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Ptolemy Revived? — The Existence of a Mild Instrumentalism in Some Selected British, American, and South African High School Physical Science Textbooks

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Scientific theories are our intellectual constructions about the nature of the physical world. There are at least two ways of relating scientific theories and the world: the first is called *realism*, and the second *instrumentalism.*

A realist believes that theories actually describe what the world is really like. For the realist, the kinetic theory of gases claims that "gases really are made up of molecules in random motion" (Chalmers, 1986, p. 146). On the other hand, an instrumentalist holds that scientific theories do not actually describe the world, but simply relate sets of observations. For the instrumentalist, the kinetic theory of gases is merely a convenient fiction enabling scientists to relate and make predictions about the observable properties of gases, in order to make use of them in a variety of ways. Theories are only useful devices for prediction.

Instrumentalism, then, is an approach to scientific inquiry which shelves questions about the real nature of the universe, and is solely interested in whether its practical purpose of computative predictions work or not. Instrumentalist science stems from tough-minded, common-sense *empiricism*, which regards all knowledge as coming from sensory experience. The inductivist-empiricist assumes that such sensory observation is objective and theory-free. So too does the instrumentalist.

According to Popper, "the *instrumentalist view* . . . has become an accepted dogma" in contemporary physical science, and in fact "has become part of the current teaching of physics" (1956, p. 360). Since physics teaching begins in schools, it is important to see if instrumentalism is present in school science, and if so, its pros and cons.

Instrumentalism from Ptolemy to Dewey

Saving the Appearances

Instrumentalism has its origins in the compartmentalized thinking, the "controlled schizophrenia," as Koestler puts it, which began to emerge with the Greek astronomers around the 2nd century A.D. In order to account for the retrograde loopings of planetary paths, Ptolemy devised a complex system of 40 wheels within wheels or epicycles. He never believed that there really were wheels out there, but they did "save the appearances" and provided a mechanism for accurately predicting the position of the planets. The astronomer "saved the phenomena" by inventing a suitable hypothesis; it was immaterial whether the hypothesis was true or not, that is, whether it was physically possible or not. As Koestler points out,

> astronomy, after Aristotle, becomes an abstract sky-geometry, divorced from physical reality. . . . It serves a practical purpose as a method for computing tables of the motions of the sun, moon and planets; but as to the real nature of the universe, it has nothing to say. (1959, p. 74)

Copernicus, however, put forward a theory which not only predicted but also explained. The Copernican theory provided a more comprehensive conceptual structure with a much greater power for promoting understanding. It revealed a physical link between planetary motion and theory. Copernicus believed that his theory was a true description of external reality, not a mere fictional hypothesis. It did not matter whether you believed in the existence of Ptolemy's epicycles or not; all that mattered was that his theory worked. However, Copernican theory had to be taken seriously for it attempted to describe what is physically really out there. Copernicus' sun-centred system was more than a computational device.

Realism Versus Phenomenalism

Instrumentalist science is interested only in sensory phenomena, and avoids any reference to a reality behind appearance. William of Occam was against the Aristotelian tendency to create unnecessary entities, such as a reality behind the phenomena. Reality, said Occam, is precisely what appears to the senses. All our knowledge about the world comes through our senses. All being is thus reduced to what is perceived. Theologians were quick to realize that Occam's radical empiricism (or nominalism) meant that spiritual beings, and in particular God, were threatened.

Galileo accepted Copernican heliocentric theory as a true description of reality. Cardinal Bellarmino objected to this realist interpretation, but informed Galileo that it was permissable, from the Church's standpoint, to hold the Copernican system as a mathematical device for saving the appearances. In other words, the Church was willing, temporarily, to accept Galileo's theory in a phenomenalist, instrumentalist sense.

Berkeley's Instrumentalism

Similarly, Bishop George Berkeley saw Newton's theory as a serious competitor to religion. What distressed Berkeley was that Newton talked about "forces" as if they were real. For Newton, forces were more than mere terms in an equation. Berkeley regarded forces in mechanics as analogous to Ptolemaic epicycles in astronomy, useful in calculating the motions of bodies, but without real existence. Berkeley's instrumentalism stemmed from his bold empiricism: all our knowledge comes through our senses. Since force is unobservable, we cannot have any knowledge of it. All we can observe is the motion of bodies. Indeed, the notion of force as a causal agent derives from the fact that it is a concept in the mind. Thus Berkeley's instrumentalism derives from his idealistic philosophy.

Mill's Inductivism as a Form of Instrumentalism

The aim of 19th-century positivists like John Stuart Mill was to eliminate metaphysics from science as far as possible. A tough-minded empiricist approach was adopted. Whatever was beyond the reach of experience should be rejected.

Mill was a thorough-going inductivist. He held that scientific inquiry is a process of inductive generalization from the results of observations and experiments. Mill suggested that the world of appearances should be accepted as it is. If the external world is defined as a set of phenomenal objects, the existence of an underlying sub-stratum becomes a pseudo-problem. As Gardner notes (1983, p. 20), Mill saw nothing wrong with belief in a reality behind the phenomenon; he simply found it superfluous, adding nothing to what we already know. Hence, in his view, the object of scientific inquiry should begin and end with the phenomenal world.

In the 1920s, the logical positivism of the Vienna Circle reinforced the inductivist view. It is meaningless to talk about what lies "behind" or "beyond" experience. For positivists, phenomenalism is an adequate approach to science, just as realism is. Both yield successful results. However, the language of phenomenalism is more convenient.

Dewey's Instrumentalism and Pragmatism
An instrumentalist approach to scientific inquiry tends to be pragmatic and utilitarian. Like Mill, John Dewey assumed a phenomenalist standpoint. For a realist, truth is the correspondence between an assertion and reality. For Dewey, truth is that which is confirmed by testing; it is that which works. Truth is created when an assertion is confirmed.

Suppose there is a penny in a box. The realist says, "There is a penny in the box," whether or not the assertion is verified. The pragmatist says, "There is a penny in the box," only when, on opening the box, he sees the penny. Truth is instrumental and expedient. Theories are not "judged in terms of truth or falsity but rather in terms of their usefulness as instruments" (Chalmers, 1986, p. 147). Popper rejects this notion of truth because it is relativistic.

