Chapter 8
Developing a Technology Curriculum

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This chapter proposes three procedural principles that can inform the development of a technology curriculum: being true to the nature of technology, developing a perspective on technology, and enabling technological capability. It then explores possible futures for technology education curricula using each of these principles as a lens. Drawing on these scenarios, the argument is made that using these principles will result in a curriculum that is a valid and worthwhile endeavour for all students, and that facilitates the introduction of new elements, enabling the curriculum to keep pace with changes outside of school. The chapter concludes by asserting that teachers can use the principles to devise, justify and implement programmes of study that are robust and can withstand scrutiny from those who might question the worth of technology education. In turn, policy makers can benefit from the informed discourse with an articulate and knowledgeable profession.

Introduction

This chapter is composed of three main sections. The first section considers how curricula are conceptualised and come into being. This leads to the idea that an important way to devise a curriculum is to formulate a set of procedural principles which can be used to develop and implement the curriculum. The second section identifies and discusses three procedural principles that can be used to develop and implement a curriculum for technology education: being true to the nature of technology, developing a perspective on technology, and enabling technological capability. The third section discusses possible future technology curricula in the

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light of the three procedural principles and its relationships with other school subjects. Finally there is a short summary. Before beginning the first section it is useful to consider possible arguments for teaching technology as different justifications will lead to different technology curricula. I can make four different arguments for teaching technology.

An Economic Argument

A steady supply of people who have studied technology is essential to maintain and develop the kind of society we value. Technology is central to the innovation on which our future economic success as a nation depends. Technology qualifications open doors to a wide range of careers.

A Utility Argument

It is useful in everyday situations to be able to use technological thinking, which includes design skills and technical problem solving, in being able to address and solve practical problems.

A Democratic Argument

Through the media, people encounter issues that involve technology. Some understanding of technology is needed to reach an informed view on such issues and engage in discussion and debate.

A Cultural Argument

Technology is a major achievement of our culture, so everyone should be helped to appreciate it, in much the same way that we introduce them to literature, art and music.

The question for you, the reader, is which—if any—of these do you think provides the best justification for teaching technology and, if more than one, in what order of significance would you place them? The answer you give may depend on whether you see technology education as something for ALL young people at school or whether you see it as something that applies to only a selected few.

The economic argument is difficult to justify as an argument for ALL young people as the total of professional engineers, technologists and designers is only a few per cent of the whole population of an industrialised country. Hence a primary goal of a general technology education cannot be to train this minority who will actually ‘do’ technology. The utility argument can be extended to a consideration of the personal qualities that being able to deploy design skills and technical problem solving develops. The creative activities of design and making—a major part of technology education courses—not only give immense personal satisfaction but importantly develop a sense of self efficacy which provides young people with a positive self image with regard to their ability to be successful. The cultural argument forces us to ask, “What are the grand narratives of technology that we want our young people to appreciate?” Who are the heroes of technology? Science has Newton, Galileo, Darwin, Einstein, Crick and Watson, Franklin, Higgs. In England science also has some high profile popularisers such as Brian Cox and Jim Al-Khalili. A problem facing technology here is that many manifestations of technology are the product of large multidisciplinary teams and the concept of individual ‘heroes’ does not apply. If we are to deploy a cultural argument then the technology curriculum will need to find the means within itself to do this. The role of education to produce informed citizens able to take part in rationale debate lies at the heart of the democratic argument. This is at the forefront of the recent report “Emerging biotechnologies: technology, choice and public good” (Nuffield Council on Bioethics 2013). It shows that such technologies are likely to have significant impact on society, almost certainly being disruptive of many current practices. Interestingly the report pays particular heed to the need for a public discourse about the development and deployment of such technologies. This is the nub of the democratic argument—enabling the public to contribute significantly and intelligently to any such discourse.

It seems to me that each of these arguments should inform a school technology curriculum. Although in particular circumstances their relative significance may vary, to produce a curriculum that did not respond in part to each of these arguments would be a curriculum that was lacking an important dimension.

How Does a Curriculum Come into Being?

A curriculum has to be conceived and the principles on which this conception is based will to a large extent govern its nature and purpose. Often it is politicians and civil servants who take on this task, usually in collaboration with those outside government who have appropriate expertise. This was the case in England in 2011 when the Minister of Education, Michael Gove, appointed an expert panel to decide on a new National Curriculum. The brief for the expert panel was:

> To advise and make recommendations to the Department on the essential knowledge (e.g. facts, concepts, principles and fundamental operations) that children need to be taught in order to progress and develop their understanding in English, mathematics, science, physical education and any other subjects which it is decided should be part of the National Curriculum. (Department for Education 2012)

For some, particularly politicians, this seems relatively straight forward and it would appear at first glance that the important initial step is, as required by the brief, to define the knowledge that resides in the subjects to be taught. But this is more problematic than it seems, as the nature of knowledge is itself contested. There are some who hold an absolutist view of knowledge—for example, Immanuel Kant in the past and Richard Peters (1973) and Anthony O'Hear (1992) in more recent times—and for whom the knowledge exists 'out there' independent of the knowers. This has been criticised as perpetuating "a view of man [sic] as a dehumanised, passive object" with humans seen "not as a world producer but as world produced", leading to the assertion that such a view of knowledge is fundamentally dehumanising, ignoring the intentionality and expressivity of human action (Esland 1971, p. 70).

This view is confronting for the technology curriculum, where 'taking action' is seen as a fundamental aspect of technology. The absolutist position is challenged by the post modernist movement (e.g., Doll 1993) which completely rejects certainty and insists that what is known is dependent on the communities which have generated the knowledge. It is also subject to change as these and other communities contest that knowledge. For those wishing to put established, unchanging knowledge as a central organising tenet of the curriculum this is extremely uncomfortable.

