The Shadow of the Bomb: a study of degree-level nuclear physics textbooks

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Abstract: The author presents a textual analysis of 57 nuclear physics textbooks for senior-level physics degree students. The work investigates how the textbooks relate to an aspect that is relevant and important but almost wholly avoided, namely nuclear weapons. Most of the books do however contain expositions of other applications, notably nuclear power reactors. These expositions are often enthusiastic and occasionally extravagant. When the existing apocalyptic arsenals are borne in mind, the textbooks' asymmetry is seen to be problematic. The publication dates of the textbooks range from 1950 to 2010, yet for the question addressed in this study remarkably little has changed. This study emphasises the culture in which we all live, rather than individual specialists. The author concludes that a response to our nuclear situation, based on a rational programme for long-term survival, rather than on psychological defences, has to come from all. Experts do have special responsibilities but The author maintains that it is unrealistic to expect specialist groups, such as those involved in producing textbooks, to act independently of the wider culture.

Introduction

In this work I present a textual analysis of 57 nuclear physics textbooks for senior-level physics degree students. Specifically, I investigate how the textbooks relate to a

subject that is almost wholly avoided, namely nuclear weapons. Most of the books contain at most a few muted words on nuclear weapons and from these one gets little or no sense of the connection between nuclear physics and human survival. The majority of the books do however contain expositions of other applications, notably nuclear power reactors. These expositions are often enthusiastic and occasionally extravagant. When the apocalyptic arsenals that exist are borne in mind, the textbooks' asymmetry is seen to be problematic, but if the arsenals are sequestered in a separate part of the mind, the textbooks appear unproblematic.

If the textbooks are subjected to a resistant reading, rather than a habitual reading, the discreet ways in which the books manage to avoid the embarrassing subject can be seen but this does require attention to details. Further, one can identify the relevant features only by studying a large number of the books in this manner. Some of the features which support the discreet politeness are – asymmetrical selections, formulaic phrase patterns and carefully limited self-descriptions. Some details which are clues to unease are - unusual linguistic expressions, vagueness, extravagance, errors and slips**,** and attention to marginal, speculative and specialised topics.

The High Standard of the Textbooks in Areas outside the Shadow

Conventional ideals about science education hold that textbooks should present their subject clearly and directly. My analysis focuses on deviations from these ideals. I therefore declare clearly that I find the general standard of balance, exposition and accuracy of most of the textbooks surveyed to be impressively high. This assessment has two implications. Deviations from this high standard are significant; and those involved in the production or use of nuclear physics textbooks need feel neither more nor less defensive than others, since few if any of us know how to deal with the shadow.

One may ask - how specific are the problematic features I have identified? Are they peculiar to nuclear physics education? Do they exist, in more-or-less the same form, in other areas of natural science and technology? I would go further and ask whether they exist in all areas of education and indeed of human communication. And my answer is that the management of embarrassing subjects is indeed universal. Further, in order to be effective, such management must not be easy to unmask. Nuclear physics textbooks at the senior-level for first-degree physics students, however, are unusual in comprising a homogeneous genre with features that can be revealed clearly by close, systematic study. I believe that this derives from the brutal, crude nature of nuclear weapons. There is an extreme mismatch between even their production (which always has to be for possible use) and the ideals of education and of civilisation.

Preamble on the Context of this Paper

The remarks in this section on context are revisionist, relative to the treatments that are to be found in degree-level nuclear physics textbooks, in that they attend especially to the military applications. I hope that this preamble, brief as it is, and the references therein will make it easy for readers to appreciate the problematic aspects of the nuclear physics textbooks and of the culture which creates them. An adequate understanding of the problem does require some knowledge of the history of the nuclear age in its technological, political and psychological dimensions. I have posted on the web (Cottey web link 1) a brief note written specifically as background to this paper. In addition, *Nuclear Arms Race: technology and society* (Craig and Jungerman 1986) provides a valuable overview of the history of the technology and politics of nuclear weapons to the 1980s. Since then the overall scale of the arsenals has been reduced. *Nuclear Notebook: Worldwide deployments of nuclear weapons* (Norris and Kristensen 2009) is the latest overview in a long series of updates in the Bulletin of the Atomic Scientists on nuclear weapon arsenals. This report begins

> As of the end of 2009, we estimate that there are approximately 23,360 nuclear weapons located at some 111 sites in 14 countries. Nearly one-half of these weapons are active or operationally deployed.

Nuclear physics has vital applications that are overtly military and applications that are not overtly military. The latter group of applications nevertheless has military connections. Two of these connections are especially important …

- most nuclear reactor designs produce an important nuclear weapon fuel, Plutonium, in large quantities
- nuclear-powered submarines (which may also be armed with long-range nuclear missiles), with their unique ability to cruise discreetly underwater for very long periods, have from near the beginning of the nuclear age decisively affected geo-political nuclear strategy.