Instrumentalism distinguishes clearly between observation and theory. For the instrumentalist, observation is objective and theory-independent. Scientific theories are mere fictions, nothing but convenient instruments. Theories may, or may not, describe the real world; it does not matter whether they do or not. What matters is the relationships between observations. Thus instrumentalism is a shallow form of realism dealing with appearances only.

Instrumentalism in School Science Textbooks

Cawthron and Rowell (1978, p. 31) suggest that one way of investigating whether instrumentalism is present in school science is to analyze the contents of the most widely used textbooks in school science courses. No matter how objective a science textbook purports to be, it contains explicit or tacit assertions which reflect a particular philosophy of science. Although it is recognized that the contents of textbooks represent the beliefs of their authors, nevertheless they must also reflect the views of the practising school science community who give the texts their popularity in the first place, and who presumably then become influenced by them.

The literature on the subject suggests that "a scrutiny of school science texts almost invariably reveals an implicit epistemological preoccupation with the existence of 'objective' reality" (Cawthron & Rowell, 1978, p. 32). Such textbooks "project an image of science which can be called empiricist-inductivist" (p. 33). Rowell and Cawthron state that "our texts portray science as some inexorable linear pursuit of truth" (1982, p. 93).

In a careful reading of nearly all the introductory first-year, non-major chemistry and physics textbooks in use in the United States during the 1979–1980 academic year, Factor and Kooser point out that

> as with the science and society texts, the narrow inductivism and empiricism of the 19th century, particularly that of John Stuart Mill, plays a formative role in the image of science in skills and drills texts. (1981, p. 28)

The empiricist view is strongly present in textbooks advocating the heuristic method of science education. Discovery by activity, as proposed generally by Dewey, and more specifically in science education by Armstrong, and more recently in *Science — A Process Approach*, emphasizes the role of observation and induction. Driver criticizes inductionism in that it "suggests that there is one unique interpretation of the data" (1983, p. 48). In fact, observation is theory-laden, and children can and do form multiple explanations for events, each of which accounts for the data in a particular way.

Kuhn observed that textbooks "address themselves to an already articulated body of problems, data, and theory" (1970, p. 136). The increasing reliance on textbooks, says Kuhn, accompanies the emergence of a first paradigm in any field of science. Furthermore, reliance on textbooks is becoming increasingly evident, especially in Third World countries, where the teacher often has little, if any, training in science. Thus the textbook is fast becoming the only vehicle for transmitting a correct image of science. As Kuhn says,

> More than any other single aspect of science, that pedagogic form (namely, the textbook) has determined our image of the nature of science. (1970, p. 143)

The aim of this study is to determine the image of science portrayed in a number of selected British, American, and South African high school physical science textbooks in widespread current use in schools. On the basis of the above literature, as well as our acquaintance with school texts, we made the hypothesis that *high school physical science textbooks in current use portray an empiricist-inductivist and, by implication, an instrumentalist image of science.*

Method

We began by listing the essential features of inductivism, empiricism, and instrumentalism and then drawing up a systematic check-list or questionnaire for the different philosophies. The check-list was used to try to ensure a uniform approach to our reading of selected textbooks. By careful reading, a reasonably consistent quantitative and comparative assessment emerged.

The following characteristics were chosen as being characteristic of the inductivist-empiricist view:

1. Science begins with observation.
2. Observation is objective.
3. Inductive generalizations arise from several instances.
4. Experimental data yield a unique conclusion.
5. Observation leads rigorously to laws and theories.
6. Laws are mature theories.
7. Science produces proven knowledge.

The following characteristics were chosen as being characteristic of the instrumentalist view:

1. Observation is objective.
2. Computative predictions relate observations.
3. Predictions are "expected."
4. Calculations are recipe-like.
5. Definitions are nominalistic.
6. Definitions are operational.

7. Theories are mere fictions.
8. Theories are not informative about the physical world.
9. Theories are only convenient instruments.

On the basis of these critiera, the text analysis (see Table 2) was drawn up.

Sixteen high school physical science textbooks were chosen for the study. Seven of these are texts widely used in British schools, as well as in English-speaking schools in Third World countries, such as Lesotho and Swaziland. Six are texts widely used in South African high schools, and are designed to cover the "New" 1985 Standard 8 and 9 Syllabus. (Average pupil age in Standards 8 and 9 is 15 and 16 years old respectively.) The reason for choosing these Standards was to align the textbooks with the corresponding British 0-level and GCSE, and the American *Project Physics, CHEM Study,* and *PSSC Physics.*

Eight of the books were read from cover to cover in order to obtain an overall assessment of their philosophy. These were A, B, C, D, E, F, G, and N in the list below.

Textbooks Examined

South African

A. Brink and Jones. (1985). *Physical Science Standard 8,* Juta.

B. Pienaar, Walters, de Jager, Schreuder. (1985). *Senior Physical Science 8,* Maskew Miller Longman.

C. Broster and James. (1987). *Successful Science (Physical Science) 8,* Oxford University Press.

D. Brink and Jones. (1986). *Physical Science Standard 9,* Juta.

E. Pienaar, Walters, Schreuder, de Jager. (1986). *Senior Physical Science 9,* Maskew Miller Longman.

F. Broster and James. (1987). *Successful Science (Physical Science) 9,* Oxford University Press.

British

G. Duncan Tom. (1987). *GCSE Physics,* 2nd Edition, John Murray.

H. Pople and Williams. (1980). *Science to Sixteen,* Oxford University Press.

I. Atherton, Duncan, Mackean. (1983). *Science for Today and Tomorrow,* John Murray.

J. Lewis and Waller. (1986). *Thinking Chemistry (GCSE Version),* Oxford University Press.

K. Pople. (1986). *Explaining Physics (GCSE Version),* Oxford University Press.

L. Warren P. (1985). *Physics Alive,* John Murray.

M. Lambert. (1985). *Physics for First Examinations,* Blackie.

American

N. The Project Physics Course (Harvard). (1970). *Concepts of Motion,* Holt, Rinehart and Winston.

O. CHEM Study. (1968). *Chemistry an Experimental Science,* Freeman.

P. PSSC. (1960). *Physics,* Heath.

Using random number tables, 10 pages were selected from *each* of the 16 textbooks. Thus, over the 16 selected textbooks, 160 pages were examined for their image of science.

