Science & technology education on the one hand, and communication on the other, are, to a large extent, still separate worlds and many opportunities for synergy and cross-fertilisation are yet unused. This divide is unfortunate, since educators need communication skills and communicators often use aspects of education in their strategies. Moreover, innovation processes in both domains ask for education and communication insights and skills. Therefore, scholars and practitioners in both domains must seek connections and synergy by exchanging insights and ideas. This book discusses the shared aims of science & technology education and communication, such as science literacy and engagement, as well as common processes and challenges, such as social learning, social design and professionalisation, and assessment. Aims, processes, and challenges that inspire, enhance and deepen the education and communication synergy from a theoretical and practical side. If one reads the various chapters and reflects on them from one’s own perspective as a scholar or practitioner, the question is no longer if cross-fertilisation and synergy are needed, but when are we seriously going to take up this challenge together. This book aims to initiate the dialogue that the situation in the development of the topic requires at this point.
Science and Technology Education and Communication
INTERNATIONAL TECHNOLOGY EDUCATION STUDIES

Volume 15

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Scope
Technology Education has gone through a lot of changes in the past decades. It has developed from a craft oriented school subject to a learning area in which the meaning of technology as an important part of our contemporary culture is explored, both by the learning of theoretical concepts and through practical activities. This development has been accompanied by educational research. The output of research studies is published mostly as articles in scholarly Technology Education and Science Education journals. There is a need, however, for more than that. The field still lacks an international book series that is entirely dedicated to Technology Education. The International Technology Education Studies aim at providing the opportunity to publish more extensive texts than in journal articles, or to publish coherent collections of articles/chapters that focus on a certain theme. In this book series monographs and edited volumes will be published. The books will be peer reviewed in order to assure the quality of the texts.
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Like all books, this one has a certain history that to some extent reveals itself in the content. Our original intention was to make a book in which most chapters would be written by a duo of two experts: one from science and technology education and one from science and technology communication. This was directly related to the aim of this book: to seek cross-disciplinary insights concerning education and communication about science and technology. This ideal can still be read from the Table of Contents in which a few chapters indeed have this duo of authors. But soon after we started inviting the intended duo’s we had to give up the realisation of our ideal. It appeared that many of our colleagues shied back from the challenge of working with someone from a different field. This is, of course, understandable. It takes definitely more effort to write a chapter for which firstly all possible terminological and conceptual differences have to be sorted out. Apparently, the distance between the domains of science and technology education and communication is still large enough to create a substantial barrier in writing together. The more we appreciate the effort of those that accepted the challenge we posed. But we are equally grateful to those whom we invited in a second round to write chapters on their own and build bridges between the two domains by themselves. They have invested in looking over the boundaries of their own field and seek connections with what for them was a ‘terra incognita’ to a certain extent.

Part of the history of this book that caused us to deviate from our original intentions was the unanticipated call for papers by the *Journal of Research in Science Teaching* for a special issue on science education and communication. Obviously we were not the only ones to whom it had occurred that it would be interesting to invite others to write about connections between education and communication. It confirmed the idea that sometimes the time is ripe for something and then it can spontaneously emerge in different places simultaneously. Most readers will probably know that this was also the case with the invention of the telephone in the 19th Century. We want to thank our colleagues (Ayelet Baram-Tsarabi and Jonathan Osborne) that they were prepared to cooperate with us by writing a chapter for our book (Baram-Tsarabi) and sharing names of authors that had submitted texts that would fit better with our book than with their special issue. We also would like to express our gratitude for taking the effort for writing a substantial contribution to the book and the ideas we develop all together (in random order): John Dakers, Merryn McKinnon, Judith Vos, Anne-Lotte Mason, Jenni Metcalfe, Patricia Osseweijer, Emma Weitkamp, Dawn Arnold, Nick Verouden, Caroline Wehrmann, Ineke Henze-Rietveld, Dury Bayram-Jacobs, Steven Flipse, Ayelet Baram-Tsarabi and Bruce Lewenstein. Thanks also to David Barlex and Howard Middleton, colleagues in technology education, who reviewed several chapters for us. We thank all our colleagues in the Science Education and Communication group for reading and commenting on draft chapters.
PREFACE

We hope that both colleagues in science and technology education and communication will find the content of this book a source of inspiration to seek cooperation and further exchange of insights and ideas. We are convinced that this book is no more than a beginning. Science and technology education and communication are still separate worlds to a large extent and many opportunities for synergy and cross-fertilisation are yet unused. The future will show whether or not we were justified in our idea that those who seek to build bridges between the two fields will be well rewarded for their efforts. In the meantime, within our Science Education & Communication group we continue to do so. We finally want to thank the peer reviewers of the various chapters, Peter de Liefe and the Sense Publishers people that enabled us to share this idea with many others.

Delft, July 2016
Maarten C. A. van der Sanden and Marc J. de Vries
MARC J. DE VRIES AND MAARTEN C. A. VAN DER SANDEN

1. SCIENCE AND TECHNOLOGY EDUCATION
AND COMMUNICATION

Seeking the Connections

INTRODUCTION

This book aims at building bridges between two academic domains that have long lived separate lives although theoretically they seem to be closely connected. That may sound strange, but there are all sorts of reasons why theoretically related domains in practice function separately. Academic domains can be defined by their theories or methodology, but a more practical way of defining such domains is in a social way. Academic domains and communities of researchers that have their own journals, conferences, networks, etcetera. Once such social characteristics of an academic domain have been established, it is not so easy to bring together two of such domains. In the long run that can happen. In a process of many years physicists and biologists increased cooperation in crosscutting topics and in the end a new domain, biophysics, emerged. In the course of this process, specialised conferences, journals and other ways of exchanging information and ideas, were established and thus a new discipline developed. In principle this can also happen to science and technology education and communication. This book brings together insights from science and technology education and science and technology communication in order to search for the possible content of a combined domain ‘science and technology education and communication’.

A PRACTICAL REASON FOR SEEKING EDUCATION-COMMUNICATION CROSSOVERS

The editors of this book are involved in a Master programme in which science and technology education and science and technology communication are combined. Its name is simply: Science Education and Communication (SEC) and it is one of the Master programmes that are offered at Delft University of Technology, the Netherlands, since 2008. The idea behind initiating a programme with this combination was that education and communication obviously have things in common. Educators need communication skills in their teaching practice. Science and technology communicators often want to explain. Moreover, innovation processes in both domains ask for both education and communication insights and skills. That seems to be a logical reason for having a combined academic science and technology education and communication programme, but practice has shown

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that it is by no means obvious how this can be put into practice. In the programme we have students that are primarily interested in becoming a science and/or technology teacher. Their preference is to acquire the necessary skills to teach their subject in schools as efficiently as possible and they quickly see the connection with a different domain such as science and technology communication as an unnecessary burden. We also have students that enrol in the programme to become science and technology communicators. For them, the whole world of schools, teachers, pupils, parents, exams, schoolbooks, etcetera, is something that belongs to the past rather than to the future. They want to communicate with adults, not children or youngsters, scientists, engineers, business developers and policy makers. Two different subcultures in one programme that in a number of courses have to sit together and work together. It is quite a struggle to make that work. We became increasingly aware that it is not enough to have a general (and rather vague) idea that education and communication are related. More and more we became aware of the need to build specific theoretical bridges between the two domains that would prove to have a value for practice. Our idea to bring together education and communication had to be turned from promise into practice.

