Next Generation Digital Curricula for Future Teaching and Learning

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Abstract

Changes to contemporary curricula are increasingly driven by the evolution of technology. The spread of personal digital devices and pervasive communication infrastructure has led to significant changes in global society. These changes have highlighted the need for schools to ensure that all students are prepared for the contemporary digital world. The need to provide digital skills for all students means that digital technology can no longer be taught only as a specialist subject area, but rather needs to be embedded in all subjects across the curriculum. This recognition of the importance of digital skills for all has meant that many countries have developed new curriculum areas focused on developing these skills. However, for many educators, there is still a disconnect between the technical skills that curricula often prescribe and the practical strategies needed to integrate these skills into their broader classroom activities. This chapter explores how a number of countries have approached the integration of digital skills into the curriculum and the commonalities between these diverse approaches. A number of examples are given of how certain technologies have provided opportunities for embedding digital skills across the curriculum. From these examples we identify some complementary dimensions that can help us to design future curricula for the digital age.

Keywords: digital technologies, curriculum, STEM, authenticity, mechatronics

Next Generation Digital Curricula for Future Teaching and Learning

The question of how to best integrate technology into teaching and learning has long been a concern of educators worldwide and, as technological change has intensified and digital tools have penetrated every part of society, this question has become ever more pressing. Digital curricula that consider computing a discrete subject are well-established. For example, the ACM have published computing curricula since 1968, with a subsequent increase in regularity and scope (Goldweber et al., 1997). However, the use of digital technologies in society is not discrete but is embedded in all aspects of work and life. It cannot be isolated from education and, more importantly, cannot be taught only to the select few. Rather, curricula that address digital skills and competencies increasingly need to be provided for every student, across the curriculum; an approach that has sometimes been called the "entitlement curriculum" (Unwin & Yandell, 2016). Thus, worldwide, there is a growing sense that use of digital technologies is a foundational competency like mathematical and language skills and therefore has the same pervasive role across the curriculum.

This chapter describes how the role of digital technologies in curricula is changing worldwide and explores how this change has impacted on teaching and learning in schools by providing a series of illustrative examples that represent the cross-curricular integration of various digital technologies. From these examples we extract some important dimensions that we believe can help to inform the development and implementation of digital technology use within the curriculum.

International Curricula and Digital Technologies

School curricula are an essential part of national or regional education systems, and many nations are reflecting on and developing their curricula in the context of addressing the increasing importance of digital technologies in society. In this section, using some indicative examples, we briefly outline how curricula in various nations have been responding to rapid global technological changes.

Australasia

Australia and New Zealand have both recently added specific content to their national curricula around digital technologies. From 2017, all Australian schools were required to implement the Australian Curriculum Digital Technologies, where all students to 12 years of age are taught Design and Technologies and Digital Technologies. Similarly, from the beginning of 2020 all New Zealand schools will implement changes for all students, with two new technological areas introduced to the existing curriculum - 1) Computational thinking for digital technologies, and 2) Designing and developing digital outcomes. These changes are based on the aim to grow 'digitally capable individuals' and learners being 'innovative creators of digital solutions', not just 'users and consumers of digital technologies' (Ministry of Education, n.d.). The curricula for both countries highlight a focus on providing opportunities for learners to use digital technologies with critical and creative thinking to solve authentic real-world problems. They also both acknowledge the need for a dynamic and responsive approach to technologies and developments over time.

China

Among the many goals of the eighth wave of reform in the Chinese curriculum in 2011 was to 'strengthen the relevance of curricula to students' lives, society, and the development of science and technology' (Yin, 2013, p.332). The overall strategy became more flexible and devolved, with a curriculum model across the three levels of nation, region and school (OECD, 2016). In China, use of digital technologies has progressed at a very rapid rate, even more so than in other parts of the world (Chu, 2008). As a result of this rapid growth in technology use, many of China's teenagers may now be digital natives, but they are not necessarily digitally competent. The need for ICT in the curriculum was acknowledged by several Chinese Ministry of Education publications in the early 2000s, but further curriculum development is required in the area of digital culture (Li & Ranieri, 2010). A national development plan for ICT in education up to 2020 was issued in 2012 (Wu, 2014) and the current five-year plan for education aims for in-depth integration between ICT and education (NCEDR, 2017).