Three distinct features were sought on each page: (a) level of pupil involvement, both in the text as well as in any practical laboratory work; (b) signs of inductivist-empiricism; and (c) signs of instrumentalism.

(a) *Level of Involvement*

It is suggested here that level of involvement, as discussed by Herron (1971) amd Tamir and Lunetta (1978), provides a way of determining the image of science portrayed in the textbook.

Herron determined the pupil's level of involvement in scientific inquiry by examining whether, in a laboratory inquiry, the problem, the method, and the solution, or any combination of these, were given to the pupil. Table 1 summarizes Herron's levels of involvement:

Table 1/Herron's Levels of Involvement

	Problem	Method	Solution
Level 0	Given	Given	Given
Level 1	Given	Given	Not given
Level 2	Given	Not given	Not given
Level 3	Not given	Not given	Not given

In this study, we interpret Levels 0 and 1 as giving to the pupil an image of science that is cumulative, factual, and proven knowledge. Because Levels 2 and 3, being more open-ended, give the pupil more opportunity for imaginative hypothesis-making, a more correct and up-to-date view of science would be conveyed, namely, that scientific inquiry begins with theory, and not with observation.

Tamir and Lunetta (1978) devised a more refined scheme for analyzing level of involvement. However, whereas they apply their procedure to practical laboratory inquiry textbooks, this has been extended here to include both ordinary expository text as well as any laboratory experiments present in the text. The reason for this is that some of the textbooks examined contain both text and inquiries, and others text only, with separate laboratory manuals. Ideas from Romey (1968) and Lowery and Leonard (1978) were also used, especially as far as the role of questions was concerned.

On a given page, the total number of sentences (excluding captions and headings) was counted, as well as the number of facts, questions, definitions, calculations, and instructions to the pupil-reader. These counts were then totalled for all ten pages of a given textbook, and converted into percentages of the total number of sentences on the ten pages sampled. Data for all ten pages of a given textbook were recorded on a text analysis check-list sheet (Section C on Table 2). At the end of the study, 16 text analysis check-list sheets, one for each textbook, had been completed.

These percentages were then transferred, for comparison purposes, to a summary of the text analysis (Section C on Table 3). Averages of these data were then calculated over the 16 texts in order to obtain a general idea of the overall level of involvement. This is reflected in the bar chart (Figure 1). Also included in this section (C) is a count of the number of practical laboratory inquiries found in each textbook, as well as the level of involvement, following Herron (1971).

(b) *Inductivist-Empiricism*
On a given page, all sentences in which the words "observe" or "observation" occurred were counted, and recorded under C8 of Table 2. These were totalled for a given textbook, and converted into a percentage of the total number of sentences in the ten pages examined in that text. These percentages were then summarized in C8 in Table 3 and the bar chart (Figure 1).

As far as the categories 1 to 9 in section A of Table 2 are concerned, if any of these features was encountered at least once, it was awarded a value of 1. If not encountered, a value of 0 was awarded. Totals for the ten selected pages of a given textbook thus have a maximum of ten points. These totals were then transferred to Table 3 for the sake of comparison. In order to obtain an average over all the textbooks for each category A1 to A9, say A1 on Table 3, all five rows of values in A1 were added. These totals were then added and divided by 16, then by 5, to get (for A1 on Table 3) the average 4.4. Because this is 4.4 out of 10, its percentage was charted as 44 percent on Figure 1.

(c) *Instrumentalism*
Similarly, the categories 1 to 8 under Section B of Table 2 were awarded a value of 1 if such features were encountered at least once. If not encountered, a value of 0 was awarded. Totals for each textbook had a maximum score of 10. These totals were transferred to Table 3, and averaged over the 16 textbooks. Again, because these were out of a maximum of ten, they were recorded as percentages on Figure 1.

Classification of statements according to the criteria in the text analysis often called for perceptive judgments. Therefore, in addition to these results, a detailed set of written notes was kept, justifying these judgments, especially where observation, computative predictions, definitions, induction, and theories and laws were concerned.

Also, the index at the back of the books was examined for any reference to keywords such as "theory," "mode," "law," or "observation." In the absence of an index, the book was skimmed from cover to cover for such references, especially in topics like Atomic Theory, Models of the Atom, and so on.

If any statement could be interpreted in either a realist *or* an instrumentalist sense, the latter was assumed. This was deemed to be a legitimate procedure because (a) positivism accepts both realist theory and instrumentalist theory as successful scientific views and (b) the aim of the study was to read the textbook from an instrumentalist perspective. For example, if the word "observe" was used in the text, it was assumed to refer to *objective* observation. In the same way, any calculation of the rote, plug-in type was interpreted as being a convenient computational device with no necessary connection with the real world, and hence not necessarily informative about the world.

Any references to words like "observe," "look," or "measure" were carefully noted and counted. Similarly, any historical assertion about a scientist "discovering" something was recorded. Any conclusions, or rules, or laws were regarded as inductive generalizations.

The lack of any discussion of the meaning or role of theory, or law, as well as of the theory-ladenness of observation, was also taken to be a sign of instrumentalism.

Preface Analysis
Finally, following Lynch and Strube (1985), the prefaces of all the textbooks were read to see if the author(s) claimed to be presenting a particular view of science, or of theory.

