GETTING TO KNOW ABOUT ENERGY

IN SCHOOL AND SOCIETY

JOAN SOLOMON

The Falmer Press

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I am grateful for the patient help and wise advice given to me by Paul Black during the initial stages of this work, the inspiration of my many pupils and teaching colleagues, and the continual encouragement of John Ziman.

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Preface

This book, as its title suggests, is about education in and beyond the school. But it stretches the whole notion of education to a point where including the word in its title might have been misleading.

Several of its chapters do describe the school teaching and learning situation in considerable depth, quoting liberally from the questions and answers of my own and other pupils. Chapter 2 is almost completely devoted to describing different perspectives in science education research. Parts of chapters 4 to 7 give illustrated classroom accounts of learning about the transfer, conservation and degradation of energy which are used to explore and explain children's thinking on these topics. All these chapters also develop quite new ideas about related but broader educational issues ranging from the general aims of education in the public domain, to the operation of that most intimate form of teaching inquiry—action research in the classroom. There are passages which describe those tacit understandings which make a tenuous link between doing practical activities in the laboratory and learning science concepts. There are poems and drawings by younger children and arguments about moral dilemmas related to energy use from older school students.

Some chapters in the book, and considerable sections in many others, escape completely from the classroom into considerations of energy in language, literature, beliefs, technology, history and general culture. This is partly because their absence would make the school experience of our children quite incomprehensible, and indeed the main educational thesis developed in chapter 6 is devoted to the 'Two Domains' of knowledge—life-world, and abstract academic—that children carry in their heads. But wider considerations are even more important for their vital role in informal processes for getting to know about energy throughout life. School is only an episode in this longer view of learning, and schooling itself is laced through with meanings and experiences which could not possibly figure in any energy syllabus. Television, and current concerns about the *Public Understanding of Science* related to energy, are considered in chapters 4 and 8, and few could argue that school children are not involved in either of these topics. More ambitiously a theme is developed about general knowledge and common sense knowing in chapter 1 which is used in many contexts throughout the book.

The final chapter may seem, at first sight, to abandon science education as well as children's schooling. It develops a theme about energy technology in history and how it has affected people's ways of living and their values, in earlier times. Some of this has descended to us through common figures of speech. But the purpose of this line of thought is not retrospective: it is to make a little sense of the theme which is likely to loom largest in the next century's thinking about energy.

The wide scope of this theme presents almost insuperable problems of scholarship. The width of knowledge that would be required to make proper reference to the various bodies of literature involved—in cognition, social psychology, developmental psychology, education, philosophies of all sorts and varieties, sociology, the sociology of knowledge, technology, history, etc. …is quite out of my reach. I offer apologies for this—but only up to a point. More thoroughness in quoting references and making acknowledgements would certainly serve to protect the author against imputations of ignorance, but it would also place the work in a category of review literature which was not intended. The modern habit of writing multi-author books on a loose general theme addresses this problem in another way. While each contributor then supplies expertise and enthusiasm in a separate area, the result cannot easily be a complete thesis or narrative. The choice is between continuity of purpose and narrative with incomplete scholarship—or a more learned approach with the possibility of disjointed argument and reading. Probably there is no uniquely satisfactory solution to the problem. This book may speak to many audiences so while any one reader may find it regrettably deficient in her/his own speciality, they may find it more novel in another. It has taken on board only one topic, but carried it to many shores.

The topic—energy—is just right for such a wide-ranging investigation. It is thought to be the most difficult of all concepts to teach, and yet the term has re-invaded the everyday vocabulary from which it was borrowed by physicists less than two centuries ago, and stirred up a multitude of related ideas and folk beliefs. It is also high on the list of physicists' most fundamental ideas. Scratch any physicist and you will find an enthusiast for the energy concept. As a newly-graduated physicist just going into teaching, many years ago, I was certainly one of those. The charm has not worn off.