England

The English National Curriculum for primary schools was revised in 2014. This new curriculum replaced the previous curriculum, launched in 2000, removing the previous ICT subject area and replacing it with a stronger focus on computing (UK Department for Education (DFE), 2013). With this new emphasis, the curriculum now focuses on the principles and concepts of computer science, alongside digital literacy and IT (The Royal Society, 2017). This has meant that computing is now to be taught in schools from the ages of 5 to 16, with the focus on more application and development of tools compared to focusing on just simply using them. The curriculum was developed for the recognised need for computational thinking and creativity to support learners in an increasingly changing world.

Kenya

The Digital Learning Programme introduced in 2016 included digital devices being delivered to every primary school by the end of that year. All tablets were delivered with preloaded learning material for Maths, English, Science and Kiswahili, with ICT integrated into the existing education curriculum as a teaching and learning tool. To support this initiative ICT skills were introduced in all schools and professional development opportunities provided for primary teachers. The programme was accompanied by a strengthening of the country's internet and electricity infrastructures (Ministry of Information Communication & Technology, n.d.). The

2017 Jubilee Manifesto committed to transforming education and made ICT skills and digital literacy a priority in both primary and secondary education. The Kenyan government's current 'Vision 2030' is aimed at making Kenya a knowledge based economy and stresses the need to prepare learners for the 21st century skills needed to compete globally, which includes an emphasis on the use of digital devices and digital literacy across all schools (The National Treasury, n.d.).

United States

There is no national curriculum in the United States, so each state decides its own. The U.S. Department of Education first released a National Education Technology Plan in 1996. This was updated every five years. In 2016 it was retitled as: Future Ready Learning: Reimagining the Role of Technology in Education (Office of Educational Technology, n.d.). In 2017, under the growing recognition that technology is changing too quickly to leave it for a five-year period, it was decided that there would be annual updates. This document outlines the vision for the use of technology in education across the U.S. and envisages equitable, ubiquitous, collaborative use of technology, moving away from passive towards active use. 21st century competencies and both cognitive and non-cognitive competencies are emphasised. Equitable access and the digital use divide are highlighted as challenges that need to be overcome. One of the key recommendations in the document is to increase the digital literacy of pre-service and in-service educators.

The scope of digital technologies curricula

As seen above, many countries have seen the growing need to redevelop and reshape how ICT and related technologies are taught in the curriculum in response to rapid technological change, particularly in China where the spread of technology in society has been exceptionally rapid. Developing countries also face problems of catching up with the infrastructures and digital tools of the developed world, as the Kenyan experience makes clear. Although contexts and approaches vary, each has recognised the need for digital technologies to be embedded as a fundamental part of the curriculum.

A common theme in many new curriculum developments has been a focus on teaching digital technologies outside of the traditional ICT or computing subject areas, and to embed them across the curriculum. The Kenyan, New Zealand and English curricula, for example, have focused on including digital skills earlier in the schooling curriculum and ensuring that all students develop a good level of digital fluency. The focus is now on how the teaching of digital technologies can move beyond just teaching students about technologies to integrating technology across subject boundaries to enhance learning.

Within the English, Australasian and U.S. curricula there is a strong focus on designing creative solutions supported by the selection and use of appropriate digital tools. The role of creativity in this context is not only for design inputs focused on developing technical solutions but could equally be applied to wider aspects of digital technologies used for creative purposes.

In addition, in many of the new curriculum policies (such as in England and the U.S.) there has been a stronger focus on what we might call ‘hard’ technologies (e.g. electronics, coding, robotics etc.). However, the ability for these technologies to be used in a cross curricular manner is less straightforward than the use of end-user software tools and applications that might be called ‘soft’ technologies. The challenge is how we can use these hard technologies across the full spectrum of learning.