Table 2/Examples of Text Analysis: Textbook B (Pienaar and Walters 8)

Page Number: 188315, 40319285 92147234203326 Total

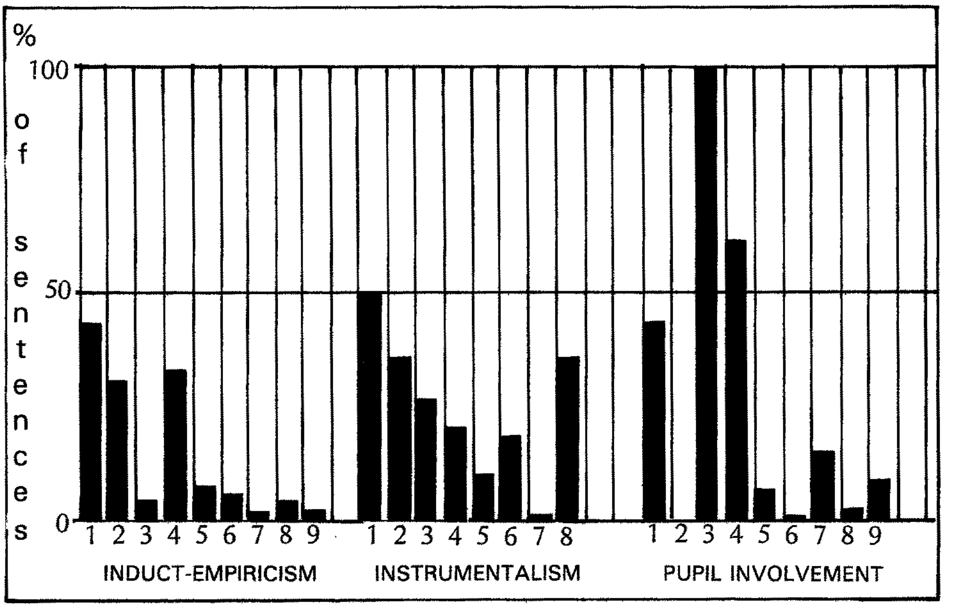
											Total
A. Inductivist-empiricism											
1. Observation	1	1	1	0	1	0	0	0	1	0	5
Science begins with observation	1	1	1	0	1	0	0	0	1	0	5
Observation objective	1	1	1	0	1	0	0	0	1	0	5
Science "discovers" facts	0	0	1	0	1	0	0	0	1	0	3
Unguided pupil inquiry	0	0	1	0	1	0	0	0	0	0	2
2. Inductive generalisations	0	0	1	0	1	0	0	0	0	0	2
No. of instances few	0	0	1	0	1	0	0	0	0	0	2
Verification	0	0	1	0	1	0	0	0	0	0	2
3. Laws and theories	0	0	0	0	1	0	0	0	1	0	2
Rigorously to laws and theories	0	0	0	0	0	0	0	0	1	0	1
Laws are mature theories	0	0	0	0	0	0	0	0	1	0	1
4. Science proven knowledge	1	1	1	0	1	0	0	1	1	0	6
Unique conclusion	1	0	1	0	1	0	0	0	1	0	4
Facts	1	0	1	0	1	0	0	1	1	1	6
Questions answered immediately	1	0	1	0	0	0	0	0	0	0	2
5. Scientific knowledge is reliable	0	1	0	0	0	0	0	0	1	0	2
6. Science leads to absolute truth	0	0	0	0	0	0	0	1	1	0	2
7. Technological "fix" (solves all)	0	0	0	0	0	0	0	0	0	0	0
8. Linear accretion of knowledge	0	0	0	0	0	0	0	0	1	0	1
9. Science always rational, logical	0	0	0	0	0	0	0	0	1	0	1
B. Instrumentalism											
1. Observation objective	1	1	1	0	1	0	0	0	1	0	5
2. Prediction and control	1	1	1	1	1	0	1	0	0	0	6
Computative predictions	0	1	0	1	0	1	1	0	0	0	4
Predictions "expected"	1	1	1	1	1	0	0	0	0	0	5
3. Convenient instrument	0	1	0	1	1	1	1	0	0	0	5
Recipe-like calculations	0	1	0	1	0	1	1	0	0	0	4
Only terms in equation	0	1	0	1	0	0	0	0	0	0	2
4. Definition: Nominalistic	0	0	1	0	0	0	1	1	0	1	4
Definition: Operational	1	1	0	1	1	0	0	0	1	0	5

5. Theories mere fictions	0	0	0	0	0	0	0	1	0	1	2	
Models convenient devices	1	1	0	1	1	0	0	1	0	1	6	
Mere hypotheses, ad hoc	0	0	0	0	0	0	0	1	0	1	2	
Games	0	0	0	0	1	0	0	0	0	0	1	
Doesn't matter if false	0	1	0	1	0	0	0	1	0	1	4	
Sterile, obscurantist	0	0	0	0	0	0	0	0	0	0	0	
Not informative	0	1	0	0	1	0	0	1	0	1	4	
Mere words	0	0	0	0	0	0	0	1	0	1	2	
6. Passive spectator, uninvolved	0	1	0	1	1	0	0	0	0	0	3	
7. Phenomenal, Superficial, Cosmetic	0	0	0	0	0	0	0	0	0	0	0	
Only observables exist	0	0	0	0	0	0	0	0	0	0	0	
8. Expedient, Pragmatic, Utilitarian	1	1	1	1	1	0	0	0	0	0	5	
C. Level of Involvement											Tot	%
1. No. of lab inquiries	0	0	1	0	0	0	0	0	0	0	1	
2. Practical (level of inquiry)	x	x	0	x	x	x	x	x	x	x	0	
3. Total no. of sentences	16	11	25	13	28	15	26	17	18	16	185	100%
4. No. of facts	14	6	13	3	16	0	0	8	18	15	93	50%
5. No. of questions	0	0	2	0	0	7	4	1	0	1	15	8%
6. No. of definitions	1	0	2	0	1	0	0	1	1	2	8	4%
7. No. of instructions to pupil	2	3	10	0	5	6	5	2	0	1	34	18%
8. No. of references to "observe"	1	2	8	0	5	0	0	0	1	0	17	9%
9. No. of calculations	0	1	0	5	0	2	2	0	0	0	10	

Table 3/Summary of Text Analysis: Totals of each book:

Book (See Table):	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Tot.	Av%
A. Inductivist-empiricism																		
1. Observation	4	5	4	2	7	5	2	0	5	1	0	4	5	3	9	6	62	
Science begins with observation	5	5	4	4	7	5	3	6	8	5	9	9	9	3	10	8	100	
Observation objective	5	5	4	2	8	5	3	0	8	1	0	9	7	2	10	8	77	44
Science "discovers" facts	5	3	4	3	6	5	2	7	5	6	9	8	5	1	7	7	83	
Unguided pupil inquiry	3	2	4	2	5	5	2	0	4	0	0	0	2	1	0	0	30	
2. Inductive generalisations	3	2	3	2	5	5	2	4	6	6	0	9	7	4	9	5	72	
No. of instances few	2	2	3	2	5	4	1	0	6	1	0	1	3	1	3	3	37	32
Verification	2	2	2	3	4	4	3	0	5	3	0	7	3	3	4	4	49	
3. Laws and theories	5	2	2	3	1	0	0	2	0	1	0	0	2	0	0	2	20	
Rigorously to laws and theories	4	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	9	6
Laws are mature theories	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	
4. Science proven knowledge	6	6	4	5	7	8	4	8	6	9	9	3	4	1	5	4	89	
Unique conclusion	3	4	2	2	5	3	0	0	5	1	0	0	0	1	0	0	26	
Facts	7	6	4	6	8	8	3	8	8	9	9	7	1	0	5	2	91	34
Questions answered immediately	0	2	2	0	2	0	0	0	1	0	0	0	2	0	0	0	9	
5. Scientific knowledge is reliable	1	2	2	2	1	1	2	2	1	0	0	0	0	0	0	0	14	9
6. Science leads to absolute truth	2	2	1	1	2	0	1	1	0	1	0	0	0	0	0	0	11	7
7. Technological "fix" (solves all)	0	0	0	0	3	1	0	1	0	0	0	0	0	0	0	0	5	3
8. Linear accretion of knowledge	2	1	1	1	2	1	1	0	1	0	0	0	0	0	0	0	10	6
9. Science always rational, logical	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	5	3
B. Instrumentalism																		
1. Observation objective	4	5	4	4	8	5	4	0	8	3	8	5	5	1	8	9	81	51
2. Prediction and control	5	6	4	6	7	5	9	9	4	1	6	1	1	1	6	3	72	
Computative predictions	4	4	5	5	4	3	8	2	1	1	1	2	1	4	1	2	48	37
Predictions "expected"	5	5	0	7	5	6	8	4	3	2	1	2	1	2	4	2	57	
3. Convenient instrument	5	5	5	6	3	3	6	7	5	0	5	5	1	3	4	3	66	
Recipe-like calculations	3	4	4	5	2	2	4	3	1	0	1	0	1	3	0	2	35	28
Only terms in equation	2	2	4	5	2	2	4	2	1	0	1	0	1	2	1	2	33	
4. Definition: Nominalistic	3	4	6	3	4	3	1	2	3	1	0	1	4	0	0	0	35	
Definition: Operational	4	5	1	2	2	2	2	3	3	1	4	0	2	2	0	1	34	22

5. Theories mere fictions	5	2	1	6	2	1	4	1	3	3	4	2	1	4	4	2	45	
Models convenient devices	6	6	1	4	4	2	4	7	3	3	4	1	0	0	1	3	49	
Mere hypotheses, ad hoc	1	2	0	2	0	1	4	0	0	0	0	0	0	0	0	0	10	
Games	0	2	0	0	0	0	4	0	0	0	0	1	0	0	0	0	7	
Doesn't matter if false	4	4	0	6	3	2	0	2	2	0	0	0	0	0	0	0	23	12
Sterile, obscurantist	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	
Not informative	1	4	3	3	0	0	0	0	3	1	0	0	0	0	0	1	16	
Mere words	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	
6. Passive spectator, uninvolved	5	3	4	5	2	2	5	1	2	0	4	0	0	0	0	0	33	20
7. Phenomenal, Superficial, Cosmetic	1	0	1	0	1	0	0	0	0	0	0	0	3	0	0	0	6	
Only observables exist	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
8. Expedient, Pragmatic, Utilitarian	5	5	6	5	6	5	4	9	3	2	4	3	0	0	0	2	59	37
C. Level of Involvement																	Tot	
1 No. of lab inquiries	4	1	4	4	7	7	3	0	8	0	0	11	10	5	7	2	73	
2. Practical (level of inquiry)	0	0	0	0	0	0	0	x	0	x	x	1	3	1	1	0	0,4	
3. Total no. of sentences	(					a	ll	100%								)	100%	
4. No. of facts	57	50	42	70	67	57	55	78	80	97	61	52	56	49	60	67	63%	
5. No. of questions	8	8	15	7	7	9	10	13	3	0	17	14	16	5	5	13	9%	
6. No. of definitions	6	4	4	7	4	3	2	4	5	3	2	1	5	2	0	1	3%	
7. No. of instructions to pupil	29	18	23	14	20	20	21	4	12	0	6	33	14	17	33	5	17%	
8. No. of references to "observe"	5	9	5	1	6	2	1	0	4	1	0	4	6	3	7	4	4%	
9. No. of calculations	9	10	22	9	3	19	39	8	5	0	14	1	1	2	0	26	168	



<u>Inductivist-empiricism</u>

1. Science discovers facts
2. Inductive generalisation
3. Laws and theories
4. Proven knowledge
5. Science reliable
6. Absolute truth
7. Science solves all
8. Linear accretion
9. Science rational

<u>Instrumentalism</u>

1. Observation objective
2. Computative predictions
3. Convenient instrument
4. Definitions
5. Theories mere fictions
6. Passive
7. Superficial
8. Pragmatic

<u>Level of involvement</u>

1. No. of lab inquiries
2. Level of inquiry
3. Total no. of sentences
4. No. of facts
5. No. of questions
6. No. of definitions
7. No. of instructions to pupils
8. No. of references to "observe"
9. No. of calculations

Figure 1/Text Analysis Average of All Textbooks

Results of the Textbook Study

With the exception of one textbook, namely, *The Project Physics Course*, all the texts examined reveal a predominance of an inductivist-empiricist approach. This is clearly illustrated in the bar chart (Figure 1). Forty-four percent of the pages sampled reflect a repeated assumption on the part of the author(s) that observation is impersonal and objective, and that it precedes any generalizations. Inductive generalizations, either as laws, but more often as the conclusions of practical experiments in the laboratory, occupy 32 pecent of the sentences sampled. Thirty-four percent of the statements sampled suggest that science is a body of proven facts, that is, achieved knowledge. In our opinion, a serious omission in most of the texts is any discussion of the limitations of scientific method. Very few texts actually make any mention of "observation," "laws," or "theories."