This book is not about higher education in the physics of energy, and yet, as the kitchen garden of all teachers, the university and polytechnic are fundamental to school learning about energy and so to the genesis of this book. The time-honoured method of teaching in colleges by means of lectures which are often monotonous and sometimes inaudible, may seem to have little of value to offer a prospective teacher. But, paradoxically, the private struggle to understand can be of enormous value. The personal construction of knowledge, which will be a theme in several chapters, but particularly in chapter 2, is much harder when the presentation of knowledge is poor; but for those who remember the head-scratching difficulty of trying to understand lecture notes taken in the desperation of confusion, it makes a quite excellent background for thinking about teaching.

The first requirement is that the student's motivation to learn about energy is maintained. For most physicists interest in energy may have begun in school, but at university the spell often works wonderfully. The story of how the spectrum of energies in the beta-emission from a radioactive source suggested to Pauli that some other particle must also be formed *in order that* the all-important principle of Conservation of Energy would not be flouted, gives a good introduction to physicists' psychological commitment to the concept. For them contravention of the principle was so unthinkable that a strange new particle had to be thought into existence without electric charge or rest mass, but yet carrying spin. The steadfastness with which the physics community put their trust in a particle so tiny and elusive that it would, by their own calculations, travel through ten thousand million million miles of solid rock with less than a 50 per cent chance of encountering a single atom in its path, was impressive commitment.

Statistical mechanics also comes early in the undergraduate course and gives another valuable lesson for energy teachers. It uses the mathematical tricks learnt for dealing with the collisions of sizeable objects, on a multitude of point masses, and suddenly energy begins to assume a new dimension. When the energy laws are applied to crowds they take on the punter's feel for the probability of happenings. Energy changes, in this domain, were less about 'doing work' and more about statistical likelihood. These lectures took us students on one of our first journeys into the transmutation of meanings. Through statistical probability our understanding of the meaning of energy began to make contact with ideas of temperature and even time.

Forming links between concepts, like the use of simile to link descriptions, involves a rethinking at both ends of the chain of comparison. This is a topic which is also important in science education where analogies from the everyday world are used and stretched to fit physics theories. Few of us make any claim to an understanding of time, and that very ignorance allows the concept some freedom of imaginary movement as it sweeps up fragments of new meaning from poetry or from physics. But everyone thinks they know about temperature. A little girl must learn to dread the fire; the autonomous reflexes of the body ensure that sensorimotor learning about temperature precedes even the thinking about it. But there are many kinds of learning and each begins to grow in almost virgin territory. To understand the thermometer we leave behind the pain of fire. To understand the temperature of an assembly of rushing molecules in a gas we abandon the thermometer. Every time a student of physics learns in a new field they need to accept that, like a child opening a Russian doll, they are looking into a new reality where concepts with familiar names may not exactly match the older ones they already have in mind. That also makes a good lesson for the intending teacher.

Other invariant concepts, like the mass of 'solid' matter and even the vectorial thrust of momentum, are too straightforward to reveal the direction of time flow.

Such concepts are precisely and prosaically conserved—exactly the same in the past as in the future. But energy is both conserved and yet time-dependent in its organization. Energy is *not* the same after an event as it was before it, except in the simplest arithmetic sense. It is that difference, from order to disorder, from hot and cold to warm, from potentiality to action, or from action to spent quiescence, which spells out the passage of time.

University lectures on energy, in those days, made no pretensions to connect with contemporary values and fears, but science can neither be constructed nor learnt in a neutral spirit and a personal vacuum. We were taught, for example, about Lord Kelvin's attempts to calculate the age of the earth using no more than the nature of energy flow, and about his prediction of the slow 'heat death' of the universe. But we were the children of the Second World War and feared the recently dropped atomic bomb far more than Kelvin's ultimate running-down. The 1950s were a time of nuclear uncertainty punctuated by test explosions, in the earth's atmosphere, of ever more powerful bombs. New meanings have to resonate with societal and affective factors as well as with intellectual ones. For us, Kelvin's programme of destruction was too intellectually conceived and too gradual. Our lecturers never touched on social issues—this was long before the movement for including 'social relevance' in science education—they merely pointed to faults in Kelvin's mathematical scale of destruction. We smiled at the thwarted ambition of Victorian theoretical physics, and passed on to learn about the world of the atom itself, which seemed so very much more threatening.