But in tackling a technological task—and perhaps any task—there is the need for what might be termed 'reliable knowledge of the moment', that knowledge which a recognised community of practice has deemed fit for purpose in tackling the task. Hence while we as technology educators might acknowledge that technological knowledge is a socio-cultural construct, subject to change and interpretation, we will have to identify, describe and limit the knowledge we believe should be taught as part of the school technology curriculum. There is of course a tension here for those educators who adopt the position that in tackling a technological task the particular knowledge, skills and understanding that are needed to be successful should be acquired by the pupil on an as needed basis as part of tackling the task, as opposed to being explicitly taught as a precursor to tackling the task.

A further complexity for curriculum development is that politicians invariably want an education system in which it is possible to show that pupils are making progress. This has immediate implications. If the purpose of the curriculum is seen as the assimilation of the knowledge, however such knowledge is identified and selected, one way to monitor progress is to assess pupils with regard to their assimilation of the required knowledge. This has led to the production of documentation detailing a sequence of statements of attainment against which progress over time can be assessed—which, in turn, has led to the introduction of national formal testing arrangements in which pupil attainment is measured. Robin Alexander (1984) has questioned this in that "assessment via *formal* testing or other publicly verified procedures can only deal with very limited and specific areas of school work and is much less important than the continuous *informal*, (even unconscious) evaluation of the pupil by the teacher" (pp. 36–37).

The impact on classroom practice in England has in some cases been pernicious. Pupils are given level descriptors for particular requirements at the beginning of individual lessons and required to meet these through prescribed activities during the lesson. At the end of the lesson they discuss with the teacher and other pupils the extent to which they have met these requirements. In this way there is a continuous lesson-by-lesson monitoring of performance and both teachers and pupils are under pressure to ensure that progress is being made in terms of moving to higher levels of achievement as defined by the descriptors.

The problem here is twofold. The first is that the reason for learning the subject is lost and becomes reduced to achieving incremental, atomised features of learning which do not embrace the totality or worth of the subject. The second is the belief that pupils need to have clear and explicit criteria so that they can take responsibility for the orientation and the assessment of their own work. In principle this is a good idea but it is fraught with dangers. Enabling pupils to appreciate the meaning of learning criteria is not a trivial exercise. In addition, criteria to decide on the worth of a significant endeavour in technology will almost certainly involve holistic as opposed to atomistic judgment. The ability to make such judgement will be demanding of both teachers and pupils and needs to be built over time through discussion and reflection. In the light of this Paul Black (2013) commented to me, "The saying that appeals to me here is 'How do I know where I am going until I get there?' There's more truth in this than is evident at first sight."

While these issues are dealt with in more detail in Chap. 7 on assessment and Chap. 5 on pedagogy, here it is important to make two points. First, assessment of pupils in technology will inevitably be a feature of the curriculum and it is essential that curriculum be assessed in ways—both formative and summative—that are valid, reliable and adaptable to pupils' individual responses to the subject. Second, the use of assessment is a key feature of pedagogy that allows the teacher to gauge understanding and progress and as such should be considered explicitly as an integral part of pedagogy as opposed to an optional add on.

The process of devising a curriculum requiring the acquisition of previously identified knowledge and developing from this curriculum statements of attainment by which progress may be assessed has received significant criticism. It is not that such approaches produce curricula completely devoid of worth in various parts. Rather, it is that such curricula do not make explicit their own ideological position as to the overall purpose of their educational intentions (Kelly 2009). If an avowed purpose is for education to develop young people who can play a full part in a democratic society this requires a different perspective from the educator in order to ensure that curricula and practice in schools derived from curricula meet this requirement.

Stenhouse (1975) and Bruner & Haset (1987) amongst others have argued that to achieve this it is imperative to see curricula as process and development, and devise curricula accordingly. Hence it is important to identify procedural principles through which a curriculum may be devised, interpreted and implemented. This approach to curriculum takes cognisance not only of what the curriculum offers but also how it is offered. The important role of pedagogy in defining the 'how' of learning technology is discussed in detail by David Mioduser in Chap. in 5 and Wendy Fox-Turnbull in Chap. 6.

I warm to the idea of identifying a set of ‘procedural principles’ as advocated by Stenhouse and Bruner to inform a curriculum for two reasons. First it provides a framework which keeps sight of the nature of what is being taught and its worth. This is important as if teachers lose sight of this then the whole exercise ceases to be educational and is reduced to rituals of good test scores and qualification acquisition. Second it allows for interpretation by a teacher as to both the content of the curriculum and the way in which it is taught. This is important as the content of technology education is subject to change perhaps more than any other area of the curriculum and there is increasing choice in ways to teach given the varieties of technology enhanced learning that are becoming available. Hence it is important to identify a set of procedural principles that might be used to devise a technology curriculum and guide its implementation. This will be addressed in the next section.

Three Procedural Principles to Inform the Development of a Technology Curriculum

For this purpose I have identified the following three key procedural principles:

- Procedural principle 1—being true to the nature of technology.

  This creates boundaries for the endeavor, avoiding confusion with other areas of the curriculum while at the same time enabling relationships with them. However, it is not simple as ideas concerning the nature of technology are contested (see Chap. 2, this volume, by Steve Keirl).
- Procedural principle 2—developing a perspective on technology.

  It is important the pupils develop a view of technology and how it might be used. Such views should be developed through discussion and reflection as opposed to being taught through instruction (see Chap. 3, this volume, by Marilyn Fleer).
- Procedural principle 3—enabling technological capability.

  It is important that pupils experience what it means to ‘do’ technology as opposed to just learning about technology. This implies that pupils will devise and produce technological outcomes in a variety of forms (see Chap. 5, this volume, by David Mioduser).