A BROADER CONTEXT

The challenge of bringing together education and communication is not just there for our Science Education and Communication (SEC) master programme. Even though this book will serve as a resource in our teaching, we believe that what is offered in this book has wider implications than just to serve as a foundation for the SEC master programme at Delft University of Technology (and of course, the few comparable programmes worldwide). There are many other situations in which building bridges between education and communication is of crucial importance. Probably the most obvious context in which education and communication about science and technology come together is that of informal, out-of-school science and technology education. This is the world of popular magazines, museums, workshops and the like. The audience for those products and activities are of all ages and backgrounds. Another domain where education and communication meet is that of the development of educational materials. This is often done in cooperation by classroom teachers and specialists in publishing, many of whom have a background in communication sciences. One of us (de Vries) had the experience of being involved in the development of a series of textbooks for technology education in the Netherlands. It was intriguing to see how the practical knowledge of technology teachers and the people working at the publishing house led to a synergy of knowledge and experience without which the product would never have been as successful as it was. A third example of a situation where education and communication have to be combined is that of school-industry contacts. If the educational expertise on the side of the schools is not complemented by expertise in communication on the side of the company, these contacts will be frustrating and useless. This can easily be extended to contacts between schools and other social agencies such as local governments, hospitals,
and other public services. A final example is the fact that education and communication processes are an integrated part of innovation processes within industry and society at large, and within the domains of science education and communication itself.

EDUCATION AND COMMUNICATION AS DIFFERENT WORLDS

Before focusing on bridges between science and technology education and communication, it is good to see the individual sides. Building bridges cannot be done without a good insight into the two sides that need to be connected. So let us first see what makes science and technology education specific and likewise for science and technology communication.

Science and technology education function in the context of a system in which young people go through different levels of schooling in order to exit the system with an appropriate indication of what they know and are able to. This is usually expressed in a diploma or certificate. In other words: the purpose of education is not only to help young people to acquire new knowledge and skills, but also to allocate them to either a further education path or a profession that fits with their abilities. That is reflected in educational theories in that they do not only deal with teaching and learning but also with assessment and evaluation. Some assessment aims at the enhancement of learning (usually indicated as formative assessment), but some assessment aims at providing a formal indication of the level of mastery a person has reached.

Science and technology communication covers two different fields. Most attention so far has been given to informing the general public about science and technology. This is the world of popular science and technology magazines, television programmes and museums. It differs from the formal education setting in that the allocative function is missing, generally speaking. Visiting a science centre does not lead to a formal diploma that allows entrance into a certain academic education programme, neither does subscribing for a popular technology magazine or watching a television programme. The same can be stated for the other main domain within science and technology education, which can be indicated as ‘business-to-business’ communication. This is the communication that takes place between two actors both of which already have specialised knowledge about science and technology, but not necessarily the same knowledge. When such actors have to work together, they have to communicate. This is mostly done in the context of innovation processes, for instance when a university of technology and an industrial business company have a joint research project or when a hospital works with a health care organisation to improve the use of a new drug by a certain group of patients (like elderly people or ethnic minorities). The absence of an allocative function (as in education) that results in a certain hierarchy (teachers decide about pupils) is compensated by the presence of a non-hierarchical relation, such as a customer-seller or university-company relation.

The consequence of these differences is that not everything that is relevant in education is also relevant in communication and vice versa, or at least not in the
same way. Yet, there are several ways in which bringing together insights can create synergy that is useful for both educators and communicators.

CONNECTIONS BETWEEN SCIENCE AND TECHNOLOGY EDUCATION AND COMMUNICATION

Let us now consider in what ways science and technology education and communication are connected. The first way has been briefly mentioned already. Part of what educators do is communicating and part of what communicators do is educating. Educators use theories about educating. Such theories deal with the way learners think. Some of these theories emphasise the importance of starting where the learner is in terms of his/her thinking. His/her preconceptions are important to get to know before we start teaching in a way that does not connect to their current thinking. When we do not relate to ideas learners hold already, we often reach no more than just adding additional ideas, but their own ideas will not be effected by that. As a consequence, misconceptions will ‘survive’ and remain used as a basis for understanding the world. What is taught in schools will only be used in a school context and often takes the nature of tricks to solve equations and make calculations. This is not a school problem only. When people in industry work with external parties, such as contractors, and are unable to explain what they want, pre- and possible misconceptions will also ‘survive’ in the external party’s mind. This is just an example of how education theories are of importance for science and technology communication also. Vice versa, science and technology communicators have their theories about communication. They work, for instance, with the expectancy-value theory that says that the ones with whom we communicate will approach our utterances with certain expectations and use values to assess how to respond to those utterances. A theory like that is very uncommon to feature in textbooks on education and learning. Yet it is clear that learners also work in a sort of expectancy-value mode when listening to their teachers. Therefore it would be useful for teachers to know about this theory and be aware of its meaning for education settings. There are also theories that are used in both domains already, e.g. self-determination-theory. In which autonomy, relatedness and competences give way to intrinsic motivation. While we discover this kind of theoretical cross overs we also explore possible bridging concepts, theories and models.

A second way in which education and communication about science and technology have common interest is in their aim to enhance literacy about science and technology. The concept of scientific and technological literacy is used to indicate a sort of basic set of knowledge, skills and attitude that all people living in a society in which the outcomes of science and technology play a vital part in daily life and in all professions. In education this concept has strongly grown in popularity in the 1970s and 1980s. Educators became aware that their task was more than just to convey a canon of knowledge in the scientific and technological domains. What is really needed is that people learn to use the outcomes of science and technology in a responsible way and can contribute to the social decision
making about what is desirable for the future. For communicating about science and technology this is also important as communication about specialist and in-depth knowledge is not possible if the other party does not have a basic level of understanding of the general nature of science and technology. Without that all specific knowledge hangs in a vacuum and will not lead to real understanding.

Thirdly, there is innovation as a way in which education and communication share interests, both innovation for science and technology education and communication itself and science education and communication as essential enabling processes for innovation in all kinds of domains. As a consequence, both science and technology educators and communicators need to constantly update their innovation skills. In other words: continuous professionalization is a must for both educators and communicators in science and technology. There is a double-edged sword here because science and technology, as the content of what is educated and communicated about, are themselves about innovation. That brings us to a next issue in this introduction: the content of science and technology education and communication.