Curriculum policy in Kenya and U.S. explicitly recognises the need to upskill teachers to deliver these digital curricula. The significant shift in how computing is seen and taught throughout the curriculum and at earlier stages of students’ schooling career has meant that teachers need support to both develop their own digital skills and also to understand ways in which these technologies can be embedded in different subjects.

It is clear from these brief summaries that countries across the world are seeking to integrate digital technologies into the broader curriculum. However, the intent to do this needs to be matched by realistic ways of making it happen in the classroom. One way of approaching this is to look at some illustrative examples, as outlined in the next section.

Cross Curricular Examples

In this section we provide a series of illustrative examples exploring how digital technologies have been integrated across the curriculum in different ways. The most direct application for these in a cross curricular manner has been in STEM (Science, Technology, Engineering and Mathematics) education. However, the increasing focus on STEAM (Science, Technology, Engineering, Art and Mathematics) education, an approach that crosses the art/science boundary and focuses on problem-solving, has meant that a wider range of skills can be drawn on from across a range of subjects (Quigley & Herro, 2016). The challenge for educators is to successfully integrate technology into subjects that go beyond even STEAM into the broader curriculum. The examples included here move from soft to hard technologies; digital storytelling, coding, makerspaces, electronics and robotics. In each example we seek to generalise the key messages about how to effectively use digital technologies across the curriculum.

Digital Storytelling

One of humankind’s oldest activities is storytelling and in recent years the traditional art has evolved with the advancement of digital technologies. Digital Storytelling has seen rapid adoption by educators and is a powerful opportunity for authentic student learning (Lowenthal, 2009; Robin, 2016). Voice, still images, video, text and the use of internet technologies can be used when developing a digital story, and there are extensive developmentally appropriate tools available for creation. Typically, digital stories are narratives and imagery shared through technology. In the past the reading, writing and sharing of printed stories were seen as critical to literacy development. Digital stories can move beyond static, one dimensional, singular viewpoints toward engaging, personalised learning opportunities which are relevant for the students of today (Ohler, 2013). There are widely documented benefits to digital storytelling - learners can consider the narratives by which they live and produce artefacts that are relevant and meaningful to them and their community (Barrett, 2016; Motteram, 2013).

Otto (2018) provides a pioneering example that explores digital storytelling in a collaborative, interdisciplinary way that promotes virtual mobility and intercultural understanding. The students within this example came from two distance learning universities in Germany and Tunisia. Digital storytelling was used as a means to collaborate across cultures and understand the problem of climate change from their perspectives. The 3-month course was designed in a way to facilitate collaborative practice, whereby learners initially met face-to-face in a workshop, then the rest of the learning was facilitated in an online environment. The intended learning outcome was for the students to create a digital story which wove together their personal narratives to explain lived experiences of climate change. The study found that by working across cultures on digital stories the students developed a range of skills and competences. For example, technological competence was developed throughout the learning task (using digital tools to compose a story) and students were provided with an opportunity to demonstrate problem-solving and research capabilities. Similarly, it was found that as learners came together to share their unique perspectives, interdisciplinary competencies were developed. Digital storytelling is an authentic, relevant and meaningful learning experience that effectively integrates multiple soft digital technologies into cross curricular learning.

Coding

Coding uses end-user software tools but can also be used to program ‘hard’ digital technologies such as electronics and robotics, so provides a bridge from one to the other. Learning to code has been widely recognised as a way to support problem solving and computational thinking. Since computers were first introduced in schools in the 1970s there has been a push to teach coding. In the 1970s and 80s the Logo programming language was taught to millions of students, but the rise of personal computers and software packages changed the emphasis of curricula to using programs rather than creating them (Resnick et al., 2009). However, interest in coding in schools has been revived in recent years by block based visual languages such as MIT’s Scratch, a commonly used application that makes coding accessible to a wider range of learners and teachers. Scratch was initially designed for users from 8 to 16 years, although it is used more widely than that demographic and is currently available in more than 40 languages in over 150 countries. Scratch enables learners to create, design and invent new ways of applying their learning through the use of technology. Users are easily able to share this learning with others through public repositories.