We learnt that energy has its own discrete, almost atomic, structure. At the turn of the century contradictions in the physics of atomic interactions had driven Max Planck, rather reluctantly, to go beyond the comfortable confines of the classical notion of the continuity of energy. The very first indivisible entity, the first quantum, he encountered was that of 'action'. This was a small but strangely enduring quantity—the product of energy and time. The act of turning that over in our minds constructed yet another meaning, and also an apparent contradiction. When a transfer of energy takes place there is a calculable uncertainty in its time-scale. The smaller the amount of energy the greater is the vagueness in how long the exchange takes. That meant that the elementary meaning for energy, explained so clearly and didactically at school in terms of the strict measurement of force and displacement, was being superseded by another. Was it possible to believe in both meanings at the same time? For potential science teachers that demonstration of cognitive conflict was the best possible preparation.

This difficult movement from one domain of meaning to another matches the problems facing school pupils as they move from the everyday world of energy to that of school text-book physics. The daily struggle to understand why children find learning science so hard, teaches the teachers. From this they come to understand, if they are prepared to listen, more about the nature of learning and knowledge than can be given through half a dozen lectures about cognition and epistemology. The restless collection of children who tumble noisily into the classroom are the stuff of an invaluable learning laboratory. Years later, when I taught experienced teachers in a Master's course about the history and philosophy of science in terms of the long struggle to redescribe natural phenomena in a coherent way, I was often surprised by the range of useful understandings and insights which the classroom activity had given them.

Britain is fortunate in having an all-graduate force of dedicated school science teachers, despite the disincentives of salary and status. They still trickle into teaching, as I had done, with their heads full to the brim with science concepts. I watch with pleasure and some sympathy as the new PGCE entrants, still warm from the spell of undergraduate physics, set out to fire the young with tales of energy, and other mysteries. They are keen to stand in front of children and talk about science in a way that will make young eyes sparkle. This is the common 'Ancient Mariner' delusion, and it deceives the novice teacher badly. Few of us, if any at all, have the necessary 'glittering eye' to hold an audience: new teachers fail most often when they try to talk enthusiasm into their pupils from front-of-class. It has been my professional duty to deter student teachers from such didactic exposition with harsh advice about classroom discipline and laboratory management. (I always hope that I only half succeed!)

Some students leave teaching after the first scorching probationary year. Others stay on for a number of reasons—for pleasure in the company and comments of youngsters, because the challenge of teaching management catches their ambition, for the rare moments when they see the glint of real understanding and enjoyment in a new young physicist, and no doubt for many other reasons. Some of us may also learn that there is an intellectual challenge in teaching which is every bit as hard as a problem in advanced thermodynamics—understanding the pupils' own difficulties.

How do children learn? What does it mean for any of us to understand energy? No book could ever answer such questions. Instead, this one describes different kinds of understandings and how each one weaves its meanings into the central business of living and learning. It has to touch upon language and personality, on the ancient and the topical, on cognitive growth and personal values, on practical technology and abstract theory, on the world of citizens and the world of schools. Learning about energy is not something which only happens at school between the nine o'clock and ten o'clock bells twice a week during the autumn term. Energy is an idea with a multitude of meanings most of which thrive prodigiously out of school but are not halted at the playground gate. Language brings energy meanings into everything we do and think. This book is about energy and, as children say, 'energy is the source of all life'.