The bar chart also reveals an emphasis on computative predictions (37 percent) and on both nominalistic and operational definitions (22 percent). A mild instrumentalism is implied by this emphasis together with the assumption, noted above, that observation is theory-free. Also implying a mild instrumentalism is the belief, reflected in 28 percent of the pages sampled, that physical science makes great use of mathematical relationships as convenient devices for prediction.

About 45 percent of the sample contained laboratory inquiries. Virtually all of these were at Level 0 (Herron, 1971).

About 63 percent of the sentences sampled were factual. Questions formed large proportions of some texts (e.g., Duncan, GCSE Physics), but on average, only 9 percent of the total comprised questions.

Examples from the Textbooks

Some examples and quotations from the various textbooks are now presented, illustrating their view of (a) observation, (b) computative prediction, (c) definitions, (d) induction, and (e) theories.

(a) *Observation*

Most of the texts assume that observation is objective and completely unaffected by previous theoretical presuppositions. Statements suggesting this are: "Because the scientist cannot directly observe the atoms . . . an atomic model has been devised which explains the different observations" (Book B, p. 229); "You have observed evidence of this" (Book E, p. 96); "Human beings find out things by using their senses" (Book J, p. 3).

The three exceptions, which briefly but clearly discuss the limitations and subjectiveness of observation, are the American textbooks (N, O, and P). The *Project Physics Course* (N) stands out from all the others in that it shows the theory-ladenness of observation by a detailed historical treatment of the Aristotelian versus the Galilean view (e.g., p. 43).

(b) *Computative Prediction*

There are naturally many examples of the use of mathematical equations in most of the texts. These may (or may not) be used by the pupil in a rote, "plug-in," instrumental way, merely "to get the right answer," with little thought of relating it to real life. If this is done, the computations are "expected" predictions (that is, not really informative about the world). There are many worked examples in the texts (for example, on Ohm's Law, Boyle's Law, heat calculations, chemical calculations), as well as large numbers of questions at the end of chapters.

Calculations using equations, like $v = f\lambda$, $R = V/I$, may be interpreted as non-causal. That is, there is no indication that V *causes* I, but only that I always *accompanies* V. The focus of interest implied here is the *relationship* between the variables. This technique side-steps problems of reality.

Inductive prediction is found in several of the texts. This is the notion that on the basis of observing regularities of some past events, we can predict the occurrence of a future one: "We can therefore predict that fluorine will be even more reactive" (Book B, p. 188).

(c) *Definitions*

Among the many types of definition, only two were systematically sought for in the textbooks: nominalist definitions, in which a name is given to a phenomenon or relationship; and operational definitions, which define a concept in terms of the actual operations carried out to obtain it. These are sometimes closely connected. For example, "density" is the name given to "mass per unit volume," and also the operation of dividing mass by volume. Operational definitions are also related to mathematical equations, such as resistance using Ohms' Law.

Here are some nominalist definitions from the textbooks: "Upthrust is the name we give . . ." (Book M, p. 94); ". . . called the critical angle" (Book I, p. 204); and ". . . are called allotropes" (Book E, p. 316).

Examples of operational definitions are as follows: ". . . Resistance R is defined by $R = V/I$" (Book G, p. 172); "(Refractive Index) . . . is defined by the equation . . ." (Book G, p. 18); and ". . . covalent radius, where this radius (r) is half the distance (d) between two nuclei . . ." (Book D, p. 285).

Operational definitions define concepts in terms of the procedures required to measure them. Operational definitions have the instrumentalist property of avoiding difficult questions of a metaphysical nature. But operational definitions have a severe weakness: not all the conditions can be specified.

Usually, a definition should be informative about the real world. It asks the question "What is it?" of the term on the left side of the definition, and answers it by the defining formula on the right. However, according to Popper (1983, p. 92), this is not the way modern science works. Modern science asks: "What shall we call mass per unit volume?" and answers with the name: "Density." It starts with the defining formula, and calls for a name for it. Hence in modern science, definitions are merely shorthand symbols, or succinct phrases, to make language less cumbersome, rather than ways of providing information. Now there is nothing intrinsically wrong with this approach. Indeed, elimination of excess baggage is one of the reasons for the enormous success of science.

However, the cost of using nominalistic definitions is great, because the tendency to give names to complex relationships and phenomena can lead to discussions about the meaning of words, rather than the physical phenomena to which the words refer. Also, the danger of any definition is that it gives the impression that knowledge is a closed book, no longer open to revision. Definitions that seek the essence of things, ultimate truth, are wrong. For, of its very nature, truth is always provisional and tentative.

(d) *Induction*

Induction is the process of generalizing from a relatively few instances. It includes drawing conclusions, formulating laws and rules, verification, and the idea that scientific knowledge is established by many confirmations. Popper endorsed Hume's criticism of induction; namely that by its very nature it goes beyond the facts. It is invalid to assert a universal property on the basis of a comparatively few observations.

An example of an inductive generalization in the text is: "The wave phenomena we observed . . . are characteristic of all types" (Book B, p. 19).

With respect to examples of verification, many of the practical experiments were provided merely so that the pupil could verify a law or principle. That is, they were of the "see-for-yourself" type, for example, Verification of Faraday's Law (Book C, p. 80).