By contrast with the under-reported significance of nuclear reactors as submarine power units, nuclear power stations are hyped. Seventy years into the nuclear age, they supply only a small fraction of the world's electricity and a smaller fraction of its energy. If there were no controlled nuclear power, submarines powered by nuclear reactors would not exist and geo-political military strategy would be significantly different. On the other hand, the world's energy resources would be, at most, little poorer (and arguably richer as alternative energy supplies and efficiency would have received more intensive development). The disparity between under-reporting and hype is even more marked in the case of nuclear fusion. The actually existing fusion weapons receive little attention while controlled nuclear fusion is much bruited. Yet despite very large R&D investments over more than half a century the goal of economic fusion power is forever claimed to be a few decades away.

One more feature of nuclear physics and engineering should be noted. The early military programs created a large number of highly skilled nuclear scientists and engineers. The repulsive nature of what they had created, under pressures of war

(including the Cold War), fed into a strong desire to put their skills to constructive use. The resulting enthusiasm for nuclear energy, especially for controlled fusion, overwhelmed the critical approach which is supposed to be a hallmark of science. This is an example of a general degrading of integrity. For another example Ravetz (1990) on pages 8 and 9 of The Merger of Knowledge with Power comments thus …

> Defence procurement is notoriously prone to lapse of quality control; and the special character of nuclear weaponry (being designed to prevent its own use) makes its testing quite problematic. All these tendencies combined and culminated in the Strategic Defense Initiative (SDI), where critics finally raised the question of whether it was an expensive fantasy.

The confusions and fantasies to which Ravetz refers are connected fundamentally with secrecy, which is wholly incompatible with science. Scientific knowledge claims must be open to the Mertonian norm, organised scepticism (Merton 1968). They cannot be exported, from a secret establishment, across the fence - see section C*b *Open Science and Ring-fenced Science* of Cottey (web link 2) - and remain scientific knowledge claims. Further, in today's dominant world-wide power structures, which are thoroughly militarised, any distinction between military and civil applications is vague and contestable. This applies to a significant extent to almost all (perhaps entirely all) aspects of culture - technology, science, education, medicine, etc. Consequently, the so-called spin-offs from military to civil applications, and from basic nuclear physics to applications of whatever kind, are impossible to state with conceptual clarity, much less to quantify. These ideas strengthened my opinion that a close textual study of the chosen type of nuclear physics textbook would be valuable, because it would contribute in an important area and there was a well-defined, publicly accessible corpus to work on.

Related Work

The paper *Physics and Modern Warfare: the awkward silence* by E L Woollett (1980) includes a study of physics textbooks for US non-science majors. The author writes on page 105

> Only 5% of these texts contain a significant discussion of a central problem of our age which is intimately related to progress in scientific knowledge: the acceleration of the arms race fuelled by science-based military technology.

Thirty years later, the bipolar arms race of that period no longer exists. Some things have changed but much remains the same. My study of nuclear physics textbooks published between 1950 and 2010 shows that remarkably little has changed, in respect the subject of the paper, between the earliest and the latest dates. The heightened consciousness of the 1980s was temporary.

In addressing today the problem of a silence, whose awkwardness many appear not to notice, I have drawn on ideas from linguistics. Works I found useful include *Texts and Practices: Readings in Critical Discourse Analysis* (Caldas-Coulthard and Coulthard 1996), *Language and the Nuclear Arms Debate: Nukespeak Today* (Chilton 1985), *Language and Society* (Downes 1998) and *Language and Power* (Fairclough 2001). Downes writes on page 412

> … the sociolinguistic phenomena we have studied enact the interests and conflicts of power in society by means of mechanisms of which participants are generally unconscious or deny. This is particularly marked in terms of various public discourses and registers, for example the media, bureaucratic, legal, academic, technical-scientific, advertising, etc., but is also inescapably pervasive since all texts are part of the social process.

The conflict which Downes notes as inescapably pervasive is especially intense wherever the shadow of the Bomb falls. I have also drawn on ideas in *Nonviolent Communication* (Rosenberg 2005a) and *Speak Peace in a World of Conflict* (Rosenberg 2005b), about communication in conflictual situations, especially the merits of empathy and the opinion that hostile judgements do not generally have a useful effect.

I end this section by observing that neither this paper nor my other efforts in nuclear education have a special connection with any single theoretical method. This paper is the result of over half a century's concern about nuclear weapons, finding relevant ideas and information from many aspects of culture (science, technology, psychology, literature). I anticipate that the ideas in the works cited in the present section will make clear both the relevance of the selections which occur in the 'Features of Nuclear Textbooks' section and the way in which this evidence leads to the 'Education and Power' and 'Conclusion' sections.

Who is Responsible for the Nature of Nuclear Physics Textbooks?

