile device. The *Scistarter* website advertises a range of community science projects that may be of interest to children. Apps such as *iSpot*, *Frog Spotter* and the *Platypus Spot* focus on learning about the natural environment, enabling children to participate in ongoing, collaborative research and conservation projects. Other examples of science-specific applications include simulations, such as *Google Sky* or those available in the elementary section of the *PhET* site, that allow children to explore more time-consuming or difficult to set up science scenarios. Effective science-specific software programs and apps position children in relevant, stimulating science activities that enable collaborative participation in meaningful science inquiry projects.

Other types of educational software and apps are more general purpose and can be used in any curriculum area to support learning. For example, Bower and Torrington (2020) categorised free online learning technologies that can be used to support content creation, social connectivity and interactive learning. Their typology is shown in Figure 8.1 and consists of a range of web-based learning technologies.

Figure 8.1. Web-based learning technologies (From Bower & Torrington, 2020, p. 2. Used with permission.)

A good way to examine the wide learning technologies landscape is to consider *how* devices and specific apps might be used by teachers and learners, and for what educational purpose. In this way, teachers can go beyond shallow discussions centred on the technical attributes and aesthetics of new technologies, to critically consider how these digital tools might be used in ways that benefit children's learning. Revisiting the general-purpose case of online applications and the groupings of tools in Figure 8.1, collaborative mind-mapping tools ('image-based tools' cluster) could allow groups of children to engage in concept-mapping, for example, to elicit prior knowledge and provide feedback to teachers. Some tools in Figure 8.1, such as blogs, wikis or other 'website creation tools', can be used to support students' reflection and authentic assessment for learning (see Chapter 7) through digital portfolios, or they could be used for digital storytelling and expression or peer collaboration. We present illustrations showing *how* other learning technologies might be used in science education for various pedagogical purposes in the snapshots later in this chapter.

A challenge for primary school science teachers is to evaluate and select high quality learning resources, both generic and science-specific, for example, from the thousands of apps in the Education categories in the Apple App or Google Play stores. The majority of apps in these repositories are shallow, rote learning apps, simply designed to provide information or opportunities for drill-and-practice (Bano et al., 2018). This can make it difficult for primary school teachers to find more creative apps that support participative, socially interactive approaches and potentially leverage more meaningful learning (see Chapters 2 and 3). Indeed, the US Office of Educational Technology (2017) warns of a new 'digital use divide' between "students who use technology to create, design, build, explore and collaborate, and those who simply use technology to consume media passively" (p. 18). Fortunately, there are resources to assist with the challenges, including various rubrics[1] for critically examining apps. Some rubrics focus on the potential use of apps to support teaching approaches, including one that is specifically designed to evaluate science apps (Green et al., 2014), and another rubric[2] that helps teachers evaluate the mobile pedagogical value of apps.

TEACHING AND LEARNING PRIMARY SCHOOL SCIENCE WITH TECHNOLOGY

Planning K-6 science learning tasks involves many decisions about the learning outcomes to cover, possible learning technologies to use, and how children might use them to optimise learning. Some of the resources and associated teaching and learning strategies are science-specific and thus science teachers need to draw these together with their pedagogical expertise. Availability of different kinds of software and hardware tools will vary considerably by school and the socio-economic background of students as will both technical support and internet access, so it is important to consider contextual variables and to understand the pedagogical purposes as well as affordances and limitations in decision-making and planning.

Digital Pedagogy

The term *digital pedagogy* describes the art of teaching and learning with contemporary learning technologies. The broad categories of these technologies introduced earlier offer a starting place to consider how the use of technology might mediate science learning. However, primary school science teachers need a theory of learning to drive their digital pedagogical decision-making and planning. In the contemporary context where high quality digital resources are readily available, teachers are expected to go beyond presentational approaches (such as using the interactive whiteboard for demonstrations) to more progressive approaches that promote children's agency in their learning, such as student-generated media projects.