Various references to scientific laws are mentioned (e.g., Ohm's Law, Faraday's Law, Boyle's Law, Snell's Law, Lenz's Law), but none of the texts discussed the notion that laws are inductive generalizations.

Examples of the proven knowledge idea are mainly of the name and date type. Science is seen as leading cumulatively and linearly to our contemporary store of established "unrevisable" knowledge: ". . . experimentation established finally that . . ." (Book A, p. 15); "Soon afterwards Madame Curie discovered radium" (Book I, p. 379).

The only explicit reference to the term "induction" that could be found in any of the texts was in *CHEM Study*. On page 3, induction is described as an elementary logical thought process, and the bounds within which inductive generalizations are valid are given.

(e) *Theories*

Discussion about the role of theory, or the interaction with and priority of theory, in all stages of the scientific inquiry process, is most conspicuous by its absence in most of the textbooks examined. There is also a lack of any explanation about models and their importance. The exceptions are *The Project Physics Course* and, to a lesser degree, *CHEM Study* and *PSSC Physics*.

In reality, scientific theories are arrived at, not by generalizing the sensory data, but by modifying already existing theories. Science begins with theories, not observation. Popper defends this priority of theory. All we know are our theories. The mind is not a *tabula rasa*, as the empiricists maintain:

> All observation involves interpretation in the light of our theoretical knowledge . . . (Popper, 1983, p. 48)

Yet, in spite of this, we read statements like these in our textbooks:

> Initially the existence of electrons was determined by experiment . . . (Book B, p. 219)

Explicit mention of theory is made only in the following texts: Book J, p. 3; *PSSC Physics; CHEM Study;* and Harvard *Project Physics*.

The relationship portrayed in the texts between theory and the real world is an ambiguous one. Most people, as Gardner (1983) states, are naive realists. When we talk about an electron, we believe that there is something out there, existing independently of our thinking, called an electron. And certainly, school pupils, particularly younger ones, are naive realists. No doubt, the authors of these textbooks believe in the independent reality of electrons and photons and other observables. In this sense, they too are realists. So when they talk about "kinetic theory," they surely hold that matter really consists of particles in constant, random motion. Yet it is possible to read their words in a purely instrumental way. Their kinetic theory could refer to reality, but equally it might not. It could be regarded as a convenient fiction only, with no sense of commitment to a common-sense reality.

Finally, it should be mentioned that there are many references in most of the texts to industrial applications of science. For example, on the pages sampled, the uses of transformers and electric motors, as well as the industrial preparation of ammonia and sulphuric acid, are described.

Results of the Preface Analysis

A reading of the prefaces reveals a general unawareness on the part of the authors of the philosophical implications and weaknesses of the instrumentalism present in their texts. Those few who do refer to scientific method have a notion of method which is strongly criticized by contemporary philosophers of science.

Book A. *Brink and Jones 8:* The separation of observation and theory is clearly stated, "It is important in the study of Physical Science that concepts and theories be developed from actual experimental observation and discovery." The authors emphasize understanding phenomena, rather than learning facts.

Book B. *Pienaar, Walters 8:* There is no explicit reference to the nature or method of science, only that the presentation is pupil-oriented, both as regards text and experiments.

Book C. *Broster and James 8:* The authors are convinced that science must be experienced to be understood, and the emphasis is therefore on the experiments. Pupils are also encouraged to keep a list of definitions.

Book D. *Brink and Jones 9:* This preface expresses the same sentiments as in A above.

Book E. *Pienaar, Walters 9:* The authors have made this text pupil-oriented. New concepts appearing for the first time are fully explained. Summaries and questions assist pupils. Practical experiments are integrated into the text.

Book F. *Broster and James 9:* No preface.

Book G. *Duncan:* Hints for pupil revision are given. There is no mention of scientific method or the philosophical aims of the author. However, immediately following the preface is a two-page (mainly photographs) discussion of Physics and Technology. Here we read that physicists "find the *facts* by observation and experiment," and "try to discover the *laws* that summarise (often as mathematical equations) these facts. Sense has then to be made of the laws by thinking up and testing *theories* (thought-models) to explain these laws."

Book H. *Pople and Williams:* The authors state that "science is about asking questions." Answers are found using experiments or looking up a reference book such as this one. "The information that scientists have gained is important."

Book I. *Atherton, Duncan, Mackean:* Each chapter contains essential facts, ideas, details of experiments, everyday applications, and questions for revision. The authors' primary concern has been to provide access to information.

Book J. *Lewis and Waller:* The aim of this book is understanding rather than memorization of facts. The main concepts are developed through analysis of experimental facts. Facts and theory are kept carefully distinct, and presented in a way that reflects the scientific approach, where observation comes first, then inference. This preface clearly reflects the philosophical standpoint of the authors, which is inductivist-empiricist.

Book K. *Pople:* This book deals with physics and its applications. However, the author does not mention his philosophical standpoint. The preface merely discusses the structure of the book.

Book L. *Warren:* Each new idea is investigated by simple experiments. The emphasis is on active involvement and learning from first-hand experience. Summaries identify a "body of knowledge" to be learned.

Book M. *Lambert:* The author states that this book is full of questions, which encourage hard thought. Summaries are given at the end of chapters. No reference at all is made to philosophical standpoint.

Book N. *Harvard Project Physics:* The declared three main aims of this course were: to design a humanistically oriented physics course; to attract more pupils to physics; and to find out more about the factors affecting the learning of science. The focus is on ideas that characterize science as a human activity. Hence it is presented in a historical and cultural way.

Book O. *CHEM Study:* The emphasis is on experimentation. Principles grow out of observations. By understanding principle, memorization of facts falls away. Active engagement permits the student to some extent to become a scientist at school.

Book P. *PSSC Physics:* This text does not present physics as a body of facts but as a continuing process by which we seek to understand the nature of the physical world. Concepts grow through exploration in the laboratory, and analysis in the text. It is humanistically oriented. How we grasp and measure physical quantities, and how instruments are extensions of our senses, is explained. Direct experience is provided, and imagination encouraged. The role and development of theory and models are explored. In kinematics, pupils learn to predict.