SCIENCE AND TECHNOLOGY AS A CHALLENGING CONTENT

So far we have not given attention to the content of the education and communication at stake. But we do have a specific focus, namely education and communication about science and technology. Does that content matter? Can we expect specific issues to emerge? This is indeed the case. Both science and technology are known by outsiders primarily by their outcomes. The process of developing new knowledge and artefacts takes place in places to which only those involved have access. When children and pupils are asked what technology is, they do not refer to processes like designing and producing, but to the artefacts that they see around them (and particularly those that are advanced and complicated). A second important feature of science and technology is that the knowledge involved is of a rather abstract nature. This holds for science more than for technology, but engineering science certainly also contains knowledge of a fairly abstract nature. This abstractness of course creates a barrier for both educating and communication about science and technology. If we want to use the concept of ‘systems’ in either an education or a communication setting, we have to realise that what people see is not systems, but cars, traffic lights and road workers. To understand that these together form part of a traffic system requires a certain level of abstract thinking. This has to be taken into account in educational as well as communicational settings. It makes science and technology education and communication different from educating or communicating about sport or politics.

THE STRUCTURE OF THIS BOOK

There are two main sections in the book following this introductory chapter. The first deals with aims that science and technology education share. We have two in the book: scientific and technological literacy for all and engagement with respect
to science and technology. The chapter by Dakers offers a critical reflection on the
nature of scientific and technological literacy, as these terms sometimes reflect a
positivist way on science and technology that is no longer generally accepted. The
chapters by McKinnon and Vos, Masson, Metcalfe and Osseweijer, and Weitkamp
and Arnold focus on engagement as an important aim of science and technology
education and communication. McKinnon and Vos argue that engagement is
crucial enough for science and technology education and communication to be
called a ‘threshold’ concept: it largely determines whether science and technology
education and communication have been successful or not. Masson, Metcalfe and
Osseweijer discuss practical ways of enhancing engagement. Weitkamp and
Arnold describe a case study of enhancing engagement in genetics.

The second main section deals with common processes in science and
technology education and communication. Verouden’s chapter is about social
learning as a process that both science and technology educators and
communicators go through on a constant basis, and particularly about the role of
talking and silence in social learning. The chapter by Wehrmann and Henze-
Rietveld deals with professionalization of science and technology educators and
communicators. A second continuous process for both educators and
communicators is designing. This process is at the heart of innovation. Van der
Sanden and De Vries show what can be gained from insights in the philosophy of
technology as the systematic reflection on technology and design, and in design
methodology as a more empirical study of design processes. The chapter by Flipse
and Bayram-Jacobs focuses on a particular concern in designing and innovating,
namely the social responsibility that innovators have and should be aware of and
for which both education and communication theories are relevant. In this chapter
the authors reflect on the practice of responsible research and innovation (RRI)
from an innovator’s perspective. Therefore, they not only make use of RRI specific
literature, but also take insights from the other chapters of the book into account.
The third process is assessment and this is the focus of the chapters by Baram-
Tsabari and Lewenstein, and Bayram-Jacobs. Although the differences in formal
setting for education and communication cause differences in the nature of
assessing, clearly there are also many communalities in that there are common
goals, like literacy and engagement, that need to be assessed.

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SECTION 1

AIMS
2. TAKING A BICYCLE RIDE INTO THE VIRTUAL WITH SIMONDON, DELEUZE AND GUATTARI

INTRODUCTION

In this chapter I will attempt to challenge conventional thinking in terms of the communicative processes involved in thinking about technology and science education. By communicative processes, I mean the way in which issues about technology and science are communicated in education settings as well as in the media as being ‘pre-determined facts’. That is not to say that facts communicated in educational settings or via the media are not necessarily ‘true’ at the time. They may well appear true at the time but they will all inevitably change over time depending on many variabilities not yet though about.

I will argue against the concept of determinism, not by arguing for indeterminism, but, on the contrary, I will attempt to dismantle this conceptual polarity that still prevails today (right/wrong, true/false, form/matter, active/passive, subject/object). I will draw upon the work of Simondon, Deleuze and Guattari and formulate my own non-dualistic theory of technology and science communications. In order to achieve this, however, we will need to institute a paradigm shift in the structure of the pedagogy that is traditionally used in conventional teaching and learning scenarios. I will argue that we need to move beyond a process of communicating established technological and scientific ‘facts’ and ‘truths’ to one of experimentation. A pedagogy that serves to critique the pre-established norms given in technology and science communications. Communication norms or ‘facts’ that are made manifest in a multitude of ways including, but not restricted to two in particular: communication through technology and science education, and the media in all its forms. My focus in this chapter will be on science and technology communications in education.

A NUMBER OF (UN)RELATED (CO)INCIDENCES

On 5 April 1815, Mount Tambora in Indonesia began to grumble. A week later the volcano blew its top in a spectacular eruption that went on until July. It was the biggest eruption in recorded history, killing around 92,000 people and ejecting so much ash into the atmosphere that average global temperatures dipped by 3°C. In the northern hemisphere 1816 became known

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as the year without a summer. New England had blizzards in July and crops failed. Europe was hit just as badly. (Hamer, 2005)

The same year,

[...] in holiday by Lake Geneva the 18-year-old Mary Shelley and her husband Percy were trapped in Lord Byron’s house by constant rain. To divert his guests Byron suggested a competition to write a ghost story. The result was Mary Shelley’s Frankenstein. Across the border in the German state of Baden the soaring price of oats prompted the 32-year-old Karl Drais to invent a replacement for the horse – the first bicycle. (Hamer, 2005)

It is important to note that this is an interpretation as to how the bicycle was first invented. Some say that the French celerifere, a bicycle without steering, was the first bicycle to be invented, whilst other have made spurious claims that a sketch produced by Leonardo depicting a two wheeled form of transport which is essentially a bicycle. However this latter manifestation is the subject of much controversy. For the purposes of this chapter, I will assume the first bicycle invented to by Karl Drais.

Some years prior to the spectacular eruption in Indonesia, a period of unusually cold weather persevered in 1788-89 and again in 1812-13 leading, among other things, to the Thames in London being completely frozen over. This led to a new kind of personal mobility which became fashionable in the late eighteenth century: ice skating (Hadland & Lessing, 2014, p. 1). Not long after but at around the same time, roller skates were invented as a method of human powered vehicular mobility that was possible on surfaces other than ice. However, at the time, this was only possible to a limited degree due to the rough surfaces available to be traversed. Other forms of human powered vehicular mobility were also being developed from as early as the seventeenth century. For example, in 1655, paraplegic watchmaker Stephen Frailer is accredited with the fabrication of what may be the first form of human powered vehicular mobility when he was only twenty two years old.²

Over the years following, “[w]ealthy disabled people could get hand-cranked wheelchairs”⁴ whilst the less well off were restricted to forms of the cheaper Bath chair which “usually had to be drawn or pushed around by another person”⁵ (Hadland & Lessing, 2014, p. 4). Despite the innovations being developed over this period, “personal transport still relied on the horse and was therefore expensive” (ibid; 7). Moreover, during this period, horses were the principle form of transporting goods, as well as people, both directly (riding a horse) and indirectly (pulling carts for example). Horses had to be fed, whether working or not thus adding to the expense. It was somewhat devastating to European society, therefore, when horses suffered a massive decline beginning around 1812, for principally two reasons: nearly 20,000 army horses died as a result of Napoleon’s retreat from Russia, the exceptionally cold weather being the principle reason (Knight, 2012) and secondly, a series of yearly bad harvests began in 1812 leading to a decline in the supply of oats.
Oats had been used as the principle form of horse feed since ancient times. Indeed, as illustrated somewhat tongue in cheek in Samuel Johnson’s dictionary, oats were defined as “eaten by people in Scotland, but fit only for horses in England”, to which the Scotsman is reported to have retorted, “That’s why England has such good horses, and Scotland has such fine men!” (Gibson & Benson, 2014). Just to make things worse and on top of bad harvests, Europe’s grain stores had been raided by Napoleon’s starving army as it retreated from Moscow causing a serious shortage in the supply of oats (Hamer, 2005).