Chapter 1
General Knowledge about Energy

The Nature of General Knowledge

The place to start any search about understanding is in the general knowledge of the public. This is important for the study of learning not only because it is the foundation on which education has to build but because it will continue to flow strongly in daily conversations throughout life. Scientist or layman, expert or novice, we are united by our general knowledge. But before it is possible to think about the contents of general knowledge concerning energy—the topics, meanings, vague concepts and vaguer theories—there is a need to explore, if only in outline, the nature of general knowledge itself. Here, right at the beginning of the subject, is quite the toughest task of all. We have to find an answer to the question—is what we all know, or think we know—without ever having learnt it—a system of knowing at all?

The vast majority of our information about energy is not specialized knowledge of the kind learnt at school. It is a rag-bag of items which may refer back to episodes or conversation, family sayings, or to advertisements which 'caught the eye', and then almost inexplicably lodged in the memory. There are a number of possible reasons—personal, literary, perceptual, emotional or social—for holding fast to this knowledge, and the purpose of this chapter is to begin to unravel some of these.

General knowledge is certainly not the kind of trivial pursuit which figures in 'Brain of Britain' and other public competitions. That is a flagrant misuse of the term. What such games are really about is *non-general knowledge* because they aim to catch out competitors, eliminating all but those with exceptional powers of recall. Only in one way does such quiz-type general knowledge resemble truly socialized general knowledge. It consists of discrete pieces of information thought to be eminently reliable. Indeed, we are forced to rely upon them with a child-like faith because, unlike theoretical or systematic knowledge, such 'facts' do not come from a familiar field of knowledge.

'What is *quercus ilex*?'
'When was the Field of the Cloth of Gold?'

'What are the main constituents of cement powder?'

To a small body of specialists these items are known because they are a part of the system of things that they have learnt to understand. The answers have a place in an ordered scheme of knowing. To the rest of us they are little more than cognitive clutter, valued more for their rarity, and for the kudos that their knowing brings, than for any real interest.

True general knowledge is general because, we assume, everyone else also knows it too. But a moment's reflection is enough to conclude that they could not possibly all do so. Even if we could list every item of general knowledge about energy known to any one person, the tally would be bound to be different for the very next individual. For this kind of knowledge it will be the *assumption of similarity* rather than its actual existence which will be the important characteristic.

Talking and Arguing

There is a reason for this grossly improbable assumption of similarity. General knowledge is valuable because it contains *meanings* rather more than facts. We can only talk to other individuals if we believe that the words we use and the allusions we make will be comprehensible to them too. We need continual reassurance that they 'know what I mean?'. Explanation over the telephone, where the usual visual clues to comprehension—nodding or smiling—cannot operate, is particularly unnerving because we are deprived of reassurance. Social beings that we are, we depend on continual affirmation in order to continue with our spoken train of thought. So, just to be able to talk to other people, we must assume that we share general knowledge meanings. As G.H.Mead put it, 'we need to exchange perspectives' with the people we are talking to.

Conversation has always been the vehicle for common meanings and associations. Generally it carries on without effort because we all have an investment in the kind of agreement which is very little different from simply understanding. Since words have several meanings depending on context (a problem area which will be discussed in greater detail through the talking and writing of children) all intelligent listening is an active 'hopping' game as we move from one meaning vantage-point to another trying to find a place from which all the landscape makes sense.

Nevertheless arguments do take place in such conversations whenever we do not get ready confirmation and want to change the other's meaning, or lack of it, to our own. For this we use rhetoric—which has had a bad press over the last many centuries. We tend to use the term pejoratively now to describe political tub-thumping and illogical verbal bullying, but in this case we need the word in its basic sense of common, alogical persuasion. The ancients contrasted logic and rhetoric with care since they practised and valued both. Zeno, we are told, compared logic and rhetoric to 'the closed fist and the open hand'. It is a little surprising to find that rhetoric is considered the more open, and logic, which mathematics and science have appropriated and elevated to the higher position, as closed. But the reason for this openness is the two-way personal persuasion which is involved. To convince another by rhetoric we need to 'show' them how we are thinking. For this we need to work hard at producing exemplar material in situations which they too will recognize. So, in the language of modern sociology, we need to 'construct' how the other is, and choose those extra pieces of general knowledge which we feel will be familiar to them.