The three procedural principles identified here can enable technology educators to develop curricula in which they can be confident from at least four perspectives. First, it will be valid in that it deals with technology in ways that recognise the nature of technology. Second, it will enable young people to take a critical yet constructive view of technological activity as it unfolds in society around them. Third, it will enable young people to be technological themselves using a variety of approaches and tools, both analogue and digital. Fourth, it will have the capacity to incorporate new and emerging technologies as they are invented and developed in the world outside school. In short the procedural principle approach will give rise to technology curricula that can be justified as part of a technology education for ALL young people.

There are of course other procedural principles that could be invoked to inform the development of a technology curriculum, for example, it must be possible to assess the curriculum that is developed, the developed curriculum must be affordable within school budgets, the developed curriculum must be 'teachable' by the majority of teachers, etc. However these principles, while important, are not specific to technology education. They operate at a lower level of significance. Hence I have restricted the discussion to the three principles I think are most important.

Each procedural principle will be considered in turn although it is important to realise that in using them to develop a technology curriculum they will interact with one another in a dynamic way, each informing to a greater or lesser extent any curriculum consideration.

Being True to the Nature of Technology

Technology is not easy to define, as different philosophical positions lead to different definitions. Kelly (2010) in his provocative book *What technology wants* discusses the idea of autonomous technology in terms of three interacting influences.

> The primary driver is pre-ordained development—what technology wants. The second driver is the influence of technological history, the gravity of the past, as in the way the size of a horse's yoke determines the size of a space rocket. The third force is society's collective free will in shaping the technium, or our choices. (p. 181)

From this perspective it appears that the influence that mitigates against technological inevitability is the smallest of these influences. He compounds this position by describing technological development in terms of a set of trends that contribute to the expression of particular technologies and how they might progress. In this set he includes increasing sentience, which may give cause for concern given that deeply embedded in popular culture is the idea of machines becoming self aware and either dominating human life as in the film Metropolis (1927) or deciding that humanity is antithetical to its own existence as in the Terminator films (1984, 1991, 2003 and 2009) and actively waging war on humanity.

Nye (2006) rejects this idea:

> From the vantage point of the present, it may seem that technologies are deterministic. But this view is incorrect no matter how plausible it may seem. Cultures select and shape technologies, not the other way around . . .A more useful concept than determinism is technological momentum, which acknowledges that once a system such as a railroad or an electrical grid has been designed to certain specifications and put in place it has a rigidity and direction that can seem deterministic to those who use them. (Location 2075 of 2662)

Arthur (2009) takes a different starting point in considering the nature of technology and the way it evolves. He argues that technology can be seen as the exploitation of phenomena revealed by science. He rejects a simplistic 'technology is applied science' view but is adamant that it is from the discovery and understanding of phenomena that technologies spring.

He notes that

> It should be clear that technologies cannot exist without phenomena. But the reverse is not true. Phenomena purely in themselves have nothing to do with technology. They simply exist in our world (the physical ones at least) and we have no control over their form and existence. All we can do is use them where usable. Had our species been born into a universe with different phenomena we would have developed different technologies. And had we uncovered phenomena over historical times in a different sequence, we would have developed different technologies. (p. 66)

John Naughton (1994) adds further weight to the rejection of a simplistic applied science view of technology when he writes that technology always involves "ways of doing things. . . a complex interaction between people and social structures on the one hand and machines on the other" (p. 12). John's description immediately, and to my mind rightly, complicates the technology curriculum in that a consideration of machines, which many would see as a basis for a technology curriculum, becomes insufficient.

The work of Wynn Harlen and colleagues (e.g., Harlen 2010) in developing statements of content for science education that were true to the nature of the subject may provide us with a useful model. They divided the content into ideas **about** science and ideas **of** science. What might be developed if we adopted such an approach for technology education? Here are my suggestions:

Ideas **about** technology might include

- Through technology people develop technologies and products to intervene in the natural and made worlds.
- Technology uses knowledge, skills and understanding from a wide range of sources, especially but not exclusively science and mathematics.
- There are always many possible and valid solutions to technological and product development challenges, some of which will meet these challenges better than others.
- The worth of technologies and products developed by people is a matter of judgement.
- Technologies and products always have unintended consequences beyond intended benefit which cannot be fully predicted by those who develop them.

Ideas **of** technology might include

- Knowledge of materials

Technological activity requires the use of materials. And if someone is going to use materials he or she will need to know something about them. So what needs to be known? Clearly the idea of properties, with different materials having different properties, is essential. Given the importance of eco footprints, it will be useful to know something about sources of materials and how they are refined to the state where they are useful. And given the finite nature of the material world it will be useful to know something about the estimated reserves of materials, especially those that are particularly useful and in short supply. This can be listed as:

Sources
Properties
Footprint
Longevity

- Knowledge of manufacturing

The next step of course is to be able to do something with these materials, so manufacturing is an important idea of technology. In broad-sweep terms manufacturing can be divided into four main methods—subtraction, addition, forming and assembly—and overlaid on each of these are methods of finishing. At the moment addition is receiving considerable attention as additive manufacture is being used to produce items of both simplicity and complexity at very different scales to the point where it will almost certainly be possible to 'print' organs for transplant. This important idea of technology can be subdivided as:

By subtraction
By addition
By forming
By assembly
With finishing

- Knowledge of functionality

Most of the made world has to 'work' so some knowledge of achieving functionality is required. Three categories spring to mind: powering, controlling and structuring. Controlling is moving on in leaps and bounds with the embedding of electronic intelligence into everyday products becoming commonplace and the technology to achieve this is within the reach of schools through microcontrollers such as picaxe and arduino. So this important idea of technology can be sub divided as:

Powering
Controlling
Structuring

- Knowledge of design

Very little of the made world comes into existence except through designing. So knowledge of design is crucial, but teaching designing has long been seen as the Achilles heel of the subject. Four broad methods will be needed: identifying peoples' needs and wants, identifying market opportunities, generating and developing design ideas, and evaluating design ideas. This set of methods taken together and used sensibly will enable people to envisage outcomes that do not as yet exist, and create these outcomes through choosing and using materials and embedding function. So this important idea of technology can be sub divided as:

Identifying peoples' needs and wants
Identifying market opportunities
Generating and developing design ideas
Evaluating design ideas

- Knowledge of critique with regard to impact

The question that immediately follows is to what extent are these outcomes of worth? How do they affect the lives of those who use them and those that make them? How do they affect the planet? Here we immediately see the need for critique. This is different from evaluation as defined in 'evaluating design ideas'. Two broad areas of critique are stewardship and justice. Critiquing for stewardship involves considering life cycle analysis and speculating about different economic models—the currently predominant linear economy and the circular economy as espoused by, for example, the Ellen MacArthur Foundation (2012a, b). In a just world all people should be able to live in freedom from hunger and fear and have shelter from harm. They should have opportunities to pursue happiness and make the best of their lives. The made world full of deliberately designed products, environments and systems must be held to account by critique. So critiquing the outcomes of others is an important pupil activity. This important idea of technology can be sub divided as:

For justice
For stewardship

Within such a framework, 'ideas about technology' would mainly inform the development of a perspective on technology while the 'ideas of technology' would be essential for enabling technological capability. It must be acknowledged that these 'ideas of technology' will lead to a view of capability that is limited to the extent that it will manifest itself mainly through pupils' designing and making activities. However, despite this limitation, these complementary aspects of technology can be used to shape a technology curriculum such that it is true to the nature of technology.

Developing a Perspective on Technology

The cultural and democratic arguments for teaching technology cited earlier in this chapter have as one of their aims giving young people insight into 'how technology works' such that they develop a constructively critical view of technology, do not become alienated from the technologically-based society in which they live, and are able to consider how technology might be used to provide products and systems that help create the sort of society in which they wish to live. Underpinning this is the idea of giving young people a perspective on technology which meets these aims.

An important concept for understanding the way technology works is that of disruptive innovation as defined by Christensen (2012): novel technologies that disrupt prevailing markets. The way in which transport was mechanised by the application of the internal combustion engine to vehicles that had hitherto been horse drawn was a revolutionary technological innovation. But it was not, at its inception, a disruptive innovation because early automobiles were expensive luxury items that did not disrupt the market for horse drawn vehicles. The market for transportation essentially remained intact until the debut of the lower priced Ford Model T in 1908. Henry Ford (1922) indicated his intention to be disruptive as follows:

> I will build a car for the great multitude. It will be large enough for the family, but small enough for the individual to run and care for. It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one—and enjoy with his family the blessing of hours of pleasure in God's great open spaces. (p. 73)

The means to mass-produce automobiles was the disruptive innovation because it changed the transportation market. The automobile, by itself, was not. It was the development of this production system that enabled the profitable manufacture of large numbers of vehicles that were affordable both in terms of purchase price and running costs, giving rise to a transport system that completely revolutionised our way of life. To accommodate the needs of the motorist (and to provide for movement of goods by lorries and tankers), a large network of roads and motorways has developed. The use of motor vehicles on this transport network contributes significantly to pollution of the atmosphere and global warming. Learning to drive and acquiring a motorcar have become a rite of passage for most young adults, male and female, in many countries. The opportunity to move from your place of birth to new and different places, to gain employment, to meet new people, to form friendships and relationships is facilitated by the motorcar. However, this physical and social mobility can have a deleterious effect on small, localised communities. Since the first road-crash fatality in 1896, motor vehicles have claimed an estimated 30 million lives globally. On average, someone dies in a motor-vehicle crash each minute in the world.

When the motorcar was invented and the automobile industry was born, no one envisaged that subsequent design iterations would be responsible for environmental damage, social upheaval, and a colossal death toll. What would Henry Ford have said if it had been suggested to him that his manufacturing innovation would harm the planet, erode family values, and kill millions of people? He would probably have been incredulous. He might have argued that society would step in and stop all those dreadful consequences by managing the way this new technology would be used. But he would have been wrong. Of course, Henry Ford and his designers and engineers were not of malign intent. They saw what they were doing as providing considerable benefit to many people. And, in that respect, they were correct. The motorcar has been highly beneficial to many individuals, communities, and societies—but at a cost: the cost of impact beyond intended benefit.

It is instructive to go back even further in time and consider the impact of a very simple technological development—the needle. The first evidence of the use of needles is circa 40,000 years ago. The ability to sew animal skins together to produce clothing and tent-like structures had a major impact on the lives of early humans. The use of the needle and thread made one's life not only more comfortable but increased one's chance of survival. Couple this with the invention of felting and weaving for the production of cloth and the humble needle can be seen as a revolutionary technological development. It was not disruptive in the sense identified by Christensen (2012) in that it did not disrupt the markets for clothing and tent production, as these markets did not yet exist. In fact one might argue that the needle created these markets. It was not until the late eighteenth century that the needle became mechanised with the invention of the sewing machine. Initially these were hand driven, later by foot pedal and later still by the addition of an electric motor. But a significant limiting factor in the use of the sewing machine, whether hand, foot or electric motor driven, is that it requires a human operator. Although computer-aided embroidery is now well established, and while the embroidery itself is computer-driven, the placing of the fabric to be embroidered on the machine is still carried out by humans. At the time of writing the robots so ubiquitous now in car manufacturing cannot handle fabric. This requires the dexterity of humans. It remains to be seen whether fabric-handling robots will be developed, but even if they are they will not be disruptive in that they cause the clothing market to be replaced or significantly reduced by another market. However it is noteworthy that the use of robots in a wide range of manufacturing is increasing and that this is seen as reducing the need for human labour (Finkelstein 2013)—an important consideration when developing a perspective on technology.