Considerable research has focused on how to best support teachers working with coding applications like Scratch to gain the knowledge and confidence to use technology to support the learning with a constructionist approach (Brennan, 2015). Generally coding and programmes like Scratch have been shown to improve mathematical thinking and problem solving, but literacy can also be supported through coding (Hutchison, Nadolny & Estapa, 2016). Bell & Bell (2018) provide several vignettes that explore the integration of music education and computational thinking. They posit that whilst on the surface these subjects seem dissimilar they do in fact have many similarities - creativity, teamwork, communication and working with notation. Both involve constructing something intended for an audience within genuine contexts. They argue that this cross curricular approach allows collaboration between teachers from different disciplines with different passions and expertise. In general, the accessibility of visual, block-based programming tools such as Scratch has revived interest in using coding to teach across the curriculum.

Makerspaces

Makerspaces are collaborative work spaces that provide practical hands-on opportunities usually within a STEM/STEAM environment to work with new technologies and innovative processes to design and build projects. Such specifically designed areas are becoming increasingly common within schools (Gilbert, 2017). While makerspaces provide a rich opportunity for students to be immersed in STEM project areas, there is also much potential for broader types of learning to be integrated into these creative and future focused spaces.

Developing the storytelling idea, Bull et al. (2017) assert that joining storytelling and making together offers a natural opportunity to integrate technologies with multiliteracies and humanities subject areas within the makerspace context - a learning activity they term storymaking. While their study is small in scale, it does serve as a useful pilot for how school makerspaces can be used as settings to enable learners to integrate digital technologies in a cross curricular manner; in this case linking literacy with computer science and engineering. Primary age students used Scratch (introduced in the coding section above), to create animatronic dioramas. Dioramas have been a traditional strategy in school literacy programmes to enable learners to act out storytelling and plays through the use of human manipulated figures or puppets. The construction of animatronic diorama incorporating the use of coding gives us insights into ways that digital technologies can be used as enablers for cross curricular learning. The linking together of hardware and software in makerspaces to construct artefacts provides a useful model for using digital technologies across the curriculum, and may integrate electronics and robotics, outlined in the following sections.

Electronics

A number of different types of electronic devices have been employed to teach multiple subject areas. They range from simple microprocessor circuit boards like Makey Makey, through more complex boards like the Arduino and the micro:bit, to simple computers such as the Raspberry Pi. The relevance for real world learning in the use of these devices comes from the prevalence of electronics in the world around us, and the increasing ubiquity of the Internet of Things. By learning about electronics, students are gaining an insight into the world around them.

Using electronics in a cross curricular way generally requires them to be linked to other devices. This frequently means connecting them to a separate computer or perhaps connecting to additional peripherals like adding sensors that are not part of the original board or allowing a number of these devices to communicate wirelessly with each other. Further, cross curricular electronics often means embedding an electronic device into another artifact such as a 3D printed object or a fabric garment.

A very relevant case for considering the role of cross curricular electronics is the micro:bit, which was distributed to around 800,000 UK school children in 2016. A specific curriculum was not provided, so ways of using it were developed by a range of educators. In terms of cross curricular use, electronics learning activities in subjects beyond STEM include embedding micro:bits into textiles to create wearables and using the accelerometer in P.E. to measure acceleration in running (Sentance, Waite, Hodges, MacLeod & Yeomans, 2017). One social science activity from the UK included exploring the future of cities by integrating micro:bits into a simulation of driverless car management (Lavicza, Fenyvesi, Lieban, Hohenwarter, Mantecon & Prodromou, 2018). On a broader scale the micro:bit Global Challenge 2018 asked children aged 8-12 to address one of the 17 Sustainable Development Goals using the micro:bit. (Gabriel, Ollard & Wilkinson, 2018). The winners leveraged various sensors in electronics to build systems that supported personal wellbeing and environmental protection.