Rhetoric is not illogical: it just avoids logic. It is altogether looser than logic since it allows the essential change of context which the act of commonplace persuasion needs. The 'rhetorical question', which is almost all the substance that most people retain of this ancient discipline, is not just a question which needs no answer. It is the result of an open process in which the persuader seeks for a context in which the other would see things from the same perspective. Then, if successful, the punch-line in rhetoric, no different in this respect from the conclusion in a logical Socratic argument, simply confirms the end-game by showing that there can only be one answer. The underlying skill in rhetoric, but not in logic, is construing the other person's likely meaning and point of view. In logic, on the other hand, the character and knowledge of the adversary is of no interest whatsoever.

> The context of rhetoric is marked by justification and criticism, logoi and anti-logoi. It is a social concern in which different points of view clash, and there is a potential infinity of these clashes. The maxim of Protagoras *(that there are two sides to every question)* suggests that an unarguable rightness and wrongness cannot be established since critical challenges are always possible. Matters are different in the realm of logic…. Deducing that 'Socrates is mortal' from the premises 'All men are mortal', and 'Socrates is a man' does not involve entering into an endless argument between religious believers and sceptics about immortality. (Billig, 1987:95)

So the consensual meanings of general knowledge are built up by almost identical social processes whether there is initial agreement or disagreement.

The general knowledge of children and adults is not likely to be quite the same because they have had different learning experiences. Nevertheless parents tend to assume that what they know is also the ultimate goal of what their children should know. It seems to be the aim of every community to pass on to the next generation, by means both open and devious, the knowledge that members of that community believe they share. It is a kind of cultural immortality in which education takes on the role of Dawkins' 'selfish gene'. General knowledge is the very stuff of common culture.

So adults talk carefully to children, as anyone who has heard a friend 'change gear' when a child enters the conversation, will bear witness. It is as if we mete out our stock of knowledge little by little, as and when we consider the child is ready for it. In the words of Joshua Meyrowitz:

> Socialization can be thought of as a process of gradual, or staggered exposure to social information. Children are slowly walked up the staircase of adult information, one step at a time.

However it is also true, as the same author points out, that the media now exposes children as never before to the full uncensored thrust of adult culture and information. Not just sex and violence, which raises so much alarm in some quarters, but adult musings on every aspect of life, have become totally accessible.

In summary, adult general knowledge about energy is likely to be insidious and persistent. It is continually reinforced by the meanings used in common talk, both person to person and through watching similar interaction on the television screen. In this way it is shot through with the kind of social understandings that we use more for understanding people than for scientific concepts.

The Operations of Common Sense

Mainstream general knowledge is what Schutz and Luckmann (1973) have called the 'social stock of knowledge'—a choice of words which carefully refrains from suggesting that it has either structure or internal logic. It might be no more than a random collection without any system—just titbits of information that have come our way in different circumstances. But human beings have to justify what they know, however it has been derived. The stock of knowledge may not be logically coherent; parts of it, as we shall see, will not stand up to even the most tolerant inspection. Yet it needs some kind of credentials—psychological if not logical—if we are to use it, and go on doing so. In place of a philosophy our collection of facts and opinions has a loose justificatory system which is defiantly referred to as 'just common sense'.

To say that something is 'good common sense' is to appeal to a silent but supposedly assenting majority, like those we imagine having confirming conversations with, and thus to dodge all argument. It also refers the matter to the arbitration of elusive principles which are thought to be enormously convincing, and yet are never named. In this way it can become a hiding place for both outrageous prejudice and total ignorance.