For many years, behaviourism has been the dominant learning theory influencing the design and use of learning technologies. Early technologies such as Skinner's teaching machine[3] in the 1950s and 1960s and technologies such as the overhead projector, instructional television and videos in the 1970s were typically associated with didactic, lecture-style, broadcast modes of teaching. Although more frequently adopted in secondary schools, primary school teachers sometimes choose to adopt these types of approaches, such as when usingYouTube, screencast apps or digital pens to present information to children. While behaviourist approaches are persistent in technology-mediated teaching and learning, education reformers in the past four decades advocate more emancipative approaches and designs that give learners more agency through inquiry, analysis and problem-solving with digital technologies (also see Chapters 2, 3, 4 and 5). Professor Seymour Papert was a pioneer in this movement during the 1980s, and, like Professor David Jonassen in the 1990s, promoted constructivist theory to underpin the development of more open-ended, generative uses of learning technologies to support children's creativity and critical thinking. Critical thinking applications, or what Jonassen labelled *mindtools*, include concept maps for collaborative planning, spreadsheets for problem-solving and modelling, and simulations for hypothesis testing. Papert's classic 1980 book titled *Mindstorms* and Jonassen's 1996 book titled *Computers in the Classroom: Mindtools for Critical Thinking* are highly recommended as introductions to contemporary student-centred, learner-as-designer digital pedagogies.

In this section, we aim to push beginning primary school teachers to think beyond the strong influence of behaviourism on teaching approaches with technology, including its significant influence on the design of alluring, glitzy but educationally shallow apps. We encourage primary school teachers to explore digital pedagogies through the lens of social constructivism (see Chapter 2) to emphasise learning science *with* (rather than *about* or *from*) digital technologies to enhance children's articulation, representation and exchange of ideas and meaning-making. Social constructivism highlights the social dimension of science learning activities, as developed elsewhere in this book (see Chapter 2), and enables learners' use of digital technologies to enhance discussion, questioning and negotiation of meaning among peers and teachers.

Social Constructivist Digital Pedagogies

Following social constructivist theory, pedagogies need to give children the opportunity to realise their own background knowledge, challenge alternative conceptions (see Chapter 3) and build new meanings through shared learning experiences. An emphasis on the social aspects of learning means that experiences need to be planned so that learners have autonomy as they build collective knowledge both in the learning process and through the artefacts they produce. This positions teachers as consultants and monitors of children's learning and supporting these experiences with digital technologies then opens a range of possibilities to help children develop their science content knowledge and skills. The following Snapshots describe pedagogical approaches driven by a social constructivist theory of learning and depict children's use of contemporary learning technologies to meaningfully support collaborative learning.

Snapshot 8.1. Technology-supported science learning procedures

A straightforward way to use technology in designing constructivist science teaching is through the well-known science teaching procedure of predict-observe-explain (POE). The purpose of a POE activity can range from eliciting children's pre-instructional science understandings, possibly provoking cognitive conflict, to a more deliberate strategy designed to support students' meaning-making. Technology can assist in the prediction and observation phases. To provoke the *predict* phase of the POE, a short video stimulus from YouTube Kids, such as a snippet of a dangerous, time-consuming or expensive demonstration, could be presented for learners to consider a scenario, before using the video controls (slow motion, rewind etc.) to scrutinise the outcome. Close observation of the science phenomenon can provoke peer discussion leading into the explain phase. Data loggers or apps can be used during the observation phase, for instance, to measure someone's heart rate or the pitch of a sound.

Importantly, technology can be used to guide pairs or small groups of learners through the POE procedure and facilitate more autonomous, collaborative learning (Kearney, 2004). Online interactive video platforms such as *Edpuzzle* or even a carefully planned sequence of *Google Slides* can be used to scaffold children's engagement in each step of a POE task and allow them to exchange ideas and progress at their own pace. Digital technology can also support the seamless collection and collation of students' responses in each phase of the POE process to inform later instruction. Importantly, children's responses may provide insights into their alternative conceptions and provoke additional questions as new points of interest. Thus, children's questioning (verbal or written) during a POE can lead discussions in many new directions. Templates and examples for designing a technology-supported POE activity and sparking ideas are available from the Learning Designs site[4]. Indeed, upper level primary school students can create their own POE task to share with their peers. Other reference materials, such as procedures available from the Project for Enhancing Effective Learning (PEEL)[5] offer robust, research-based ways to design learning activities that can be readily adapted for use with digital technologies.