The most important aspect of integrating electronics into different areas of the curriculum is the ability to create an intelligent artifact that can enhance understanding of that field. Building an electronic instrument from multiple materials in music, creating interactive installations in art or building custom sensors for biological field study all enable students to develop skills and competencies that could not be developed similarly using alternative learning materials.

Electronics is certainly a hard technology in the definition we are using in this chapter and, as with other hard technologies, we have to consider whether their use in the curriculum is appropriate across multiple subjects. Looking at the examples we have highlighted we can see that the unique affordance of electronics is that they allow technology to connect out into the real world, allowing students to create artefacts that physically interact with learning contexts.

Robotics

Like electronic devices, the use of educational robots within the classroom has dramatically increased. This popularity has largely been driven by the affordance of robots to be constructed and developed by students themselves (Alimisis, 2013). Robotics falls under the area of ‘mechatronics’, which combines mechanics and electronics as a way to enable students to construct their own products (robots) that enable hands on learning. This hands-on interaction and building of artefacts draws together the principles of constructivism and constructionism so learners develop their own learning through construction (Socratous & Ioannou, 2018).

According to Eguchi (2010), the use of robots in education has primarily been applied in three ways;

- Theme-Based Curriculum Approach: robots are used to facilitate the exploration of special topics typically focusing on a specific subject, such as mathematics or engineering. The learning activity is focused on students learning through inquiry and communication captured in the application and design of robots.
- Project-Based Approach: learning is focused on groups of students working together on authentic learning experiences explored through the development and experimentation of the robots. These projects are more likely focused on the integration and application a range of subjects with cross-curriculum application.
- Goal-Oriented Approach: the applications of robots are typically used as extracurricular tournaments or competitions, where children compete in challenges held between schools, these include tournaments like RoboCup and other tournaments such as the FIRST Lego League.

In general, robotics has been typically integrated within the teaching of traditional STEM subjects. Most examples of robots in education have focused on the application of these robots for problem solving, construction, programming and debugging designs (Alimisis, 2013) within the teaching of science, engineering, technology, mathematics, and computer programming (e.g. Menegatti & Moro, 2010; Goldman, Eguchi & Sklar, 2004; Veselovská & Mayerová, 2015). The application of robots to facilitate the teaching of these subjects has shown that it fosters high student motivation and develops learning skills such as problem solving, collaboration, scientific inquiry and critical thinking (Socratous & Ioannou, 2018).

Like electronics, robotics can be considered a hard technology from a learning perspective. However, its application within the broader context of STEAM education or integrated across the curriculum offers significant promise. Typically, the major link within STEAM has been largely focused on the application of creative problem-solving (Kim & Kim, 2018). There is also a growing focus on how robotics can be used more widely, such as for the development of artwork (Kim & Kim, 2018) or through artistic expression and brainstorming (Yoon & Baek, 2018).

Analysis

From our initial discussion, and from the examples that we have presented, we believe that there are a number of complementary dimensions that can be considered in terms of how digital aspects can or should be integrated across the curriculum. The first is digital technology integration into the curriculum, the understanding that curricula need to consider the technology both as a discrete subject and as an integrated skill set. We see a range of applications here from technology as a subject area, through technology supporting STEM subjects, technology supporting STEAM subjects and technology integrated across the whole curriculum. From our discussion of international curricula, we have seen how this is a common focus.