Most books are strongly associated with their authors. Teachers and students informally identify their textbooks by the authors' names alone. This association is formalised in the Harvard referencing system, used in most academic journals. The implicit assumption of this convention and its important effects generally go unnoticed. These assumptions and effects are especially significant for the present study. I therefore attempt to defamiliarise the Harvard referencing system with the following remarks …

If the convention were used without comment in the present study, two important difficulties would arise. One is that the textbook study, with its focus on deviations from the usual norms of physics education, would be at risk of inducing defensiveness in those involved in the production of the textbooks. I believe it is

desirable and possible to avoid inducing a defensive response by explaining thoroughly the spirit in which this study was undertaken.

The other difficulty is that referring to textbooks by their authors' names alone creates an oversimplified representation of what the textbooks are and of who (persons, institutions, cultures) are responsible for their form, production and use. Using this oversimplification without comment in the present study would reduce its ability to produce a useful analysis and reduce its chances of being heard. It is true, of course, that *any* citation form creates an oversimplified representation. The defamiliarising remarks presented here are intended as a constant reminder that this is so.

Any textbook of the kind studied here is far from being solely the individual work of the physicist(s) named as the author(s). From its conception (when a publisher, colleague, friend or family member encourages a prospective author, or an author makes a proposal to publisher) the project is embedded in an ambient culture. Everyone directly or indirectly involved in such a project, whether as scientist, editor, marketer, designer, proof-reader, friend or family member has been influenced throughout their lives by highly relevant norms. These include – currently accepted usages in language, values relating to knowledge, values relating to hierarchy (social power) and economic values.

These norms, being widely consensual, feed powerfully into social constraints on what should appear in nuclear physics textbooks. The frightening and repulsive properties of nuclear weapons produce a widespread desire to look away. This inattention feeds into and is reinforced by the political setting of nuclear weapons. They were developed in the greatest secrecy. Nuclear decisions were, and to this day still are, taken without accountability, behind closed doors, by political elites. The public knows little of how such decisions are taken, of which individuals or institutions have influence, or even of what the policies and decisions are. This is the

culture of reticence in which almost everyone is raised and which constrains virtually all discourse. It sits uneasily with other aspects of culture such as desires for democracy, freedom of enquiry and freedom of speech. The education of physics students and the production of nuclear physics textbooks take place in this culture.

In view of all these circumstances, I decided to flag the usual way of referring to the textbooks surveyed, with the authors' names strongly foregrounded. I often refer to the books by the title, rather than the authors. In referring to specific features of particular textbooks, I often use constructions like 'the book tells us', rather than the more normal 'Smith says', etc. My aim is to present a critique of the textbooks which foregrounds the culture in which we all live. I suggest that the psychological defences underlying the peculiarities of the nuclear physics textbooks are the same as those that are used by almost all of us in this alarming nuclear world.

Texts and Discourse

In the preceding section I have emphasised that understanding a text requires awareness that texts are not simply marks on paper and are not solely the product of their authors' labours. Since this study is based primarily on close textual analysis, a few words are needed here to make clear the relation of this limited study to discourse analysis in general. My approach relates closely to the exposition in *Language and Power* (Fairclough 2001). *Discourse* is (page 14) "language as social practice determined by social structures". *Order of discourse* is defined (also on page 14) by "Actual discourse is determined by socially constituted *orders of discourse*, sets of conventions associated with social institutions." From this point of view the printed content of a particular nuclear physics textbook is a *text.* The book is part of a greater entity, a discourse, which includes the *process of production* of the text. This process runs from the germ of a proposal, through many stages to the physical production and on to the transfer to point-of-use. The discourse also includes the

process of interpretation (how readers respond as they use the text) for which the text is a *resource*. Discourse is *practised.* It is a process whereas a text is a product.

The nuclear physics textbooks of the present study are remarkably homogeneous. This reflects the homogeneity of the social milieu in which they exist and function. The discourses around these individual books belong to a particular order of discourse, which we might call the senior-level physics degree nuclear physics textbook order of discourse. Using the concepts just discussed we could divide an exhaustive study of this order of discourse into three parts (which are however interconnected)

--- production (a process)
--- the text (a product)
--- interpretation by users (a process)

An exhaustive study of the senior-level physics degree nuclear physics textbook order of discourse would be a large project. The present study is more limited. It looks closely at what is written in the textbooks on matters relating, directly or indirectly, to nuclear weapons. A study of texts has the great advantage that the material included can be defined exactly. The results of the study cannot however be as precise as this because the meaning of the textual material depends on the other two parts, production and interpretation. In the present study I am, for reasons of practicality, not including a full study of the production and interpretation parts. I do however (necessarily) bring to the study my own general knowledge about the cultures, from the 1950s to recent times, within which these textbooks have been produced and received.