In his book on *World Hypotheses* Stephen Pepper defined three traits of common-sense knowing. The first of these is best described as 'taken for granted'. If it were otherwise, if the general knowledge we justify as common sense could be analyzed and confirmed in a more logical fashion, then it would cease to rely on the disreputable arguments of 'common sense' and become instead part of another and more formal and logical knowledge system, such as science. Common sense has to allow for the inclusion of values and feelings as well as facts, so the normal processes of logical analysis cannot accommodate it. Yet, because it is such comfortable ‘taken for granted’ knowledge, it does not even notice this absence of logical justification.

Pepper’s second and related property of common sense is its *security*. To abandon, even for a moment, what is held to be common sense is like entering a looking-glass world where everything is unfamiliar and horribly disturbing. Learning school science can be just like this. It leads into regions where ‘correct’ principles seem to be grossly at odds with common sense. Who could believe, for example, that a bouncing glass marble is reversibly ‘squashed’ on impact like a soft rubber ball? We are taught in science lessons that potential energy *must* be stored in this way *in order that* the logical coherence of another knowledge system be maintained. Because children are still intellectually biddable they mostly go along, for a while at least, with this protection of the logical bastions of science; but it is at the expense of the comfort and security of common sense.

So scientific knowledge may require a kind of courage, even reckless-ness, which can be hard to keep up around the clock. School pupils often retreat back into the familiar arms of common sense when the tough logic of physics becomes too hard to maintain.

> No cognition can sink lower than common sense, for when we completely give up trying to know anything, then is precisely when we know things in the common-sense way. (Pepper, 1942)

The third characteristic of common sense is peculiarly awkward. Not only is it taken-for-granted, it can also flout almost every rule of argument and not be found out. Its security and obviousness seem to resent inspection. Social experiments which flout this convention by questioning everything which appears to be common sense, are frankly infuriating. Ask someone *in what way* they are ‘feeling fine’, or *why they think* someone ‘looks shifty’, and the greater your show of interest the more irritated they will become. The attitude of common sense is so alogical that it can tolerate neither attack nor probe.

When science writers like Joseph Bronowski recommended the thought of science as *The Common Sense of Science* because it ‘asserts the unity of knowledge’ we must treat the phrase with caution. The only unity in common-sense knowledge is the comfortable assumption of sharing. And that very comfort may depend on a belief that if we share the knowledge with everyone then no one will challenge it. In the words of Stephen Pepper common-sense knowledge is ‘cognitively irritable’; like an amoeba it may even change shape when poked by an inquisitive outsider.

The fourth and final characteristic of common-sense knowledge is that it is *intersubjective.* For whatever reason it seems so obvious and secure to us, we expect it to be so also for others. That is not to claim that this vague knowledge-attitude provides us with similar cultural views about energy because they are based on similar observations and deductions. They are similar because they have achieved intersubjectivity—the result of deliberately matching our accounts to the views of others by watching for signs of understanding and agreement. Common-sense knowledge is born and bred in our everyday chat; it is reinforced and added to there, and achieves its greatest polemic triumphs there in the shifting ground of social arguments. These arguments are won not by logical confrontation, but by the art and practice of rhetoric.

All these curious characteristics of general knowledge will be important for studying children's ideas about energy. In particular they give strong hints about the way in which we should go about the task of exploration. Knowledge which is 'cognitively irritable' might be expected to squirm and even transmute under the probing of an intensive interview. Indeed, there is no shortage of published transcripts which show just such retreat and reinvention under the pressure of continued questioning, however gently it is carried out. On the other hand a knowledge system which is believed to be held in common, would be expected to be most itself in a social setting. Many of the illustrations to be quoted will be extracts from children or adults talking to each other in groups.