Closely linked with integration is embedding digital technology in the curriculum. This relates to how broadly digital activities are integrated within and between subject areas. We have outlined a dimension that goes from technology used for a stand-alone activity within a subject, through technology used across activities in a single subject, and on to problem-based learning as a way of integrating technology based activities across multiple subject areas. Incorporating technology successfully across the curriculum has been rare (Brush & Saye, 2017). Project Based and Problem Based Learning (PBL) are seen as ways to authentically integrate digital technology more widely and naturally across the curriculum with the technology supporting the learning (Brennan, 2015). Developed from the broader framework of constructivism, PBL provides authentic learning experiences where learners are able to build their own understandings in meaningful contexts. Whilst it is recognised that problem- or project-based learning can be done meaningfully without the use of technology, PBL approaches provide genuine platforms to integrate technology authentically within the curriculum (Brush & Saye, 2017). Many of the examples of practice described in the previous sections have links to PBL, and it may be that PBL provides an overarching concept that can be used to help embed a range of digital technologies across the curriculum.

The next dimension in our analysis is the placing of digital technology in the curriculum. This relates to whether technology use is driven by leveraging digital tools for new purposes, a ‘technology-out’ approach, or from a perspective of integrating digital tools into pre-existing curricular frames, a ‘subject-in’ approach. The ‘technology out’ approach is based on ideas that technologies have intrinsic characteristics that render them relevant to disparate fields of study (Goldweber et al., 1997 p.8). While these natural links may be asserted, it is often harder to make convincing cases for how, for example, coding, electronics and robotics provide support for learning areas beyond the purely technical. Similarly, the ‘subject-in’ approach may enable students to use a range of software tools that already exist to create other artefacts that relate to their learning across subjects, but may not allow full use of the potential of digital technology, because the curricular frame is substitutional - digital tools being used to do the same things as before in a slightly different, but non-transformational, way. In either approach, it is important to acknowledge that learners today should be able to utilise digital tools as designers and builders, not just as end-users. In our dimension we have suggested that an ‘integration space’ (such as a makerspace or a problem-based project) may help to address the potential drawbacks of both of these approaches.

The next dimension is the nature of digital technologies in the curriculum. As we have discussed, not all technologies are alike, and hard technologies (e.g. mechatronics) are qualitatively different from soft technologies (such as web-based applications). Integrating them in authentic ways across the curriculum is a greater challenge than the use of end-user software applications. A danger with hard technologies is that they may lend themselves to a technocentric approach, where the learning is focused only on how to use the tool. Papert argued against technocentrism in the mid 1980s and warned that conversations should not start and end with the technology or tools but on the learning itself (Brennan, 2015; Emihovich, 1990). It is important that the technology is pedagogically grounded and engages the learner in meaningful learning experiences instead of the technology being the focus (Bhattacharyya & Bhattacharya, 2009). Teachers are more likely to effectively integrate technology when the focus is teaching with technology and using new approaches to traditional teaching practices rather than focusing on technology skills (Kopcha, 2010). Coding may be seen as a bridge between hard and soft technologies, in that coding tools are applications, but are needed to make hard technologies perform useful tasks.

The final dimension is that of authenticity. Kafai & Burke (2014) explain authenticity as comprising of four parts. The first being how the learning in the classroom relates to how professionals use it in the real world. These authentic learning experiences should mimic how professionals would themselves be using the tools. So rather than sitting in a classroom learning abstract disciplines they should be putting into practice real applications. The second is personal authenticity and how it relates to the learners' own lives and what they are interested in, and what is meaningful to them. The third is the need for authentic audiences, which reinforces the need for relevance, and experiences that are meaningful to each other, not just the teacher, and the fourth is designing for real-world audiences which enables genuine feedback and grounds the learning in real-world contexts. However, education is not only about preparing students for a current work context, it is about preparing them for the world to come. Authenticity here is harder to achieve but acknowledges that things that are unusual or challenging now may well be the norm in the near future. Our authenticity dimension therefore includes the future work context. Figure 1 summarises these dimensions of integrating digital technologies across the curriculum.