Features of the Nuclear Physics Textbooks

I turn now to a sequence of short sub-sections indicating some of the features of the nuclear physics textbooks which relate to the menacing shadow. The features to which I draw attention occur frequently. The few brief quotations which support the analysis are taken from a much larger number of examples, some hundreds, which I collected from the textbooks.

Asymmetry: All of the nuclear physics textbooks are highly asymmetrical in their treatment of the applications of the subject. They promote a picture of beautiful basic physics (I agree!) and wholly or principally civil applications (I beg to differ!) The fundamental question for this study is – how is this highly asymmetric picture created and accepted?

In nearly all of the textbooks one can detect a desire to downplay applications but, inconsistently, to give attention to power reactors. For example the Preface of *Elements of Nuclear Physics* (Burcham 1979) asserts on page xi "As in the earlier book, no account is given of the many important applications of nuclear physics in modern technology" but in fact the earlier book, *Nuclear Physics: an Introduction* (Burcham 1973), does have a substantial section on nuclear reactors. The asymmetry which is a principal object of study in the present paper appears to be largely or even entirely subconscious in many of the textbooks. Taken as a whole, *Fundamentals of Nuclear Physics* (Jelley 1990) gives the impression of compartmentalisation. On page xiii of the Preface we read

> … a microscopic description of nuclei, which is an intriguing many-body problem and forms an important part of this book. Besides this interest, parts of nuclear physics are of importance in the study of elementary particle physics and several nuclear phenomena have particular significance in other fields: for example, fission in nuclear power, fusion in astrophysics and radioactivity in biological tracer techniques.

Self-description (by authors or publisher of the general character of the textbook): It is relevant to see what the authors and publishers themselves say about the general character of their books and what they are for. Usually there is an explicit or implicit claim along the lines of "The authors' aim is to provide a clear and comprehensive account of the basic concepts" (back cover of *An Introduction to Nuclear Physics*; Cottingham and Greenwood 1986). A similar claim occurs in the Preface of *Particles and Nuclei: an Introduction to the Physical Concepts* (Povh et al 2006) which contains, on page VII, the phrases "conveys the fundamental knowledge in this area", "traditional grounds" and "strongly emphasise the physical concepts". The first chapter then opens with a quotation from Wilhelm Busch's *Max und Moritz*, which recommends the student to "... hear with pleasure Sages/ Teach the wisdom of the ages". From this and some other quotations, inserted without real connection, into about 350 pages of technical material, I infer that the quotations and other features suggest a strong desire to express something important about wisdom, which is however even more powerfully repressed by the ideology of knowledge-inquiry (Maxwell 2007). I plan to publish separately a detailed account of this interpretation of *Particles and Nuclei: an Introduction to the Physical Concepts.*

Claims about applications are carefully worded and less than frank, as in

> This book should therefore be useful in an advanced undergraduate course in nuclear physics, to engineers interested in the large-scale applications of nuclear physics grouped together under the name "nuclear engineering," or to anyone else with the indicated preparation who might be interested in nuclear physics.
>
> page v in the Preface of *Nuclear Physics* (Kaplan 1955)

Hamlet without the Prince: This is a feature of almost all of the texts. *An Introduction to the Physics of Nuclei and Particles* (Dunlap 2004) is a notable example because the book gives (pp 167 -8) an unusually detailed and clear exposition of a supercritical fission reaction without even a hint of its military application. The nearest the reader gets to this is that the number of neutrons "becomes very large very fast and the chain reaction is uncontrolled."

Page xi of the Preface of *Modern Atomic and Nuclear Physics* (Yang and Hamilton 1996) provides another example

> Thus, examples of very recent developments and future plans are described to excite students by allowing them to see how the techniques and ideas of atomic, nuclear, and particle physics have been used and are being used to attack important problems in other basic and applied areas of physics, chemistry and biology on to major societal problems in medicine, energy resources, new tailor-made materials and environmental pollution, and in areas of wide cultural and historical interest such as dating the Shroud of Turin, the levels of civilization revealed by the compositions of ancient artefacts, and the cause of the extinction of the dinosaurs.

The references at the end of this passage to civilization and extinction are clearly made with no sign of irony. It is nevertheless hard to imagine that those who wrote and worked on it had no buried sense that something was missing.

Narrative flow: In general the textbooks have a smooth narrative flow. Close attention to the flow itself is necessary if one is to understand how this is achieved. A particular transition which needs managing is the transition from basic physics of nuclei to controlled chain reactions with minimal attention to explosive chain reactions. One way in which this is commonly achieved is by making an early mention, when the basic physics of neutrons is discussed, of the nuclear reactor as a source of neutrons, that is, primarily as a research tool. *Nuclear Physics* (Green 1955) page 87 is an example. Further along, when the chain reaction is discussed, the scene has been set to proceed smoothly to reactors (that is, controlled chain reactions). Later, on page 314 of the same book, there is another example of control of narrative flow, this time by means of (distinctly artificial) vocabulary. When Plutonium is mentioned it is "a fissionable fuel". The term *fuel* generally refers, of course, to what supplies a steady controlled reaction and not to material which undergoes an explosive reaction. Features like these, which steer thought away from destructive applications and towards constructive applications, are extremely common in all the textbooks.