No human being, singularly or collectively, conspired to bring about these events. Moreover, I will argue that no transcendent being or force determined that these events should happen. In other words, these events were not pre-ordained, they were not determined in advance. Whilst history suggests to us that it is credible to assume that Napoleon was determined to overthrow Russia in and around 1812, and will have certainly planned accordingly, a number of unforeseen events led to his retreat, events that he clearly did not determine in advance. If he had, events might have been different. But is it credible to assume that some other force did pre-ordain the outcome? This leads us to the philosophical question of determinism. But what is determinism?

A full and reasoned discussion about determinism is beyond the scope of this chapter. However, I will consider briefly, determinism mostly in terms of Newtonian physics.

A BRIEF BUT NECESSARY EXCURSUS INTO THE CONCEPT OF DETERMINISM

While debated for several centuries, there is no doubt that a Universe that obeys, rigidly, Newton’s laws is strictly determinist. And while, for science, a determinist world is not logically impossible, it does seem in conflict with our common sense. Common sense tells us that we make choices. For example, while it is true that I can push a rock on a lake of ice and predict its motion with Newton’s laws, […] surely my decision to push the rock, the initial cause of motion, was not pre-determined since the beginning of time. Laplace’s “vast intelligence” implies that if a supercomputer had access to all the velocities and momentums of the atoms in my brain, then it could calculate my brain’s future state forever. It would know my thoughts, my thoughts tomorrow, who I will fall in love with, what music I will compose, simply a vast assortment of information that seems completely absurd from our everyday experience. Implicit to determinism is the fact that every event happens of necessity. It has to happen; the Universe has no choice. (Schombert, 2014)

And could it be possible, the debates go on, that some superior transcendent being, some hierarchical force or energy, one that cannot be defined by Aristotle’s categories or be realisable in Kant’s depiction of experience, could actually have determined the past and future for the entire universe? Put another way, is it possible that Napoleon’s defeat in Russia and the invention of the bicycle, as well
as all forthcoming events in the future, have, or continue to be determined in advance?

Determinism, considered thus, in terms of Napoleon’s invasion of Russia must therefore conclude that, everything that happened regarding the invasion, including his decision to invade, his plans for the invasion, the weather conditions, the effect on horses and his subsequent withdrawal, could not have happened otherwise. Given that the events unfolded in a pre-determined fashion, one after the other, as prescribed in advance, suggests that time must be linear and reversible, otherwise it could not be determinable in advance. A deterministic plan, like a recipe, requires a series of sequential steps to be followed absolutely in order to achieve exactly the same outcomes. Any deviation renders the plan or recipe to be something other, something different. This in turn, however, introduces novel entities or events into the plan or recipe that had not previously been considered. Multiply this by one hundred and the idea of a rigid deterministic worldview enters into chaos. Nevertheless, this deterministic view of the word continues to prevail. Its correspondence with Newtonian physics that have roots reaching as far back as Aristotle, continue to lend authenticity to the notion that history can be/is determined chronologically in terms of a single line of time: a time line. Just look up ‘time line bicycle’ on the internet for example, indeed look up ‘time line’!

This time line traces history chronologically, a series of events that happened in sequence one after the other, or one before the other depending upon which direction we choose to study: forwards or backwards. However, this mechanistic, calculable, deterministic view of the cosmos made famous by Newton is challenged by philosophers such as Simondon, Deleuze and Guattari, who trenchantly reject the concept of transcendence on the one hand and time as linear on the other. Holland (2014) offers an illustration of the difference:

[T]wo billiard balls on a collision course always interact the same way, and if you could rewind and replay the interaction 100 times, the billiard balls would take the same trajectories every time. (p. 17)

Classical science attempts here to describe the world as it is as accurately as possible. It uses tried and tested methodologies, methodologies that rely upon the control of variables and the repetition of experiments. This is why science makes claims that it can determine, repeatedly, what it is that will happen when billiard balls collide under controlled conditions. However, Holland goes on to challenge this linear scientific perspective that is predicated upon the concept of universality:

Start the process of evolution over 100 times, however, and you get up to 100 different results: this is an example of the difference between linear mechanistic casualty and non-linear, emergent causality; the latter involves singularities or bifurcation-points, and it is particularly at these undecidable points that time reveals itself to be irreversible. (p. 17)

Putnam argues further that the concept of scientific objectivity also predicated upon the concept of universality are not only flawed but are essentially a fantasy:
Apparantly any fantasy—the fantasy of doing science using only deductive logic (Popper), the fantasy of vindicating induction deductively (Reichenbach), the fantasy of reducing science to a simple sampling algorithm (Carnap), the fantasy of selecting theories given a mysteriously available set of “true observation conditionals”, or, alternatively, “settling for psychology” (both Quine)—is regarded as preferable to rethinking the whole dogma (the last dogma of empiricism?) that facts are objective and values are subjective and “never the twain shall meet. (Putnam, 2002, p. 145)

Thus, if we were able, under scientific conditions (although which scientific conditions?) to consider, observe and record every single event that took place in 1812, this would have to include all events occurring in the entire universe, because an uncontrolled change elsewhere, say a small change in atmospheric conditions, could lead to a significant change in weather conditions in Russia which could impact upon the outcome even if only imperceptibly, and if we could then repeat the process 100 times, we would clearly still get 100 different outcomes. The only way we could repeat the outcomes exactly, would be by containing and enclosing the entire universe, (given that we were ever capable of knowing the entire universe), in a controlled, and therefore closed system capable of being projected back in time, following in reverse, the exact same events as they had previously unfolded to a specific starting point (linear), and then re-run them again, in sequence, ensuring that no extra unforeseen event (like a small atmospheric event in Australia for example) entered into the experiment, thereby getting exactly the same result as previously.