In developing a perspective on technology it will be important to engage young people with technological trajectories into the future as opposed to simply providing information of past trajectories up until the present, although appreciation of technology history is not seen as without merit. Witness the inclusion in recent design & technology National Curricula in England of statements such as ". . . they evaluate present and past design and technology, and its uses and effects" (QCA 2007) and "Through the evaluation of past and present design and technology, they develop a critical understanding of its impact on daily life and the wider world" (Department for Education 2013a).

Might it be possible for pupils at school to speculate in a rational way about the future uses of technology and will they respond positively and enthusiastically? There is some encouraging evidence from the Young Foresight project (Barlex 2012) that this might be the case. The Young Foresight project required pupils to work collaboratively in designing but not making products and services. The project identified four factors that teachers should encourage their pupils to take into account:

- The technology that is available for use. This should be a new and/or emerging technology and be concerned primarily with how the new product or service will work. Pupils should not concern themselves with manufacture.

- The society in which the technology will be used. This will be concerned with the prevailing values of the society, what is thought to be important and worthwhile. This will govern whether a particular application of technology will be welcomed and supported.
- The needs and wants of the people who might use the product or service. If the product does not meet the needs and wants of a sufficiently large number of people then it will not be successful.
- The market that might exist or could be created for the products or services. Ideally, the market should be one with the potential to grow, one that will last, and one that adapts to engage with developments in technology and changes in society.

Clearly, these factors interact with one another and influence the sorts of products and services that can be developed and will be successful. Considering these parameters, unencumbered by the necessity of making the proposed designs, enables pupils to be creative and develop highly original conceptual design-proposals. Some of the products and services devised by groups of Year 9 pupils in response to the challenge of utilising the stress sensitive conductor QTC (Quantum Tunnelling Composite) included the following:

- clothing that changes colour as you dance
- car tyres that sense their internal pressure
- an epileptic fit detector
- a self-weighing suitcase
- an arthritis treatment device
- keep fit apparatus
- a depth sensitive submersible
- an internal heart beat monitor.

The development and justification for products and services derived from new and emerging technologies could be a first step in developing a perspective on technology and the Young Foresight approach provides one way of doing this. To enhance this perspective it would be necessary for pupils to put their suggestions into an historical context: what, if any, similar products or services had existed before, how were they received by society, and what impacts did they have on society? It would also be important for pupils to speculate about impacts beyond the intended benefits that might arise if their ideas had wide implementation. Three important features of this approach to developing a perspective on technology are (a) it enables the curriculum to keep pace with the technological developments and innovations taking place in the world outside school, (b) pupils can choose for themselves which new and emerging technologies they wish to consider, and (c) pupils can be encouraged to actively speculate about the way new technologies might play out in alternative technological futures.

Enabling Technological Capability

This principle is important because it captures an essential feature of technological activity—that its main concern is with intervention as opposed to understanding; a key difference between science and technology. Drexler (2013) captures this well when he describes the difference between engineering design and scientific enquiry. Whereas science begins with a physical system (the object of study) and moves towards an abstract model (theory), engineering starts with an abstract model (a design concept) and moves towards a physical system (useful product). David Layton was particularly insightful here when he wrote that the primary purpose of design & technology education is to develop in pupils the ability to "intervene effectively and creatively in the made world" (Department for Education and Science and the Welsh Office 1988). Kimbell and Perry (2001) captured this requirement as follows:

> The real products of design & technology are empowered youngsters; capable of taking projects from inception to delivery; creatively intervening to improve the made world; entrepreneurially managing their resources; capably integrating knowledge across multiple domains; sensitively optimising the values of those concerned; and confidently working alone and in teams. (p. 19)

The comment "sensitively optimising the values of those concerned" is particularly important since the technical content identified in 'ideas of technology'—knowledge of materials, manufacturing and functionality—does not exist in a vacuum. When operationalised through designing, value judgements have to be made as to what is worth doing with technical know how and what the consequences of doing such things might be. This is of course reflected strongly in the last two statements in ideas 'about' technology and in the inclusion of knowledge of critique in 'ideas of technology' (see the previous section).

Most technology curricula enable technological capability to some extent through activities in which pupils design what they are going to make and then make what they have designed. This is often seen as the heartland of technology education, although it does not reflect the reality of technological activity in the world outside school, where those who design artefacts are usually not those who manufacture them. As has already been acknowledged, this approach can be seen as a limited view of capability, but it terms of feasible pupil activity it does embody 'intervention' in a powerful way.

Underpinning the activity is the act of designing, which featured significantly in 'ideas of technology'. Although making the designs of others is not without educational worth (see Barlex 2011a), the essence of capability comes from pupils conceiving their own designs that they then realise. Hence it is important to pay considerable attention to the role of designing in enabling technological capability.

The decision making that students have to undertake when they are designing and making has been described as involving five key areas of interdependent design decision:

- conceptual (overall purpose of the design, the sort of product that it will be)
- technical (how the design will work)
- aesthetic (what the design will look like)
- constructional (how the design will be put together)
- marketing (who the design is for, where it will be used, how it will be sold).

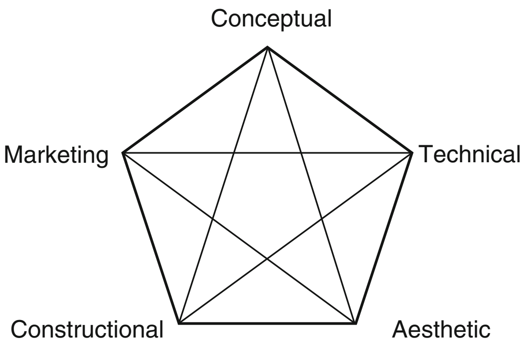

Fig. 8.1 The design decision pentagon

This approach can be represented visually as a pentagon diagram shown in Fig. 8.1. The interdependence of the areas is an important feature of design decisions; hence the lines connect each vertex of the pentagon to all the other vertices. A change of decision within one area will affect some, if not all, design decisions that are made within the others. Although the teacher usually identifies the sort of product the students will be designing and making, which makes it very difficult for students to engage in conceptual design, there are still many opportunities for making design decisions in the other areas. It is the juggling of these various decisions to arrive at a coherent design proposal that can then be realised to the point of a fully working prototype that provides the act of designing and making with such intellectual rigour and educational worth that it is seen as an essential aspect of technology education.