Attention to marginal, speculative and specialised topics: This occurs in many of the textbooks, usually when applications are listed or outlined. Elsewhere the books are sober and focus on the essentials. For example, a textbook widely used for many years and recognised as a classic, nevertheless contains a suggestion that, even at the time of publication, could be seen as marginal, speculative and perhaps even bizarre

> A large canyon could be lined with concrete and fitted with a concrete roof so as to produce a giant steam boiler. Once every hour or so, a hydrogen bomb could be detonated inside the boiler …
>
> page 454 of *Introduction to Nuclear Physics* (Enge 1966)

Euphemism: If nuclear weapons are mentioned or indicated at all it is usually in a euphemistic manner. On page 267 of *The Atomic Nucleus* (Evans 1955) we read

> Then the military significance of separated U-235 resulted in the extension of established laboratory methods to full industrial-plant scale. As an enormously useful by-product of this great technical development, the isotopes of any element can now be separated…

Dilution: In many cases a book avoids the charge of ignoring the Prince altogether but a very low salience is achieved through dilution in a mass of other topics, some of which may be quite minor.

> Today, nuclear physics has entered into our world in a significant way. It influences other branches of science: chemistry, biology, archaeology, geology, engineering, astrophysics and cosmology. It is used widely in society at large - in industry, the environment, medicine, defence, criminology, power production and many other areas. Applications are found even in religion and the arts, where equipment and methods developed originally for nuclear research have found novel application. However, the exploitation of such a powerful force carries with it some danger and is the subject of much debate.
>
> p 3 of *Nuclear Physics: Principles and Applications* (Lilley 2001)

Misleading: In some cases expositions are positively misleading, as in

> During the war years most of the physicists were unable to continue their fundamental work. The discovery of fission had, however, raised the possibility of a neutron chain reaction, and this was achieved by Fermi in 1942. This was the first nuclear reactor, the prototype of the civil reactors that now provide much of our energy. This has also led to the construction of the first nuclear weapons.
>
> page 9 of *Introductory Nuclear Physics* (Hodgson, Gadioli and Gadioli 1997)

The “also” in the last sentence is too obviously misleading to require further comment here. It is less obvious that the whole passage is tendentious in several other

places. Starting at the beginning, the first sentence overlooks the fact that, but for the enormous military science projects of the war, “most of the physicists” at the time would not have been pursuing primary research physics of any kind, fundamental or not. In the penultimate sentence, “the first nuclear reactor” was part of the Manhattan project to build nuclear bombs, required especially to develop the reactors which would produce large quantities of plutonium. The phrase “prototype of the civil reactors” guides the reader away from an accurate understanding of the history. In this same sentence “provide much of our energy” is an exaggeration even in respect of *electrical* energy and is far from the truth in respect of the whole of our energy. Finally, the passage tells us that reactors “provide” energy but that the first nuclear weapons were “constructed”. If reactors do something, might not the first nuclear weapons have done something?

Under the shadow: Nuclear physics textbooks are in general written and produced to a high standard. It is therefore noteworthy that the standard slips when nuclear weapons are onstage or, more usually, in the wings. In a section on stellar fusion of *Nuclear and Particle Physics* (Blin-Stoyle 1991) we read (page 97) “for reactions of this kind to proceed in an, inevitably, relatively infinitesimally smaller fusion reactor on earth requires ...”. In more ‘normal’ contexts one hardly ever finds solecisms, much less anything as outstanding as this. Misprints and other minor slips are also more common in the nervy areas. For example *Nuclear Physics: an Introduction* (Burcham 1973) refers on page 635 to 289Pu. (It should be 239Pu.) Again, the shadow of “the first two bombs” is cast on page 592 of *Modern Atomic and Nuclear Physics*. A surprising error is introduced between the first and revised editions (Yang and Hamilton, 1996 and 2010) of this book - “Nobel Prize” is changed, twice, into “Novel Prize”.

And the standard of exposition drops, as when an otherwise sophisticated and accurate book, *Concepts of Nuclear Physics* (Cohen 1971), suddenly descends (page 407) to “An atomic bomb is basically a fission reactor with a mass very much larger

than the critical one." This manages to be simultaneously wrong and confusing. Wrong because, for a workable atomic bomb, the mass of weapon-grade material cannot exceed about three times the critical mass, which does not qualify as "very much larger". The phrase is confusing because in normal usage 'reactor' means 'controlled reactor'. The proximity of "reactor" and "very much larger" risks sending readers on a wrong track, since a controlled reactor does indeed have a mass very much larger than that of a bomb.