The debates surrounding the concept of determinism have abounded for centuries concerning whether it is, or is not the case that some transcendent force or energy, may or may not be involved in the determination of every possible event that has happened, is happening and will happen in the future. This is essentially a form of rhetorical tautology. For example, I can state, without necessarily being able to prove it empirically, that I cannot predict the future with any certainty. I can speculate, but cannot determine it. I would follow up this argument by making the same claim for anybody. (Should someone have evidence to the contrary please let me know and ask said person to meet with me at the nearest horse racing track.) My point is this. It actually does not matter whether the claims for or against determinism are true, the future is unknown to me, whether pre-destined or not. Whatever path I follow into the future, whatever choice I make, even if it is pre-destined for me in advance, whether it echoes an existence in Plato’s cave, matters not a jot, for two reasons: First, given that any actualised future is either determined for me by some external force or energy (transcendence), or results because of some internally driven structure within my psyche (transcendence for Kant) or is realised as part of an ongoing process resulting from my ongoing experiences (immanence for Spinoza, Simondon and Deleuze and Guattari), or is, indeed, a result of some other process altogether that I am blissfully unaware of, is not something that influences my actions. I may choose to follow some transcendent ideology or philosophy believing it was so determined, but the possibility remains that it might not have been, it might have been otherwise and I
can never know that, I can only speculate. This leads to my second reason; whatever path I follow, whether determined or not, will always have an alternative and this serves to problematise the concept of determinism. Even if it is determined that I should turn right, eat a chocolate cake or climb up a mountain, there will be always be other alternatives, even although it may be determined that I should follow them, they will nevertheless, still exist: turn left, do not eat a chocolate cake do not climb up the mountain.

Every event, whether simple or complex, therefore, has at least two trajectories that it might follow. Indeed, there will always be possible trajectories or ‘lines of flight’ in Deleuze and Guattari’s terminology, that we might embark upon even though we might not be aware of them in advance. Weather systems, as mentioned earlier, are today considered to be the outcome of short term chaotic events that are not capable of being known in advance, hence the difficulty we have in predicting long term weather patterns. We may argue that it is possible that we may develop a supercomputer that will be able to calculate these chaotic events in advance. This would support what has become known as ‘Laplace’s demons’. Considered to be the French equivalent of Newton, Laplace postulated that:

We may regard the present state of the cosmos as the effect of its past and the cause of its future. An intellect [supercomputer] which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes. (Laplace, 1951, p. 4)

In order to reach this conclusion however, Laplace, like Newton, had to accept time as being reversible as was discussed above. However, today, thermodynamics, and particularly the second law relating to entropy, indicates convincingly that time is not reversible. This, together with relatively new and emerging theories such as those of chaos and complexity, tend to disprove the potential of Laplace’s theory that we will be able to pre-determine the unfolding of the cosmos, even with a supercomputer. For example, whether determined or not, along the lines discussed above, I may decide to stop writing this chapter now and go for a drink instead, or to watch television, or to …. Whatever I decide, and for whatever reason I decide it, will have some impact which will in turn, subsequently result in some change, however small. If I choose to go for a drink I may meet friends who may in turn invite me to a party or they might invite me for a meal at their home, or I may meet new people who will become my new best friends in the future (or not), I may meet with a colleague who will challenge my thinking to the extent that I revise this chapter … or I may stay at my desk and keep working. The potentialities of my actions are manyfold and whether or not they rely on some external transcendent force, does not actually affect the choices that I make, at least not from my perspective. My choices are therefore ‘my choices’ and immanent to me, even if they have been pre-determined for me in advance, I will never actually know that. I
may believe it but I can never actually know it. Therefore they will always appear to me to be based upon my own free will.

Deleuze and Guattari, who incidentally were influenced by Simondon, together with Simondon, argue against the concept of deterministic universal stable states, as seen to emerge from what Simondon refers to as the ‘deterministic age’ “which postulates the order of Nature as uniform, necessary, universal and analytical” (Simondon, 1966, pp. 288–290, cited in Bardin, 2013). They argue instead that processes, whether scientific, technological or social, can only ever be partially deterministic due to the metastable structures inherent in any given structure. Determinism in this sense “is a conceptual tool that allows the understanding and forecasting of portions of reality” (ibid) as they continuously emerge and change over time. However, Simondon is at pain to distance himself from adopting the opposing perspective; that of indeterminism.

It is possible, in the last instance, to suppose that the theory of singularity can be ascribed neither to the framework of a deterministic physics nor to the framework of an indeterministic physics. The two would rather be considered the particular cases of a new conception of the real that one might call the theory of transductive time or theory of the phases of being. This completely innovative mode of thinking – which conceives determinism and indeterminism as mere limit-cases – can be applied to different domains of reality beyond the one of elementary particles. (Simondon 1958, p. 144, cited in Bardin, 2013)

In this precise sense Simondon’s philosophy can be said to preserve the efficacy of science as a weapon against the ideology of determinism without defending the counter-ideology of indeterminism. And Simondon’s epistemological critique of the ideological assumption of the deterministic model as an ontological reality, opens up a field for political invention, conceived as the process of experimentation within which finality does not pre-exist (either in the form of a disincarnated subject or of an ordered objectivity) the transindividual processes and the political struggles it emerges from. (Bardin, 2013)

It is this process of experimentation that will be considered later in this chapter.

The cosmos considered as pre-organised and determinable presupposes it is an isolated closed system. Deleuze and Guattari (2008) consider the cosmos in exactly the opposite way, as an open system with a tendency towards self organisation. This corresponds to the observable evolution of life on earth, hence the difficulty in re-running the process 100 times. They call this a self-organising ‘chaosmos’ (cosmos + chaos) whose modes of organisation emerge from matter immanently instead of being imposed from above as form or law” (Holland, 2014, p. 21). It is how this evolutionary emergence of matter occurs immanently that engages important aspects of Simondon, Deleuze and Guattari’s respective philosophies. They postulate that science and technology is not a relation of knowledge between the subject and object. It is, rather “a relation at the exact scale of each of the
systems concerned: always mixed systems in which different physical, chemical, biological, psychical and social processes simultaneously take place according to a singular and unique configuration” (Bardin, 2013), much like the emerging collective process described above relating to the invention of the bicycle.

Influenced by Simondon, Deleuze and Guattari, I will go on to use the emergence of the bicycle as way to express my own philosophy of the way technology and science communications emerge, a concept that might otherwise be considered under the rubric ‘technological or scientific literacy’ (see, for example, Dakers, 2014a, 2014b).

REDUX: CONSIDERING THE EMERGENCE OF THE BICYCLE

The events leading up to the emergence of the bicycle as discussed above, simply constitute an interpretation of the evidence outlining some of the events that are recorded as having occurred before and during the time Karl Drais invented what has now become known as the bicycle. These events, together with an infinite number of other a priori events, constitute what Simondon refers to as an associated milieu. A milieu, in conventional terms, is understood to be a stable, pre-existing environment, one that that serves, amongst other things, to shape culture. Living in a city is different from living in a rural area. A milieu in this sense is considered to be an environment that, whilst subject to some degree of change, nevertheless represents a recognisable stable state. The United Kingdom Government for example, argues that immigrants (a different culture) should be required to adopt British cultural values as part of their ‘assimilation’ into the Country. This implies that there is considered to be something distinct and different about British culture, something stable and lasting, something that is resistant to change. Immigrants are expected to become something other; ‘British’, whilst the indigenous population of British citizens retain their stable identity. But this is an impossible construct: the concept of being ‘British’ today is fundamentally different from being ‘British’ fifty years ago which, in turn, was fundamentally different from being ‘British’ one hundred years ago.