The pentagon diagram can be further developed by adding three important supplementary questions when considering the combined effect of the design decisions that result in a particular product: What is the social impact of the product? What is the economic impact of the product? What is the environmental impact of the product? (See Barlex 2011b.)

It is worth noting that enabling technological capability can be situated in contexts in which there are inequalities to be resolved. In short, issues of justice are an important feature of critique noted in ‘ideas of technology’. The writing of Emily Pilloton (2009) in *Design Revolution* is inspirational in this regard. Emily adopts an unashamedly social activist position with regard to design, and to my mind by implication technology.

It is through design and subsequent making that technologies of various sorts are developed and then utilised, be it for good or ill. Engaging students in using technology for societal improvement through designing and making is challenging, but can be defended by applying the procedural principle ‘enabling technological capability’ to curriculum development and implementation.

Possible Futures for Technology Education

In this section I consider possible future technology curricula in the light of each of the three procedural principles developed above. I also consider briefly the overall future of technology education in the school curriculum, particularly in terms of its relationships with other school subjects.

A Future Curriculum in the Light of Being True to the Nature of Technology

Recently, Williams and Lockley (2012) explored the views of early career science and technology teachers to identify what might be considered ‘enduring ideas’ within the subjects they taught. Interestingly, this research revealed that while the science teachers had little difficulty in identifying such ideas this was not the case for the technology teachers. The authors noted that this may be in part due to the extensive place of procedural knowledge in technology but also that technology has no commonly agreed upon epistemology. A similar enquiry that I carried out with a colleague (Barlex and Steeg 2013) with trainee design & technology teachers at two universities in England revealed similar findings. The responses of the trainees indicated that there was little uniformity concerning enduring ideas and that there was considerable difference between their individual perceptions of the nature of the subject.

To those of us who know design & technology teachers this might not come as a surprise, but the lack of unanimity is a cause of great concern. If the subject community has difficulty in reaching agreement on subject content then it is small wonder that those outside the subject, especially government ministers and their officials, find the subject difficult to fathom. Hence the procedural principle of being true to the nature of technology is of fundamental importance to the future of technology curricula.

It is noteworthy that understanding the nature of technology is an explicit feature of the New Zealand Technology Curriculum (Ministry of Education 2007), while such understanding is only implicit in the curriculum of England (Department for Education 2013a). At a research level, attempts are being made to establish a more coherent view across various communities of practice. These include the Delphi study carried out by de Vries et al. (2009) and the recent publication of *New principles for Design & Technology in the National Curriculum* by Education for Engineering (E4E 2013). Clearly technology curricula in different countries will need to respond to their particular cultural contexts (see Chap. 4, this volume) and it would be inappropriate for orthodoxy to become uniformity, but some generally accepted view is required if the subject is to be understood and valued.

A small case study that I recently conducted indicates that those training to be design & technology teachers respond positively to the complex and contested nature of technology (Barlex 2011b). The students were challenged with the following questions:

- Is technology autonomous and beyond our control or is technology under human control?
- Does technology control us or do we control technology?
- Is technology value-neutral or does it have implicit values?
- Does the availability of technology change human behaviour?
- Who decides which technologies are developed?
- Who decides which technologies are adopted?

These prompts led to wide-ranging discussions and an overall agreement that the nature of technology should feature in school design & technology curricula. While there were differences of opinion as to when such consideration should be introduced, the overwhelming view was that to avoid such a consideration would be to the detriment of the subject and compound the erroneous view of the Expert Panel that the subject lacked disciplinary coherence.

A Future Curriculum in the Light of Developing a Perspective on Technology

Helping young people to develop a perspective on technology requires them to appreciate values that empower them to critique, a facility that Layton (1995) has argued is an essential feature of technology education. The specific inclusion of critique in 'ideas of technology' and the place of both intended and unintended impacts in 'ideas about technology' highlight critique as an increasingly important aspect in technology education.

It is only relatively recently that concern has been raised about the impact of technological activity on the environment, although some prescient voices such as Rachel Carson (1965) in *Silent Spring* began making the case much earlier. The recent pronouncements of the Intergovernmental Panel on Climate Change (IPCC) indicate that the science underpinning concerns about global warming is robust and that such warming will have considerable effects on the weather patterns of the planet:

> Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system. (IPCC 2013, p. 13)

It is also generally accepted that the rate at which we are consuming finite resources is unsustainable. Both global warming and the rate of finite resource consumption can be laid at the door of technological activity, although it is reasonable to describe these as unintended consequences or impact beyond intended benefit. Unintended or not, however, they are the cause of considerable concern and now most school technology curricula give significant place to what might be termed 'education for sustainable development'.

Pavlova and Pitt (2007) believe that it is vital to avoid the implicit suggestion that sustainability is just another thing to think about in technology education, but that it should be a major consideration throughout the entirety of a school technology curriculum. However they are wary of preaching to achieve any significant change:

> There is a danger, however, that students (many of whom are products of a materialistic, individualistic, hedonistic, high-consumption-and-bugger-the- consequences, instant gratification society) will be bored out of their heads by overt moralising. (p. 86)

This poses a significant challenge to a school technology curriculum, as individual students and their families have little power over which technologies are created and, if they are to take part in society, little power over which technologies they use. To achieve a society in which a prevailing value is 'stewardship of planet earth' thinkers such as Braungart and McDonough (2009) and Webster and Johnson (2008) are arguing for a radical shift in the way technological activity is carried out. They argue that we should move from the current linear economy to a circular economy, which mirrors the way nature operates. In a linear economy finite materials are gathered from the natural world, turned into goods, which are used and then disposed of. In most cases this disposal leads to the materials becoming part of landfill. Hence, society will ultimately run out of these useful materials. The use of recycling, which is not an efficient process, only delays the time until the materials run out. It is not a long-term solution. In a circular economy, by contrast, the concept of waste is eliminated. Materials that would be seen as waste in a linear economy become the feedstock for other processes, mirroring the way materials in the natural world are always part of cycles that move them through a variety of linked ecosystems.