Vagueness: The writing in nuclear physics textbooks is, almost everywhere, impressively precise and pithy. This ceases to be so for passages which fall under the shadow. For example, on page 115 of *Nuclear Physics in a Nutshell* (Bertulani 2007) we read "…only a few [unstable nuclides] exist in nature in significant amounts … 235U92, 238U92, 232Th90 are of great importance in nuclear engineering". That is all. There is no follow-up anywhere. It is not helpful to tell a student that something is important but not say why. All the student will get is a subliminal reinforcement of the conventional connection of nuclear engineering with civil nuclear power.

Laconic: Deviations from the generally high standard of connected exposition occur at those places where a connection between the acceptable and the unacceptable material could logically be made. For example, in *Nuclear Physics* (Green 1955), only near the end of a 35 page chapter (*Liquid-Drop Model and Fission*), do we read (page 312) "Information concerning these cross sections has recently appeared in the unclassified literature" and this is the first hint in the chapter of the military significance of fission. A little further on, we come to the exposition of the discovery of nuclear fission and the question of whether the relevant parameters might sustain a chain reaction. Here, the language can even be said to be dehumanised - "The fact that these parameters were found suitable is recorded in history" (page 313).

The so-called hydrogen bomb: Fission bombs are dreadful enough, yet fusion weapons (H-bombs) can be hundreds of times more powerful. I think there is evidence from the nuclear physics texts that the general attitude to the two types of

weapon is not that both are equally at the top end of the scale of horror. Even nuclear physics textbooks seem reluctant to acknowledge the existence of fusion weapons. *Nuclear and Particle Physics* (Martin 2006) is more explicit and detailed than most in acknowledging fission weapons (pp 258 - 60) yet in twelve pages (266 - 78) on fusion, covering the physics, astrophysics and (the prospect of) controlled terrestrial fusion, the book manages to 'slip around' fusion weapons. An application that has been achieved and is of prime cultural (economic, social and political) importance is not noticed. This is very common in the textbooks surveyed and it is worth looking closely to see how so large an elephant can be invisible. In the case of *Nuclear and Particle Physics* (Martin 2006) it is done, within a few lines of the beginning of the section (page 266), by comparing fusion with fission and focusing on the greater abundance of the light nuclei available for fusion.

> Since light nuclei contain fewer nucleons than heavier nuclei, the energy released per fusion is smaller than in fission. However, as a potential source of power, this is more than balanced by the far greater abundance of stable light nuclei in nature than very heavy nuclei. Thus fusion offers enormous potential for power generation, if the huge practical problems could be overcome.

What is happening here, I submit, is that the "energy released per fusion" and "abundance" remarks comprise a safe route to (controlled) "power". The difference between the - very large - amount of energy which is available from fissionable materials, and the "enormous" amount which is potentially available from fusible materials, is not, in fact, of primary importance. The (probably subconscious) reason for arguing in that way is to get to controlled fusion (which is still only a remote potentiality) without noticing fusion explosives (which have long been a profoundly important reality). When safely 'home', at either controlled fission or controlled fusion, nuclear physics textbooks usually expand into longer and often enthusiastic expositions. Apparently smooth flows like this occur in all of the textbooks. In my opinion they can only be understood from a broad perspective which takes account of

the full range of cultural and psychological influences on all persons involved in the production, distribution and use of textbooks. Indeed, even to refer to ‘all persons’ is not enough, because some of the cultural influences are institutional.

The phrase *the so-called hydrogen bomb* is sometimes used, for example on page 129 of *Nuclear and Particle Physics* (Williams 1991). Obviously the term *hydrogen bomb* is not scientifically sophisticated, but that, I suggest, is not the point. The real significance of the appearance of *so-called* is that it undermines the reality of the fusion bomb. Nuclear physics text authors are as disturbed by the shadow as everyone. Their extensive scientific training has not protected them from irrationality. How else do we understand the appearance of the phrase *these so-called thermonuclear reactions* on page 389 of *Concepts of Nuclear Physics* (Cohen 1971)? For *thermonuclear reactions* is a technical term neither more nor less *so-called* than hundreds of others. It seems that the author and checkers have lost concentration and been influenced by the formulaic phrase *the so-called hydrogen bomb.*

Extravagance: Nuclear physics textbooks are almost everywhere precise and restrained but under the shadow other qualities often appear and one of them is extravagance. *Introductory Nuclear Physics* (Wong 1998) for example ends with a purple passage, page 395, that includes the phrases *fundamental, intrinsic interest, pointing the way to new physics, great expectation, important, basic, interesting by themselves and may also lead to new knowledge, interest, questions that will be revealed, improve our knowledge, development, find out more, new heights, extremely rich, unravel the mystery of the physical universe.* And in the excitement an error in one phrase, *importance of the problem cannot be understated,* was overlooked.