Simondon uses the term meta-stable to describe a milieu, an environment. He argues that an environment is complex, one that encompasses all forms of actualisations whether human, natural or technical, whether value based or culturally orientated. By meta-stable, he means a system that only appears stable, and appears so for a variable, but finite period of time; a chaotic state. In other words change, in any milieu, is inevitable, no matter how imperceptible it may appear to be, no matter over what period of time. The concept of an enduring ‘British’ culture having a set of unchanging values is, for Simondon, not credible. A multiplicity of forces are continually acting upon all forms of milieu. Thus, in the case of Britain, it is not just immigration that challenges the stability of ‘British’ culture and values, it is a multiplicity of ongoing factors many of which are technological; global communication made possible by the internet being one very potent agent of change. The evolution of the bicycle serves as an example of this.
According to Hadland and Lessing (2014) and Lessing (2003), it seems that Karl Drais, a German inventor who studied technology at the university of Heidelberg, had an abiding interest in all forms of human powered transport. He is credited with having invented and fabricated two forms of human powered transport called a Fahrmaschinen (driving machine).

Fahrmaschinen 1, intended to carry as many as five people, had a treadmill fastened to a shaft between its rear wheels. The driver sat, facing backward, on a suspended saddle, and operated the treadmill with his feet. Fahrmaschinen 2 had a forged crankshaft between the rear wheels that allowed the driver to be seated facing forward while treading the crankshaft. Fahrmaschinen 2 attained speeds of 4 miles per hour. (Lessing, 2003, p. 117)

Significantly, Fahrmaschinen 1 was designed and fabricated in 1813, the year after the dreadful events of 1812. Fahrmaschinen 2 was designed and fabricated in 1817, the year after what became known as the 'year without a summer', a year in which there were widespread shortages of food, especially amongst the lower classes, and corn hastily bought in the Netherlands or in Russia couldn’t be distributed from Mannheim’s Rhine harbor [where Drais lived] into the interior because there were no horses left – those who hadn’t been slaughtered had starved. (Hadland & Lessing, 2014, p. 10)

It became somewhat evident, albeit perhaps not to everyone, but certainly to Drais it seems, that there was clearly a need at this time for some form of horseless transport, hence the evolution of Fahrmaschinen 2. According to Hadland and Lessing, it was in 1817 that Drais had invented/designed/fabricated his Laufmaschine (running machine) which had two wheels, one in front of the other. It is reported that Drais “reduced his four wheeled Farmaschine to the two wheeled Laufmaschine in order to accommodate it to the narrow forest footpaths upon which the machine was to be used” (Dunham, 1956, in Hadland & Lessing, 2014, p. 11). Another account suggests, as written in a local weekly journal called Badwochenblatt that “[t]he main idea of the invention has been taken from ice skating” (Translated from Drais 1817 in Hadland and Lessing, 2014: 11). Whatever the reason it appears that a four wheeled form of human transport, a form that continued to endure, appears to have assisted in enabling, to some degree, the evolution of a two wheeled version as was invented by Karl Drais around 1816/17. At around the same time, and again for potentially many reasons, one of which might have been death of her two weeks old baby daughter in 1815, a novel ghost story evolved in the shape of Mary Shelly’s Frankenstein. In both cases there existed a prevailing chaotic milieu of emerging change from which evolved the two instantiations referred to above.

Pre-existing forms of travel formed part of the local associated milieu at the time, as did many other things including, but by no means exclusively restricted to: human beings such as Karl Drais’ associated friends and colleagues, many
technologies such as the wheel, the cart, many techniques such as ice skating, cart making, wheelwrighting, many influences such as Drais’ engineering course at university, books he came into contact with and so on. The list is endless, it is complex, it is chaotic. It is from this milieu that Simondon’s theory of individuation emerges. “Simondon’s theory of individuation cannot be thought outside the relationship between the individual’s ontogenesis and its milieu” (Boucher, 2012, p. 92). Considered in terms of the bicycle, (or more accurately the Draisene or Velocipede but I will use the term bicycle), the relationship between the ontogenesis of the bicycle and its associated milieu is what Simondon refers to as the pre-individual which in turn, forms part of the process of individuation. Deleuze and Guattari, influenced by Simondon, refer in similar fashion, to the virtual as being part of the process of actualisation.

According to Simondon, there are five phases of individuation: Vital, physical, psychic, collective and transindividual. These different phases do not follow one another in succession; rather they compliment or supplement – they complexify – one another. They are not chronological but correlative. That is why one should not distinguish them substantially, but rather focus on the ‘rhythm of their becoming’; that is, on the differences of speed in the process of their formation. (which in turn are also related to a generative field of emergence, or plane of immanence, what he calls the pre-individual nature: namely a reality charged with potentials. (Boucher, 2012, p. 92)

It is this in-between pre-individual ‘zone of becoming’ (Simondon) or virtual ‘plane of immanence’ (Deleuze and Guattari) that we can find the relationship between the individual’s ontogenesis and its milieu. The individual, for Simondon, is (any)thing whether human, natural or technological.

It is this ‘middle’, this in-between that I will call the ‘liminal zone of indeterminacy’. I use the term indeterminacy in order to distinguish between being and becoming. Being, considered under the rubric of classical science, is some stable condition: a bicycle is a bicycle. A wheel is a wheel: In grammatical terms, both are nouns. Becoming on the other hand is likened to a verb, to a process: a bicycle is an ongoing process as is a wheel. Becoming “retains the complexity and non-linearity of antecedent conditions, so that a [bicycle’s] present being is understood as a more or less temporary and unstable contraction of its becoming” (Holland, 2014, p. 19). This is why the bicycle, as well as any other way to communicate science or technology (or human or tree …) evolves over time, hence it is indeterminate. It could always have been otherwise. The bicycle continues to evolve, to change both spatially and temporally. (Consider, for example, the bicycle developed by Drais and compare it to modern motor bicycles, tricycles, recumbent bicycles, folding bicycles etc. Whilst forming part of the ‘species’ known as ‘bicycles’ they are all different as a result of change.) The concept of liminality refers to a middle transitional zone in which change emerges, change that cannot always be given any definitive causal explanation. Consider, for example, an elementary school at morning break. The children are outside playing. The scene, looking from the staffroom window is one of chaos. Some children are
talking in a small group, others are running others are chasing others are …. There is a lot of noise. Break-time is over and the children are summoned to return to the classroom. Something happens to the children’s demeanour in the ‘liminal’ space between being outside and inside. It is the same group of children but something has changed. Their behaviour is different, the chaotic scenario that existed outside has settled into a more controlled environment inside. A change has occurred in the transition from outside to inside, this liminal zone between the two environments. The associated milieu of the playground plus the children plus the weather plus many other factors is different from the associated milieu of the classroom plus teachers plus ….