To become effective, products and production systems will need to be redesigned to meet this circular economy approach. This approach has been adopted by the Ellen MacArthur Foundation, which is actively and successfully lobbying both politicians and business leaders about the commercial and environmental benefits of moving to a circular economy. The Foundation has produced two significant reports (2012, 2013) identifying the considerable business opportunities in moving towards a circular economy. By responding to the procedural principle 'developing a perspective on technology', the curriculum will be able to consider the way technological activity is carried out in the world outside school and how different economic models can give rise to different futures.

A second dimension of critique that was identified in 'ideas of technology' was justice. It is clear that new and emerging technologies will have considerable impact on society in ways that affect the lives of individuals and communities. Which technologies are developed, the ways in which they might be deployed, and to whom they are made available are all important considerations for developing a perspective on technology. I think it is likely that technology curricula will respond to the 'perspective' procedural principle not only in terms of stewardship but also justice. This is starting in a small way in England through a curriculum development project concerned with disruptive technologies (Barlex et al. 2013) which will consider how the following technologies might be introduced into the school technology curriculum through a collaboration between school teachers, teacher trainers and those engaged in related research and development:

- Additive manufacturing
- Artificial intelligence
- Augmented reality
- Big data
- Intelligent matter
- Internet of things
- Neurotechnology
- Robotics
- Synthetic biology

Reasons for including aspects of disruptive technologies in the design & technology curriculum include:

- To help learners in design & technology engage in futures thinking.
- To engage learners with the ways in which technology leads to change.
- To help teachers understand what critiquing disruptive technologies offers to design & technology education.
- To begin to equip learners for a world in which many technologies are rapidly becoming more democratised and more available to the masses.
- To start to unpick, with learners, how new affordances will redistribute social, moral, environmental, financial, etc. responsibilities.

Here again we see how the adoption of the procedural principle approach outlined above facilitates the introduction of new elements into the technology curriculum.

A Future Curriculum in the Light of Enabling Technological Capability

The tools available to young people engaged in technological activity at school are becoming more sophisticated. The E4E (2013) publication *New principles for Design & Technology in the National Curriculum* deliberately formulated its approach in terms of a toolbox containing features that pupils could use in developing and demonstrating their technological capability. The availability of a wide range of CAD software with significant tutorial support, some freely available as in the case of SketchUp and Autodesk, enables young people to develop design proposals that range from the simple to the sophisticated.

An issue for those teaching pupils to use such software as part of the technology curriculum is of course the worth of what is being designed. My view here is that it is important to generate ideas of worth. A question that should be addressed by both teachers and pupils is, “To what ends are we deploying our technological capability?” This might be rephrased as, “Is what we are designing worth making?”

An additional issue in pursuing the procedural principle of enabling technological capability is the extent to which pupils have a voice in deciding the nature of the tasks they tackle. Brundrett and Silcock (2002) raise this issue when they discuss the idea of a partnership curriculum in which teachers and pupils are engaged in a process of negotiation. Recently, the Design & Technology Association in England posted on their website a set of open starting points for designing and making electronic products (Design and Technology Association 2010). These starting points are available as visual brainstorms that the teacher can use with the class to explore the context and identify many different sorts of electronic product that could be designed and made in response. These open starting points provide the opportunity to give pupils a voice as to what sort of product they want to design and make. The exact nature of the products designed and made will depend on the age and previous experience of the pupils and the resources available in the school, but giving the pupils a voice will increase their influence on the curriculum and provide greater ownership, which is likely to increase their motivation. It is easy to see how such negotiation could be enhanced through using social media, and I suspect that tasks of worth identified through teacher-pupil negotiation will feature more prominently in future technology curricula.

Computer-controlled tools for manufacture are now increasingly available in schools in England. The laser cutter is almost ubiquitous, with some schools having two or three machines. Since their introduction they have become cheaper, more reliable and durable. They allow ‘cutting out’ of complex shapes from a range of sheet materials, including textiles, that could never be achieved by pupils using conventional hand or machine tools. The 3D printer is also becoming more widely available and while it has yet to achieve the reliability and durability of the laser cutter it is coming down in price. There is also the possibility that some pupils will have access to 3D printers at home—there is a burgeoning hobby market—or via local stores which provide 3D printing facilities. So it is likely that in the near future that pupils will have access to these modern manufacturing tools that rely on digital design information. This will place the designing and making of pupils in the context of digital rights management issues as applied to products, an arena of activity that some are arguing should be tackled by Apple given their success in handling the issue with regard to music (Cilderman 2013).

It is not only in the production of form that pupils have access to sophisticated tools. The availability of inexpensive microcontrollers such as PICAXE and Arduino along with significant free-to-download tutorial support puts the designing of products with embedded intelligence easily within the grasp of pupils aged 11–14 years. The development of even more accessible programming languages based on, for example, Scratch as being developed by MIT, will enable pupil technological capability to take on a contemporary dimension unimaginable in the days of hard-wired electronics.