Then and now: The publication dates of the textbooks analysed range from 1950 to 2010. Unsurprisingly, the authors and publishers justify a new book by emphasising novelty but in truth the changes in nuclear physics, at the level of these textbooks have, over this period, been minor. For the senior-level undergraduate, nuclear physics is a mature subject. I do not decry the publishing of updated nuclear physics textbooks, of which indeed the number is relatively small. Rather, I observe that for the question addressed in this study – how do nuclear physics textbooks relate to nuclear weapons? – little has changed over the 60 years. The ways of dealing and not dealing with applications has remained remarkably constant. One blip occurred in the late 1970s and 1980s, when the developments in nuclear arms and strategy - which had in fact gone on discreetly all the time - became a matter of heightened public concern. (Readers looking for an overview of the place of nuclear weapons in world politics are recommended to consult (Heuser 2000) *The Bomb: nuclear weapons in their historical, strategic and ethical context* or (McWilliams and Piotrowski 2005) *The World Since 1945: a history of international relations*.) Following that blip, two nuclear textbooks were published, *Nuclear Physics: Energy and Matter* (Pearson1986) and *Introductory Nuclear Physics* (Krane 1988), which gave more than lip-service to the problem of the nuclear weapon arsenals. *Introductory Nuclear Physics* has nearly four pages (553 – 557) on thermonuclear weapons and near the end writes "It is apparent to any reasonable thinker that this silly overkill capability compromises everyone's security". *Nuclear Physics: Energy and Matter* has a little on nuclear weapons, fission and fusion. On page x of the Preface we read, of fission and fusion chain reactions "Since both of these self-sustaining processes constitute sources of enormous amounts of energy, they offer the brightest hopes, and at the same time pose the most appalling threat to mankind". These two books can now, more than twenty years later, be seen as a reflection of the public concern of the times. Yet they did not start a trend. On the whole, later books are, in relation to nuclear weapons, very similar to earlier books. At first sight one might think that an exception to this assessment is provided by the change between the first (Martin 2006) and second (Martin 2009) editions of *Nuclear and Particle Physics*. The

second edition has extensive added material (pages 271 and 273 - 278) on nuclear weapons and the treatment is direct and is more salient than usual, having its own main section (8.3) and being flagged by the publisher on the back cover. Still, these changes do not amount to getting to grips with the basic cultural and moral problem. A technical exposition culminating in bald expressions about kilotons and megatons does not help the student towards an understanding of the *meaning* of nuclear weapons.

Education and Power

Degree level nuclear textbooks have some characteristics that are not at all close to the ideal of education as usually expressed. Education is supposed to encourage independent, fair-minded critical thought. From this point of view the textbooks generally reach, in my opinion, an impressively high standard *in respect of knowledge and understanding of the relevant basic physics.* Claims to this effect are widely, and justifiably, made in Prefaces and publishers' descriptions. (Publishers' descriptions, I hasten to add, while obviously for the purpose of marketing, are not at all trivial. The many contributions along the trail of a book's inception, production, marketing and use are all important. To ignore or deny this is to fail to see the difference between a ripple in the ocean which dies away immediately and a swell which propagates.)

Another group of claims - that a treatment covers important applications - is however more problematic. The publishers' description on the back cover of *The Atomic Nucleus* (Reid 1984) asserts

> A growing number of engineers and students of physics need to understand the technical implications of nuclear physics. This book has been developed to meet their needs.

In fact, the book has the usual asymmetry, that is, almost complete silence on military applications.

This brings us to a consideration of *power*. A Candide might well be amazed at the mismatch between the sophisticated and professional production and transmission of some kinds of knowledge, in this case of the basic physics of nuclei, and the experts' ability to ignore an elephant in the corner. Yet those who point to an elephant that others do not see do not directly convert those others. On the contrary they usually cause the others to reinforce their psychological defences. What is needed in such cases is to understand the reasons for inattention, diversion, and similar defences. Obviously the horror of nuclear weapons is a factor but I believe it not the only, or even the principal, one. For each of us as individuals, crossing a road carelessly is also likely to have horrific consequences. Yet we do not retreat into inattention, just hoping that nothing will happen. We take care, and the reason is that *it is in our power to do something effective*. I suggest that although there is something highly unsatisfactory about the nuclear physics textbooks genre, it is not in the power of authors alone to do something about it. That is not even in the power of the nexus of physicists-publishers-distributors-users alone. We all are faced here with a deep problem for human culture and we have not approached it at the required level. Seventy years on, we still hide behind psychological defences instead of addressing nuclear issues with realism.