Personal Knowing

The characteristics of common-sense thinking which protect it from either inspection or introspection also differentiate it sharply from another kind of untutored knowledge. Some children and some adults have built up their own idiosyncratic theories and hypotheses about the world out of active private reflection. Such homespun explanations of the way things are can be described, tested and argued about. This is valuable 'personal knowledge' and not unreflective common-sense knowledge.

The boy Tim, for example, in Rosalind Driver's book *Pupil as Scient-ist*?, held a private theory that gravity was greater higher up because objects released from greater heights fall faster. He set out to test it by raising the arm of the clampstand to find out if the extension of a spring was greater at a greater height. This kind of personal knowledge which may even invite disconfirmation through experiment, lies poles apart from elusive commonsense knowing. It is just as much a kind of proto-science as that of the young Einstein who imagined running after a beam of light, and later deduced that the speed of light is invariant.

The conclusions of personal knowledge, like those of common sense, may be either 'right' or 'wrong' in the light of the prevailing judgements of science, but they differ totally in their methods of justification. Personal proto-scientific notions are the products of private work on an idea or image, teasing and testing it to find how far it will match reality. It will be strongly championed in conversation. Elusive common sense is not open to such examination: it needs to remain flexible and even indefinite to match the meanings of those who may be engaged in conversation. It has little pretension to logical coherence. Phrases like 'Well it all depends on the circumstances' can be used to ward off attacks of inconsistency. As Schutz and Luckmann wrote, such life-world knowledge has a small-scale ‘horizon of meaning’. Common sense has traded in logic in return for popular agreement. It is what everyone knows, and no one really wants examined. But personal knowing is private, treasured, and defensible.

Talk, Meanings and Historical Relics

There are at least three different ways in which we might go about the task of finding the common meanings for ‘energy’. We might simply reach for the dictionary, especially for one which conveniently lists the different accepted meanings along with their first dated use in the literature. This is easy to do and we shall begin our investigations here.

In the second place we could listen to groups of people talking together about energy and try to infer their meanings, contexts and attitudes. We shall expect rather opaque and general purpose opening gambits as they begin to search for points of contact. It is where one person answers another that the agreement on meaning might begin to emerge. Recordings of the discussions of three different groups of adults who knew each other well, will be used for this purpose.

The third way of exploring meanings is more arcane. We will assume that at least some of these meanings might be relics of past theories about the nature of energy, albeit somewhat damaged and disfigured, as relics so often are. This supposition is based on the stability of metaphor or figurative speech in the language. There are so many examples of out-of-date terms, ranging from ‘harnessing energy’ to ‘reaping benefit’, in which old ideas are submerged in modern usage. It seems likely that words like these exercise some influence on meanings even if their original familiar impact has been lost. So it is profitable to refer to ideas in the history of energy to identify nuances of meaning in colloquial speech about energy. This will also be done.

Each method has its own problems. Dictionaries are far too sharp in their authoritative meanings. Discussions may be better, but only if we resist the temptation to interrupt and ask for explanations. Because of the nature of the common-sense attitude, such requests rarely bring any satisfaction. Sometimes the participants give a non-response or a repetition; on other occasions they seem to feel rebuked, fall silent, or search their memories for something which might sound more scientific and impressive. This does damage to the flow of taken-for-granted talk. The third method could provide an endless historical study in itself. It is the use of all three methods *in combination* which probably provides the best chance of sketching in some of the outlines of the meanings of energy in the general population. Three general themes were identified by this exploration.

I
An Immaterial Agency

In classical times the word ‘energy’ derived from the world-view of Aristotle and meant something like the *potentiality for change*. Physics itself was derived from the Greek word for change so that this meaning gave energy a central position in scientific thought. However, even by the standards of Greek philosophy where immaterial essences were considered to be more profound than perceived reality, energy was an essentially immaterial affair. By the time the English word is first recorded in literature this esentially abstract quality still seems to linger on.