Here it can be seen see that pursuing the procedural principle of enabling technological capability with regard to designing and making products of worth makes it possible to give pupils access to sophisticated computer-based design and manufacture tools in parallel with the availability of similar tools to technology professionals. This provides an opportunity to continually update the technology curriculum to keep it in line with parallel developments in the world outside school. An important caveat here is that the newly available design tools should not be used for their own sake but in pursuit of tasks of worth, which can increasingly be identified through teacher-pupil negotiation.

Identity and Relationships

The sense of technology's own identity is important for two reasons. First, it becomes possible to establish technology as a subject in its own right within the school curriculum. This is necessary for the subject to be recognised, understood and valued by those responsible for the rest of the curriculum. This leads to the second reason: the nature of technology is such that it calls upon knowledge from other curriculum areas. Relationships between technology and other subjects that are mutually beneficial can only be developed and sustained if technology has a clear sense of self and its own unique contribution to education. Without this, relationships with other subjects become ones in which their educational goals dominate and technology is always the lesser partner, sometimes to the extent that it is no longer true to its unique nature. This is particularly in the case of relationships with science when technology becomes reduced to applied science. This need not be the case, and Banks and Barlex (2013) have identified a wide range of activities and approaches which exemplify the synergy and enhanced learning that can be achieved through so-called STEM activities without compromising the integrity of the contributing subjects. Chap. 10 of this volume also explores possibilities for alignment between technology and other subjects, and the potential implications.

Here it must be acknowledged that in the short term technology is unlikely to become a 'gatekeeper' subject like science or mathematics although recently the government in England has indicated that a qualification in design & technology can contribute to the school performance measures used as an accountability system for secondary schools (Department for Education 2013b). In New Zealand, a significant political step was the inclusion of technology education into the canon of subjects recognised for University entrance. However, in many countries it is unlikely that achieving qualifications in school technology courses will become an essential pre-requisite for entry into particular forms of further or higher education or occupation. This does not in any sense deny its value as an essential component in the general education for all pupils, but it does mean that those who teach technology in these countries will have to be pro-active in promoting its benefits and ensuring it is valued by those who have influence in the curriculum.

Some argue that limiting links to mathematics and science alone, as in many STEM proposals, is insufficient. Hence there is a small but growing STEAM movement— where STEAM stands for science, technology, engineering, arts and mathematics. White (2012) provides a rationale for this widening of links to the arts as follows:

- Arts education is a key to creativity.
- Creativity is an essential component of, and spurs innovation.
- Innovation is agreed to be necessary to create new industries in the future.
- New industries, with their jobs, are the basis of our future economic wellbeing.
- A win-win situation—low cost, job growth and insuring the future.

He cites US Education Secretary Arne Duncan speaking to the Arts Education Partnership National Forum in April 2010:

> The arts can no longer be treated as a frill . . . arts education is essential to stimulating the creativity and innovation that will prove critical to young Americans competing in a global economy. . ..

I would question this highly utilitarian approach to arts education but I think that another rationale can be developed based on our second procedural principle of developing a perspective on technology. This is exemplified by the work of James Bridle (2013), an artist and an activist, who hopes his work calls into question our sometimes blind reliance on technological systems with which we come into contact every day. Hence he has engaged with the debate on the use of drones for covert warfare through his project *Dronestegram*, a social media tool that identifies recent areas of drone strikes, and *Drone Shadow*, a full-scale outline of a drone painted on the sidewalk outside of the Corcoran Gallery across the street from the White House. I think this provides an interesting model for developing critique, a key feature of developing a technological perspective.

For teachers who wish to develop their own technology curricula the three procedural principles identified provide signposts for their endeavours. Teachers can identify areas of learning and associated activities they think will be appropriate and use the principles to scrutinise their validity. In a similar way the three principles give technology educators the tools with which to consider and critique any technology curricula that might be espoused by governments or agencies seeking to modify current technology curricula or to introduce technology curricula for the first time. Once the worth of any proposed changes has been clarified and acknowledged the extent to which technology teachers are able to respond positively to any worthwhile changes can be discussed. This allows teachers to identify and lobby for relevant professional development. It also allows teacher educators to modify their offerings in initial teacher training.

In looking at future technology curricula it is worth considering the views of Keri Facer (2011), who challenges the prevailing concept of the school. In her book, *Learning futures, education, technology and social change*, Facer reconceptualises schools as places where communities build their *own* future. Keri is particularly concerned that advances in new and emerging technologies will have significant and as yet unknown impacts on our society and by implication on education. At the end of the book she outlines nine conditions to enable future-building schools. Of these, one is particularly relevant to technology education: develop an ethical code for the educational use of digital and biotechnologies. Here Facer argues that schools should no longer be recipients of new socio-technical practices developed in the world outside school but could rewrite the relationship between education and socio-technical change as one of active design, critique and engagement. Facer envisages these changes as having the potential to influence the nature of schools within 20 years. Just imagine what that would mean for teaching and learning technology.

Summary

This chapter began by asking the question "How does a curriculum come into being?" Through exploration and discussion, the first part of the chapter moved to the position where it was necessary to identify procedural principles to inform the development of a technology curriculum. The second part of the chapter introduced the following as three procedural principles: being true to the nature of technology, developing a perspective on technology, and enabling technological capability. These were then each discussed in some detail. Finally, the discussion of these principles was used to explore possible futures for technology education and to consider the relationships between technology and other school subjects.

A key question must be, "Who gains and who loses from the use of the three procedural principles identified and argued for in this chapter?" I believe that the use of the procedural principle approach to technology curriculum development will empower teachers to devise, justify and implement programmes of study that are robust and can withstand scrutiny from those who might question the worth of technology education. Governments wishing to influence or dictate technology curricula will find it more difficult to go against the justified arguments of educational professionals. While this might seem to put such governments in a 'losing position' the opposite is the case. Their thinking could become more informed through discourse with an articulate and knowledgeable profession. Those who will lose are those who adopt a narrow economic argument for technology education to the exclusion of wider considerations.

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