Snapshot 8.2. Inquiry-based science learning
As developed in Chapter 6, inquiry as a teaching approach gives children the opportunity to explore a question of interest to them. Curriculum scholars have developed several inquiry frameworks, but Bybee's 5Es model is among the most popular. There are particular focal points for each of the Es (Engage, Explore, Explain, Elaborate, Evaluate) and working through each of these stages mirrors the work of scientists in conducting an inquiry that can be supported with various technologies. For example, a 5Es inquiry could focus on a community science project investigating local fauna. Here, students could use their mobile devices during the early phases of the inquiry to explore the phenomenon and generate areas of interest and project goals. In a similar way to real scientists, students can use apps to communicate in real-time, collect data in situ, and co-author and share findings. Teachers can arrange to have children liaise with an expert biologist-in-residence in a real-time video chat to discuss the project goals and seek guidance for data collection procedures. In later stages of the inquiry, children could travel to different local areas, collecting multimodal artefacts in the field, including photos and videos and make annotated notes to share amongst themselves, the teacher and the biologist. As part of a team, the students in this scenario use password-protected online spaces such as the school's learning management system or a class blog, to pose questions and share their predictions and interpretations with peers doing similar projects in other local or more distant neighbourhoods, or with other scientific experts. In this way, the mobile learning activity enables the children to think and behave as part of a real scientific community and act as co-constructors of knowledge through authentic activity. Sharing materials in a safe online space means that the biologist also has access to their shared notes and real time data and can quickly give feedback. The students can then co-write a brief report in an online collaborative document and share their findings with the science community in the Elaborate and Evaluate phases.

Snapshot 8.3 Digital Explanation
A designed-based example of a digital learning experience for primary school science students is student-generated digital media or *digital explanation* where children develop an explanation of a science concept for a specified audience. For example, children can generate an animation to represent conceptual knowledge or interpretations of dynamic relationships such as forces. Movie making programs such as iMovie allow easy upload of still images, video and other digital media forms and support development of a progressive sequence of representations that can be edited and narrated to make a mini-movie to explain the science concept to others. Other software or apps allow children to easily create animations, or slow-motion animations (see the Slowmation[6] and Digiexplanation[7] sites). Developing an explanation of a science concept for others is a highly effective way for children to learn science content because to explain something, they need to understand it. So, in creating a digital explanation, children consider

the science content, choose what will be represented (and how) and then work with a range of digital tools to communicate their science understandings. These short, stand-alone mini-movies can be engaging as a task; allowing children to work with science content in an open-ended way that is well-suited to groups and collaborations. The process of developing a digital explanation can also help children to develop new media skills and digital literacies because they both learn from and produce multiple representations while working to produce an accurate explanation. Research in this area has productively demonstrated the value for a range of science learners, including preservice teachers (Hoban, Nielsen, & Shepherd, 2013).

Developing your Science Digital Pedagogical Knowledge

This chapter cannot begin to cover all of the possible digital resources that primary school teachers can use to effectively teach science. However, through initial teacher education programs and career-long professional development, beginning teachers will develop a variety of approaches to creatively exploit the affordances of different technologies. Fortunately, there are many ways to keep current with new and emerging learning technologies and associated digital pedagogies. Well-known education bloggers such as Kathy Schrock[8] and Richard Byrne[9] help teachers keep current with an ever-growing list of learning technologies and digital teaching approaches. There are many professional organisations, such as the Australian Council for Computers in Education (ACCE) and the International Society for Technology in Education (ISTE) in the US that produce pertinent publications and other resources for teacher professional development. The Australian Science Teachers' Association (ASTA) and state-level science teachers' associations hold annual conferences that offer networking opportunities to share and discuss innovations in teaching, including emerging digital pedagogies in science. Attending teacher conferences and developing a professional learning network (or PLN) incorporating links with other teachers and organisations, both locally and globally, serve to connect teachers to others interested in similar questions of teaching and learning. For example, many teachers attend TeachMeets and then use social media to continue their professional learning conversations in spaces such as Twitter (e.g. using #PrimarySTEMchat, #ozscied and #aussied memes) and Facebook.