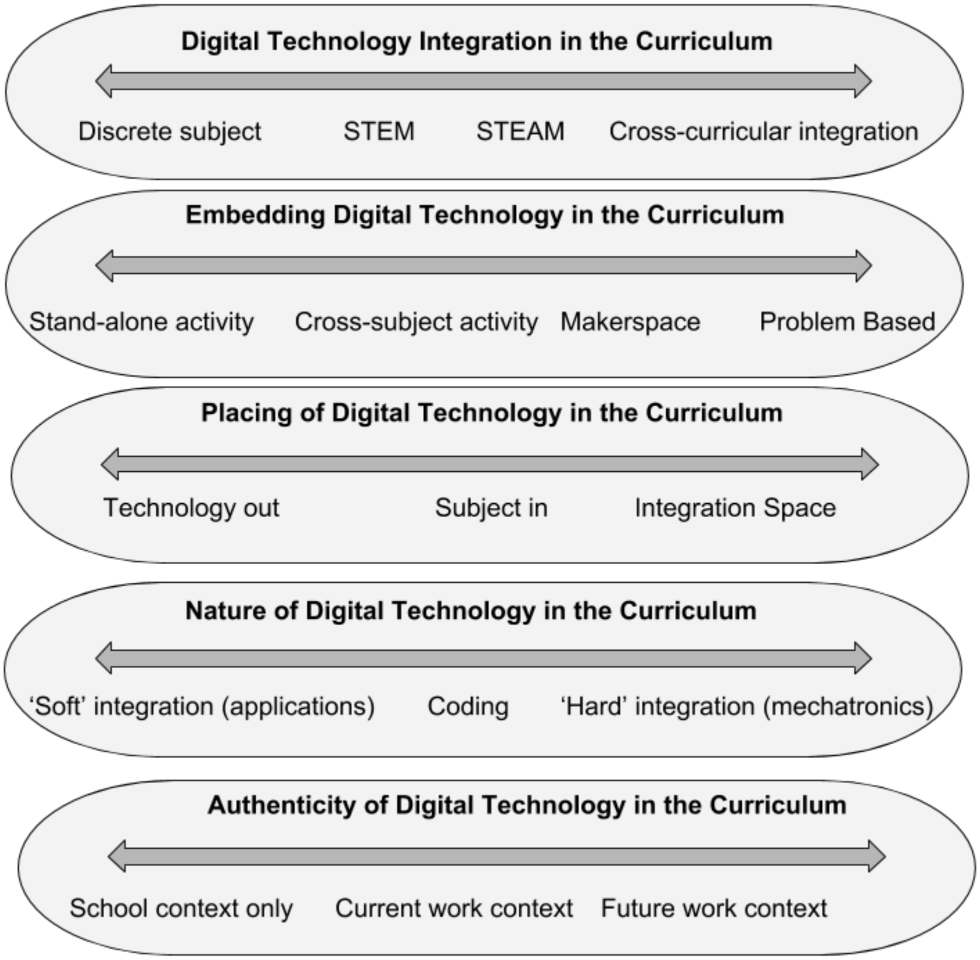

Figure 1: Dimensions of integrating digital technologies across the curriculum

Summary and Future Work

In this chapter we have highlighted the current trends towards school curricula including digital technologies, not just as a discrete subject area but as a cross-curricular skill set that is seen as essential for all students. To explore how digital technologies can effectively be used across the curriculum, we have provided some examples from various contexts that illustrate good practice and may help to inform educators who wish to contribute to, or implement, curricula in the digital technologies area. We have provided an analysis that summarises some key dimensions that we believe are important considerations when using digital technologies across the curriculum. We believe that these dimensions can be useful in both developing future curricula and providing teaching and learning experiences within existing curricula. This chapter provides an initial proposal for ways that we can usefully categorise aspects of learning in digital curricula, considering how technology is integrated into the curriculum, how it is embedded into other subject areas, how technology is placed in the curriculum, the nature of technologies that may be used, and the authenticity of learning with those technologies. Further work is needed to apply these concepts to real-world contexts and promote best practice in developing digital skills in all students.

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