Within this liminal zone of indeterminacy resides a spatio-temporal network of superabundant potentialities, only some of which will ever be realised, but not necessarily in conjunction with the actualisation of the individual in question, suggesting that the individual can always become something other, something beyond its original intent. Moreover, it may also have complimentary functions resulting from its re-insertion into its now augmented milieu. In the case of the school, the ontogenesis of the various individuals will be subject to their exposure to a multiplicity of associated milieus both in the school and beyond. None of the schoolchildren will be specifically programmed to become world leaders or criminals (neither vocation being a specific subject domain on the curriculum) but there is always the potentiality, whether realised or not, that that some will. In the case of the bicycle, the following diagram represent a simple and incomplete depiction of three novel potentialities that were actualised complimentary to, and as a result of, the invention of the bicycle:

A bicycle wheel + an art gallery + Marcel Duchamp + paint + a stool = Roue de Bicyclette

Lots of Bicycles + athletes + various terrains + supporting infrastructure = Tour de France

A bicycle + engine + stuntman + ramps + lots of stationary vehicles = exciting daredevil act

Deleuze and Guattari refer to this as an assemblage.

Circumstances self-abstract to the precise extent to which they evolve. This means that the [liminal zone of indeterminacy] is not contained in any actual form assumed by things or states of things. It runs in the transitions from one form to another. (Massumi, 1998, pp. 16–17)

The liminal zone of indeterminacy constitutes becoming. It is the zone between one form of being and its evolution or transfer into another amplified form. Simondon refers to this evolution or transfer as concretization.
Concretization brings not only new properties, but complimentary functions, beyond those sought after, which we might call ‘superabundant functions’. [...] These properties of the object surpass expectations; it is a partial truth to say that an invention’s purpose is to attain an objective, to produce an entirely predictable effect. An invention is brought into being in response to a problem, but its effects extend beyond the resolution of the problem, due to the superabundant efficacy of the created object when it is a true invention. (Simondon, 2008)

This is why question asked by philosophers such as Simondon, Deleuze and Deleuze and Guattari is never deterministic or even scientific, in the classical sense. They never ask ‘what is it?’ (a bicycle), a question related to being. Rather, they ask of a bicycle ‘what can it become of it?’ (A human powered flying machine done already, an electric power generator done already, an eco friendly form of transport work in progress, a nuisance to automobile drivers a problem to be resolved politically, a dangerous form of transport in major cities a problem to be resolved politically. These are just a few of the becomings I can think of.)

A FEW PARTICULAR SUPERABUNDANT FUNCTIONS TO EMERGE AS A RESULT OF THE EVOLUTION OF THE BICYCLE

The bicycle that Drais invented was intended to replace the horse as a form of human powered vehicular transport. It was not the intention that this novel, and perhaps unlikely, but certainly untried form of transport would become part of the mainstream. Nor was it intended by Drais, that it would elicit a change in culture in British society (and similarly in other occidental cultures), such that it had a significant impact on movements like feminism, socialism anarchism and environmentalism. But it did. These cultural shifts are attributable to what Simondon refers to as some ‘superabundant functions’ of the evolution of the bicycle. The following table, taken from a fascinating and academically astute blog by Horton (2014) offers a brief but succinct outline of the way the evolution of the bicycle ran concurrently with the evolution of these movements and how, as a result, the various assemblages of bicycle plus feminism, bicycle plus socialism, bicycle plus anarchism and bicycle plus environmentalism evolved into something other, something beyond the sum of each other’s parts, a series of novel multiplicities that became different, that evolved differently from what had been before.

Social Movements of the Bicycle

It becomes evident by changing the concept of human powered vehicular transport on four wheels into one with two wheels, as invented by Drais, we not only change the object, the technology, we also change the associated value structure. Technology becomes more than purely instrumental, purely functional. As any technology unfolds it not only impacts upon the environment but has a significant impact upon cultural values. In so doing, the study of technology not only implies,
but must elicit an ethical dimension. "In such an ethics, the subject lives on by affirming its relative character, or more precisely, its relational character, by inscribing its acts into the network of other acts as much as it can" (Combes, 2013, p. 65).

Table 1. Social movement and the bicycle (from Horton, 2014)

<table>
<thead>
<tr>
<th>Social movement</th>
<th>Use of bicycle facilitated by</th>
<th>Primary significance of bicycle</th>
<th>Orientation to mobility</th>
<th>Role of bicycle in identity</th>
<th>Bicycle affording opposition to</th>
<th>Primary class location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feminism (1880–1910)</td>
<td>advent of ‘safety-bicycle’; rise of ‘leisure class’; growing impatience with patriarchy</td>
<td>pastime enabling freedom from patriarchal control</td>
<td>seeking more independent mobility</td>
<td>promoting freedom in movement and dress</td>
<td>patriarchal control</td>
<td>upper middle class</td>
</tr>
<tr>
<td>Socialism (1895–1914)</td>
<td>falling price of bikes, rising pay and leisure time; increasingly urban lifestyles</td>
<td>means of escaping city for pleasure and politics</td>
<td>seeking cheap, independent mobility</td>
<td>promoting class consciousness, solidarity and health</td>
<td>industrial capitalism</td>
<td>middle class</td>
</tr>
<tr>
<td>Anarchism (1960s–present)</td>
<td>dominance of car; marginalisation of bicycle; critiques of consumer capitalism</td>
<td>symbol of alternative vision, tool of political activism</td>
<td>against automobility; seeking humane, authentic mobility</td>
<td>embodying critique of the car; promoting prefigurative politics of the city</td>
<td>consumer capitalism</td>
<td>new middle class</td>
</tr>
<tr>
<td>Environmentalism (1960s–present)</td>
<td>mountain bike boom; oil crises; rising environmental concern</td>
<td>symbol of alternative vision, vehicle for intra-urban mobility</td>
<td>against automobility; seeking green, sustainable mobility</td>
<td>embodying critique of the car; demonstrating green lifestyles and sustainable futures</td>
<td>ecological crisis</td>
<td>new middle class</td>
</tr>
</tbody>
</table>
I have argued before that science and technology education focusses upon the development of learning about pre-existing technological knowledge, knowledge that is, for the most part, value neutral: knowing how to do something or knowing that something is. This scientific or technological knowledge is set within a curriculum and presented to the learner by a designated (and qualified one at the secondary school level) technology or science teacher. The learners’ task is to absorb the given information and later to demonstrate their level of mastery achieved by way of examination. Both the curriculum content and the examination result are accredited by powerful transcendent authorities both internal and external to the school system. What is to be learned is determined by them. ‘Learning’ takes place in the relation between the re-presentation of given information by the teacher, and subsequent absorption of that information by the student (reproduction of the same) (Dakers, 2014a, p. 138). In this view, no account is taken of the learners’ existential experience. Information relating to technology and science is pre-packaged. In extreme, this is tantamount to programming: information in, essentially the same information out. Freire calls this the ‘banking concept’ of education:

Narration [or demonstration] (with the teacher as narrator) leads the students to memorize mechanically the narrated account. Worse yet, it turns them into “containers”, into “receptacles” to be “filled” by the teachers. The more completely she fills the receptacles, the better a teachers she is. The more meekly the receptacles permit themselves to be filled, the better students they are. (Freire, 2005, pp. 71–72)

The evolution and development of technology is clearly much more complex than simply developing a mechanical understanding of its fabrication, of the properties of the materials used in its fabrication and of the tools, machines and techniques utilised. This is surely too superficial an approach to learning about technology, especially in the complex technologically textured world we occupy today. To simply learn about the processes involved in the fabrication of the bicycle for example, misses completely the many social and superabundant potentialities that went on to, and continue to shape the associated milieu that we, along with the bicycle, form part.