LEARNING SPACES FOR PRIMARY SCHOOL SCIENCE EDUCATION

Primary school teachers should also consider the growing range of physical and online contemporary learning spaces when designing technology-mediated learning tasks and enacting digital pedagogies. Formal physical spaces may include classrooms and school libraries, while virtual spaces may include structured class blogs or school learning management systems. Semi-formal physical spaces may include school playgrounds, break-out spaces, and excursion sites such as science museums, while semi-formal online spaces could include science chat sites, other online communities or virtual tours and field trips (for example, *Google Expeditions*). In these formal and semi-formal spaces, children's learning experiences are typically designed and mediated by a teacher or external expert such as a museum tour guide.

With the availability of mobile devices and accompanying educational apps, there is a growing range of informal learning spaces where children can learn science. Even for primary school aged children, these spaces could include buses, shopping centres, and spaces at home, all of which are appealing because the spaces are typically more convenient and intimate for learners. Informal virtual learning environments can be connective, participative spaces for upper-level primary school children, such as tween-friendly social media networks and immersive online worlds that can be accessed using mobile tools anywhere and anytime. Designing science learning activities that utilise these physical and virtual learning spaces, some of which are learner-generated and therefore unpredictable, is a new and exciting challenge for primary school teachers.

Children are increasingly comfortable moving and learning across multiple learning spaces – formal and informal – for example, when carrying out citizen science projects. Some educators describe this boundary-crossing between learning spaces as *seamless learning*, for example connecting learning in classrooms and science museums, or providing a bridge between classroom-based inquiry and more realistic, in-situ collection of data from a beach or forest. Mobile devices and associated learning technologies can mediate this flow of learning between formal and informal contexts, for example, through children's use of online role-playing or cloud-based applications such as *Google Sheets*.

A FEW CAVEATS

A chapter on using digital technology to support science learning would be incomplete without a few caveats. Factors affecting technology use in schools will continue to evolve and shape the digital education landscape in primary school science teaching and learning.

Enablers and Barriers to Integration of Technology in Primary School Science Teaching

Both enablers and barriers of digital technology adoption and integration in schools have been well documented. First-order factors include access to technology, school budgets, technical administration and support, as well as time for planning and professional development. Second-order factors are more critical and include teacher beliefs, digital competencies and pedagogical approaches (Ertmer et al., 2012). Teachers' pedagogical beliefs are perhaps the most critical influence on the way learning technologies are used in and beyond the primary school classroom. If teachers have behaviourist beliefs, they tend to use educational technologies that support didactic, transmissive teaching approaches, for example, using PowerPoint to 'teach by telling', or an interactive whiteboard in a presentation style to transfer information. This may promote rote learning. In contrast, teachers with social constructivist beliefs will design more student-centred, collaborative, expressive and creative technology-enhanced science learning tasks. Notably, such constructivist approaches are consistent with contemporary directions in both learning theory and curriculum and provide extensive opportunity to utilise learning technologies in generative and engaging ways.

Drivers of Technology in Primary School Education

Many learning technologies, such as interactive whiteboards and laptops have been introduced into schools via a *top down* approach under the influence of external bodies such as governments and powerful corporations such as Google, Microsoft and Apple. An economic rationale is typically central to arguments driving investment, for example, to prepare students with 21st Century skills that are relevant in a rapidly changing global economy and for future workplaces. An example from state-level Government is the 2011 NSW Connected Classroom program that spent $23 million on 4,300 interactive whiteboards for classrooms.

Professional organisations, regulatory agencies and curriculum designers are also influential. The national-level government in Australia recently instituted regulations in the form of the

Australian Professional Standards for Teachers (APST, ACARA, 2013), with three standards addressing the effective and safe use of technology for teaching: Standards 2.6, 3.4 and 4.5. (See Illustrations of Practice for these standards via the AITSL website[10]). The General Capabilities section of the Australian Curriculum explicitly states students should develop ICT capability and use it to develop conceptual understandings, research science concepts and communicate findings. The Technologies curriculum also specifies a range of skills and knowledge for learning about and working with technology.

More recently, the use of learning technologies such as cloud-based software (e.g. *Google Documents*), digital video editing software and many education apps have been introduced and promoted in schools. Arguably these more *bottom up* strategies have had greater impact because they are under the influence of smaller-scale, localised drivers such as pioneering teachers and school leaders, parents, local authorities or school systems. For instance, more locally developed school-based laptop or Bring Your Own Device (BYOD) policies can positively influence practices and children's access to technology.