> They are not effective of anything, nor leave no work behind them, but are energies only. (Bacon, 1606)
>
> The light of the Sonne is the energie of the Sonne and every phantasm of the mind is the energie of the soul. (More, 1642)
>
> …powers and energies that we feel in our minds. (Bentley, 1742)

The common phrase ‘pure energy’ to denote something at a very far remove from the imperfections of matter, shows that this ancient view of energy still lingers on.

It is sometimes suggested that physics is a perversely abstract activity whilst common thought is not. This is quoted by those who want to excuse the shortcomings of pupils, and is a part of the educational polemic which seeks to find a kind of science which may be more accessible to all. The objective may be laudable and faultless, but the argument—that abstract ideas are foreign to everyday thought—does not stand up to examination through conversation.

All the talk about energy recorded for this exploration was full of abstract notions. None of the adults had ever studied physics and yet, soon after the discussion was set going by asking what was meant by the word ‘energy’, there were explicit attempts to emphasize the abstract nature of energy.

> ‘A motivating force…which can include fuels but is also something more abstract.’
>
> ‘Energy is a state of mind, it’s how you feel.’
>
> ‘At the heart of every living cell there is pure energy.’
>
> ‘The sun is the symbol for energy.’

It is very easy to find other contemporary evidence for the abstract, almost anti-material, sense of the word. Popular science fiction is riddled with this attribute of energy. A creature of ‘pure energy’ is one without a material body. Teletransportation, a commonplace of television space sagas, is said to be accomplished by changing people into ‘massless energy’ (a somewhat worrying phrase for those of us familiar with Einstein’s mass/energy equation!). ‘Fields of energy’ are used to transfix the merely material, and occasionally superior races of beings acquire the ‘mental control of energy’. All of this might be said to constitute fragmentary and rather bizarre evidence that the most modern of popular space fiction perpetuates seventeenth century meanings of energy, which themselves may well derive from a metaphysical concept of Aristotle’s which dates back some two thousand years earlier still.

II
The Living Force

There is another general meaning attached to the word 'energy' which has been powerful at different times in the development of science. This is the connection between *energy and life*. By the seventeenth century it existed in non-scientific literature in a way which is not unfamiliar to a modern reader.

> Energie is the operation, efflux, or activity of any being. (More, 1642)

> When animated by elocution it acquires greater life and energy. (Holder, 1696)

By the eighteenth century phrases such as 'animal energy' or 'life energy' became much more common. The strict etymological sequence of the word is rather hard to disentangle, partly because these scientific theories originated in languages other than English, and also because the words used in this early science had not yet been fixed so tightly by formal definition as they are today. Well into the nineteenth century the words 'force', 'energy' and 'power' were still interchangeable. But the connection between energy—or some similar word—and life, was explicit. By the early nineteenth century it was to become the focus of a scientific controversy which will be described in chapter 9.

The history of the modern concept of energy might be taken to begin in the seventeenth century with the works of Galileo, Huygens, Newton and Leibniz. Each one of these founding fathers of modern physics identified a mathematical concept involving matter and velocity, or power, which seemed to have special and enduring significance. Of course there were high level arguments about the value of each formulation but, like most mathematical statements, they probably had minimal impact upon the general knowledge.

The works of the German mathematician and philosopher Leibniz are difficult for a modern lay reader. As co-inventor of the mathematical calculus there was bitter rivalry between him and Isaac Newton. While most of his books are punishingly hard to understand, his theories of force and movement include a curious strand of what may be the common thought of his times. He introduced the notion of creation, and of life itself, into the dry calculations of mechanics, and by so doing may have made contact with a strand of meaning already existing in the general culture. He identified a mathematical entity, *`vis viva'* which he calculated by multiplying the mass of a body by the square of its velocity—mv^2, and this he held to be the link between religion and mathematics. As an aristocrat and a scholar, Leibniz would probably have denied any influence from cultural general knowledge with great indignation. However, from the perspective of another age, it is easier for us to glimpse the meanings of a religious world-view beneath his properly academic protestations.