These defences separate parts of our thinking from other parts. Linguists have used a number of terms and ideas in order to bring into consciousness features of language that are subliminal in normal flowing discourse. Fowler (1996) discusses, at various places in his book, the concept (developed notably by M A K Halliday) of *register*. A dictionary definition (Soanes and Stevenson 2003) is

> a variety of a language or a level of usage, as determined by degree of formality and choice of vocabulary, pronunciation, and syntax, according to the communicative purpose, social context and standing of the user.

Another concept especially relevant for the present study is that of *formula*, or *formulaic phrase* or *formulaic pattern*. This concept is discussed at several places in Fowler (1991). Language users, through constant repetition in flowing, natural situations, recognise registers and formulae instantly and largely unconsciously. This is how, in the above quotation from a publishers' description of *The Atomic Nucleus*, the terms "engineers" and "technical implications" can be written, approved and read without anyone tripping over them. In the register of the present article, of course, one does trip over them, for it is admitted and constantly remembered that a large part of "nuclear engineers" and "nuclear technology" is military and the book does not "meet their needs". Especially important for this study are a number of formulaic phrases constructed around the words *energy* and *power*. The terms *energy* and *power* themselves and the phrases *nuclear energy, nuclear power, a nuclear power, nuclear powers* exist in many registers, in the mass media, in academic social/political/cultural studies, and in physics. The term *nuclear power* is used when referring to the large-scale continuous controlled production of energy. In nearly all registers, however, this is in a context that implies the large-scale generation of electricity by a power station for supply to an electricity grid. Registers in which *nuclear power* implies or includes the generation of the energy requirements of submarines occur only in specific discourses. Such is the power (that word again!) of registers that the association of unqualified nuclear power with terrestrial power stations and its separation from military matters goes unnoticed. And this is so despite there being a strong case, as argued in the Preamble, that the latter are far more important than the former.

According to the definition offered by the Oxford Dictionary of English (Soanes and Stevenson 2003), the core, or central, meaning of the word *power* is "the ability or

capacity to do something or act in a particular way". Thus power is relevant for everything to do with human social existence and it is not surprising that it enters into all human discourses. Even from a mere dictionary list (Soanes and Stevenson 2003) of more specialised meanings and associated constructions and phrases of the word, we can understand why *power* occurs in different ways in a very large number of registers. There remains the puzzle, how is a (supposedly) sophisticated, educated society able to finesse such obvious inconsistencies as the ones studied here in nuclear physics textbooks?

I suggest that at least a part of the answer lies in the *continuous* role of language in human consciousness, and indeed even in semi-consciousness. From early childhood, we think our thoughts in language. What we make of our perceptions depends on those thoughts. What then, are a few inconsistent impressions (no matter how incontrovertible), if they are placed against an enormous number of contrary impressions and teachings? Are we to revisit everything we thought valid in order to resolve the few inconsistencies? That would seem too high a price. But how to decide what to re-examine? A rational answer to this question is obvious - look to what is inconsistent with what. That is however not usually so simple, otherwise the inconsistency would never have become established and maintained. Inconsistencies survive in our discourses courtesy of devices like inattention and obfuscation. It is therefore necessary, in a resistant reading, to look out particularly for expected connections that are not made and if we find them to pay special attention. This may at first sight seem an obvious and easy thing to do but when buried reasons for inattention, etc, have their own powerful, albeit inadmissible, logic, it is far from easy. This is why the irrational features of the nuclear physics textbooks are so refractory and have remained remarkably stable for more than half a century. Education, with its ideology of encouraging independent, fair-minded critical thought, should be exactly the needed tool. That this tool is to be turned on an element of education itself, namely the content of some textbooks, makes the task complicated but not impossible.

Conclusion

In this study I have drawn attention to unusual features of nuclear physics textbooks in areas which fall under the shadow of the bomb. These features have been nearly constant for more than half a century. Most of the users of the textbooks, as well as those involved in their production, and indeed the wider society, must, at some level, be satisfied with these products. People must throughout the considered period have desired a comfortable image of nuclear physics and turned away from a realistic image. Experts do have a special responsibility to 'tell it as it is'. The analysis in this paper will, no doubt, lead many to conclude that in this case the experts - editors and marketers, etc, as well as authors and referees - have failed to discharge important social responsibilities. Nevertheless, I maintain that it is unrealistic to expect such specialist groups to act *independently* of the wider culture. An adequate response to the nuclear situation in which we all find ourselves, based on a rational programme for long-term survival, rather than on psychological defences, has to come from all. When the social and political attitude to nuclear weapons becomes one of sustained concern, rather than inattention, there will be a demand for books reflecting the change. Then authors and publishers will quickly respond. Textbooks, after all, are expressions of what is consensual. Changes are initiated by critical elements in society. In the case of nuclear education, these may be expected to come from outside and from within the ranks of those with professional expertise.

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APPENDIX. Chronological Bibliography of Nuclear Physics Textbooks Surveyed

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