Moreover, this approach to teaching and learning about science and technology is deterministic. Feenberg (1995) tells us that scientific or technological “[d]eterminism rests on the assumption that technologies have an autonomous functional logic that can be explained without reference to society” (p. 5). Technological progress considered thus follows a linear determined pathway where, using the example of the bicycle again, “the end of the story was inevitable from the very beginning by projecting the abstract technical logic of the finished object back into the past as a cause of development” (ibid., p. 7). But, as Pinch and Bijker (1984) demonstrate, this linear model regarding the evolution of the bicycle
is fallacious. One example is the simultaneous development of two very different bicycles, one with a large front wheel and small rear wheel (known in the UK as a ‘penny farthing’, given representation by two round coins of the time, the penny being considerably larger than the farthing), as well as one with two wheels the same diameter. After some years, the ‘penny farthing’ eventually disappeared and the concept of a bicycle having two wheels the same diameter progressed until this day. The ‘penny farthing’ represented an actualised potentiality that evolved out of the liminal zone of indeterminacy (as did the other bicycle), however, as part of its process of individuation, other conditions within its associated milieu, mainly social, led to its demise, but not its death; it could still evolve into something different.

Beyond the current narrow perspective relating to technology education, is emerging a new conception about knowledge related to technology, a more critically orientated form of knowledge that goes well beyond the current ‘knowing how’ and the ‘knowing that’ dimensions. This is known as technological literacy. I have argued before (Dakers, 2014a, pp. 135–136) that there can be no universal definition for the concept of technological literacy. Taking account of the discussions in this chapter, I believe that the concept of technological literacy is not something that can be defined specifically or developed and processed in a linear fashion. Like Simondon’s concept of individuation, and Deleuze and Guattari’s concept of assemblage, becoming technologically literate is a reticulated process. It is neither absolute nor universal nor does it ever reach some final stage (being). It constitutes the relation between immanently held perspectives about a technology or technologies, and subsequent changes or differences in these perspectives that develop within the individual. It exists within the multiplicity of liminal zones of indeterminacy and bears a strong correlation with Vygotsky’s zone of proximal development:

The zone of proximal development (ZPD) has been defined as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers”. (Vygotsky, 1978, p. 86)

It is within this ‘in-between’ (Vygotsky), this ‘pre-individual’ (Simondon), this ‘virtual’ (Deleuze and Guattari) zone that change is constituted. There is no beginning, there is no end, there is only change. Everything, whether physical or metaphysical starts somewhere in the middle of its associated milieu, becomes something other as a result of its relationships within that associated milieu.

This new and progressive way of thinking about science and technology communications as emerging knowledge rather than given, stable and universal forms of knowledge is given form in an online academic journal called Rhizomes (available at http://rhizomes.net/index.html). Philosophically, rhizomatic thinking is a concept drawn from the philosophy of Deleuze and Guattari. In the journal’s manifesto it states the following:
Rhizomes oppose the idea that knowledge must grow in a tree structure from previously accepted ideas. New thinking need not follow established patterns.

Rhizomes promotes experimental work located outside current disciplines, work that has no proper location. As our name suggests, works written in the spirit of Deleuzian approaches are welcomed but not required.

We are not interested in publishing texts that establish their authority merely by affirming what is already believed. Instead, we encourage migrations into new conceptual territories resulting from unpredictable juxtapositions.

Likewise, my concept of technological literacy is less interested in the functional aspects of technology (how a bicycle is fabricated), how it works (gear ratios for example), nor is it interested in the history of a technology as presented in time line fashion (the linear development of the bicycle over time). Technological literacy, for me, is more about understanding first, the actualised technology in question. As an example, in this chapter I have considered the technology of the first two wheeled bicycle as was invented by Karl Drais. This information is not too difficult to establish in the first place. However, in order to better understand how this invention came about, it is important to then consider the relationships that existed between the various individuals whether human, natural or technological. How did they coexist within their associated milieu, prior to the actualisation of the technology in question? This constitutes an investigation into the prevailing conditions that existed up to, and just prior to, the new manifestation of the said technology. In other words, an historical investigation of as many of the prevailing conditions that it is possible to establish just before the actualisation of the bicycle for example. This is not a simple linear process. It involves the study of a reticulated, and therefore chaotic milieu. This complex investigation will enable the multiplicity of potentialities existing within the associated liminal zone of indeterminacy to be revealed, at least to some degree, thereby offering a much more informed sense of the evolution of the technology. This will involve a considerable degree of speculation as is the case with any historical investigation. This methodology is what I have referred to as Speculative MultiDimensional Time-Line Thinking (see Dakers, 2014b). It enables a form of investigation that offers the development of a more informed account of any technology from the past, as well as enabling a speculative account of how things might have been otherwise, given that some of the other potentialities situated within the liminal zone of indeterminacy had been realised.

For example, using this methodology, one could try to establish what conditions prevailed, at the time, that enabled the evolution and actualisation of the penny farthing. What were the subsequent conditions that contributed to its ultimate demise? How might things have been otherwise? Knowing what we know now, is it possible to design a safe and reliable penny farthing bicycle today? What might that look like? Technologically, this is a much more relevant and meaningful
learning experience for young people today. Certainly more so than designing and fabricating a pencil case, a CD holder or learning how a digital NOT gate operates, important as these things might be still be thought to be in school based technological education.

By considering the liminal zone of indeterminacy, in a speculative sense, one can engage in a reasoned and critical debate regarding new and potential technologies of the future, together with the impact they may have on their associated milieu. Issues relating to the impact of global warming, communications technology and many other technological issues can be learned in a much more meaningful way than the narrow focus that currently forms the dominant orthodoxy in schools today. Technological literacy is more than just knowing about technology, it is more that just talking about technology. It is about thinking critically about technology, technology from the past, the present and the future. Questions like is it possible for example, is it even conceivable, that a bicycle might one day fly?

With apologies to JFK, consider not what a bicycle is; consider what a bicycle might become…

NOTES

1 I define human powered vehicular mobility (or transport) as a type of transport that requires human muscle power that forms an integral part of the technology (in other words not external to the technology such as pushing), and some form of wheel assembly. This is distinct from non-vehicular human powered mobility (or transport) which would include walking, running, swimming or even climbing. I do not include boats or flying machines for the purposes of this chapter.


3 See http://www.amazon.com/ThePrintsCollector-3-Antique-Prints-MECHANICS-PHYSICS-SCIENCE-WHEELCHAIR-Diderot-Benard-1751/dp/B00DM0I0Q31

4 See http://en.wikipedia.org/wiki/Bath_chair

5 See the Draisene or Velocipede at: http://en.wikipedia.org/wiki/History_of_the_bicycle

6 See http://rhizomes.net/index.html (retrieved 05/06/2015).

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