SUMMARY OF KEY POINTS

Teachers' beliefs about teaching and learning critically influence the way that educational technologies are used by children in learning science. Social constructivism is a useful theory for beginning teachers to develop digital pedagogies that emphasise students' learning *with* technologies to support discussion and exchange of ideas, open-ended questioning and co-construction of meaning. Collaborative technology-supported design and inquiry-based activities are highly suitable for these purposes. Teachers also need to think about where and when science learning might take place and how the use of mobile technologies and associated apps might leverage new physical and virtual learning spaces for science students to think, co-create and investigate.

DISCUSSION QUESTIONS

1. Where do you need to focus your own professional learning to develop your repertoire of digital pedagogies? How could your professional learning network [PLN] help you?
2. You are teaching in a school with a *Bring Your Own Device* [BYOD] policy. Design a science learning activity that exploits the *anywhere, anytime, any pace* flexibility of learning with a mobile device. How could the notion of *seamless learning* across contexts inform your design? Use this short Youtube video[11] as a stimulus for your planning.
3. Use one or more of the evaluation rubrics flagged in this chapter to compare and contrast two of your favourite science learning apps for children.
4. Use a constructivist perspective to inform the design and implementation of a science activity for children that exploits the use of one or more carefully selected education apps. Evaluate your activity using the teacher and student versions of these validated surveys[12].
5. Video-based examples of science lessons informed by a constructivist perspective are available at the University of South Florida's well-known Technology Integration Matrix (TIMS)[13]. Choose and view a K-6 science example that is tagged 'Collaborative'. How is peer collaboration supporting student learning in the lesson?

REFERENCES

Australian Curriculum, Assessment and Reporting Authority. (2013). *Australian Professional Standards for Teachers.* Sydney: ACARA.

Bano, M., Zowghi, D., Kearney, M., Schuck, S., & Aubusson, P. (2018). Mobile learning for science and mathematics school education: A systematic review of empirical evidence. *Computers & Education, 121*, 30-58. doi:10.1016/j.compedu.2018.02.006

Bower, M., & Torrington, J. (2020). A typology of free web-based learning technologies. EDUCAUSE digital library, https://library.educause.edu//media/files/library/2020/4/freewebbasedlearntech2020.pdf, accessed 14 May 2020.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers and Education, 59,* 423–435.

Green, L. S., Hechter, R. P., Tysinger, P. D., & Chassereau, K. D. (2014). Mobile app selection for 5th through 12th grade science: The development of the MASS rubric. *Computers and Education, 75,* 65-71.

Hoban, G., Nielsen, W., & Shepherd, A. (2013). Explaining and communicating science using student-created blended media. *Teaching Science: Australian Science Teachers Journal, 59*(1), 32-35.

Jonassen, D. H. (1996). Computers in the classroom: Mindtools for critical thinking. Merrill/ PrenticeHall: Columbus.

Kearney, M. (2004). Classroom use of multimedia supported predict-observe-explain tasks in a social constructivist learning environment. *Research in Science Education, 34*(4), 427-453.

Office of Educational Technology. (2017). *Reimagining the role of technology in education: 2017 National Education Technology Plan update.* US Department of Education. Retrieved July 17, 2020, from https://tech.ed.gov/files/2017/01/NETP17.pdf

Papert, S. (1980). *Mindstorms*. Basic Books, New York, NY.

Resources

Resources 1 - 13 from this chapter can also be accessed online at: https://bit.ly/nielsenkearneyresources

[1] https://www.schrockguide.net/assessment-and-rubrics.html
[2] http://www.mobilelearningtoolkit.com/app-rubric1.html
[3] https://youtu.be/jTH3ob1IRFo
[4] http://www.learningdesigns.uow.edu.au/index.html
[5] http://www.peelweb.org/
[6] http://www.slowmation.com/
[7] http://www.digiexplanations.com
[8] http://www.schrockguide.net/
[9] http://www.freetech4teachers.com/
[10] https://www.aitsl.edu.au/tools-resources
[11] https://youtu.be/9zxlZvJ-3Aw
[12] https://www.ipacmobilepedagogy.com/
[13] https://fcit.usf.edu/matrix/matrix/subject-area-index/