Apart from the last three texts listed above, all the others reflect a strong separation between observation and theory. Their implicit approach is empiricist-inductivist. Even *PSSC Physics*, while acknowledging the limitations of scientific procedures and the importance of creativity, follows an inductivist line. It does not mention that observation is theory-laden.

The prefaces generally reveal a strong commitment to traditional Baconian scientific method. Since this inductivist-empiricist approach has serious inherent philosophical weaknesses, we feel strongly that a brief discussion of its educational implications should be included in every preface.

General Discussion and Conclusion

The dominant image of science portrayed in all the British and South African textbooks examined is strongly inductivist-empiricist.

First, in these books, there is a sharp distinction between observation and theory. This is the chief characteristic of a positivistic approach, and the main attribute of inductivism, empiricism, and instrumentalism.

Second, our tests to detect instrumentalism in these textbooks reveal a mild instrumentalism. There is ample evidence that calculations are of the plug-in, recipe-like type, leading deductively to a solution that is isolated from the real world. These are mere computative devices for prediction and control, nothing but "puzzle-solving," in a way, only games.

Third, analysis of definitions in these textbooks reveals the existence of a number of operational and nominalistic definitions, which indicate an instrumental approach.

Our conclusion is that there are clear signs of a mild but widespread instrumentalism in the selected British and South African high school physical science textbooks. The British textbooks contain a stronger emphasis on an instrumentalist attitude than the South African texts. The three American textbooks examined, while not nearly as instrumentalist as the British and South African textbooks, nevertheless do show signs of it.

From the kind of textbook presentation revealed in this study, the pupil could perhaps perceive science as a method for verifying facts already known. He might obtain a view of observation as being completely objective. And he could possibly regard science as a convenient tool for predicting and calculating, in a rote fashion, with little relevance to real life. It is difficult to see how any textbook can be written in any but an inductivist-empiricist way. The very aim of a textbook is to be a condensation of the current state of science. It is a reference book, and so must contain a large proportion of facts. Kuhn (1970, p. 188) believes that one of the primary tasks of textbooks is to introduce the future scientist into the scientific community by means of exemplars (typical problems and solutions of the scientific community). The student needs to *act* on such problems in order to get a feel for science.

Similarly, Ravetz acknowledges that, while a textbook is a caricature of real science, it is necessary for standardization to occur. Ravetz says that

> it is quite necessary, if the fact is to be useful to those who lack the time, skill or inclination to master the elaborate theoretical context. . . . (1971, p. 200)

Something is lost in this process. School science textbooks, in particular, are "standardizations of standardizations," according to Ravetz. Vulgarization of science can easily occur in schools, where many teachers are not science specialists and lack sufficient training in physics and chemistry.

> These inherent limitations of the schoolteaching situation, along with its function of imparting basic craft skills rather than "understanding" must be recognised if there is to be any fundamental improvement in its quality. (Ravetz, 1971, p. 207)

To write a good textbook requires a special skill. Ravetz makes a plea for the inclusion of historical case studies in textbooks. However, cost factors unfortunately impose a severe limitation on this.

In the end it seems that textbooks cannot be otherwise than largely inductivist, empiricist, and instrumentalist. So the responsibility rests squarely on the teacher to counter-act the philosophical disadvantages of these approaches. Hence the teacher must be aware of the dangers involved. For this reason, we believe that all authors should, at the very least, provide some guidance in their preface. This is often especially desirable in Third World countries where teachers lack the required training in science. We recommend that all physical science textbooks should include in their preface a short summary of the following discussion.

The Unsoundness of Instrumentalism

Popper opposes instrumentalism on the grounds that observation is theory-laden. Modern science tends to be phenomenalist, but Popper (1956, p. 383) maintains that it is silly to say that my direct perception of, say, a piano, is valid, whereas my knowledge of its underlying molecular structure is a mere fiction. For surely even my direct observation is steeped in theory, as are my mental constructs of the structure. Both appearance and underlying form are theoretical interpretations. They differ only in the degree of conjecture.

We should consider three reasons why instrumentalism should be avoided in science education. First, it leads to idealism. It makes a clear distinction between appearances and reality, and maintains that we can never have knowledge of things-in-themselves. Such an attitude leads to scepticism. If reality is reduced to action, and action is reduced to what takes place in us, our experience is closed to the transcendental. Berkeley objected to this viewpoint. In order to undercut scepticism, Berkeley rejected one of the most fundamental tenets of the common-sense view of the world, namely, that an external reality exists apart from any consciousness of it. Objects are nothing more than ideas in our minds. All we ever perceive are our ideas. Thus Berkeley adopts idealism in order to escape from scepticism.

Second, positivism is instrumentalist. Logical positivists hold that unless a statement can be verified, it is meaningless. This view, of course, means that any statement made in morality, religion, philosophy, politics, or art is meaningless. The whole notion of God is seriously undermined. Popper regarded this view as nonsense, for truth is much wider than science.

Third, the phenomenalism of instrumentalism commits us to nominalism. For if we do not know things-in-themselves, our concepts of things are only *names*. Knowledge becomes instrumental instead of physically real. Further, because names are arbitrary, instrumentalism tends to become relativist and subjective.

Thus instrumentalism, in its pure form, tends to lead to idealism, agnosticism, and relativism. Our high school physical science textbooks contain a mild form of instrumentalism. We, as science educators, should be aware of its philosophical implications.

But instrumentalism rears its head in other books as well, namely, popular science paperbacks (Capra, 1975; Zukav, 1979) about contemporary particle physics, enjoyed by many pupils. These books portray an idealist-instrumentalist approach. They relate many of the paradoxes of particle physics to Eastern thinking. They make statements, such as "nothing is real unless it is observed" (Gribbin, 1984), and that the Aspect experiments done in Paris in 1982 prove that there is no underlying reality to the world.

The Instrumentalism of Computer Games

Pirsig (1974, p. 24) divides people into two classes: those who are against science and technology; and those who enjoy it. Yet, he says, there is a large third group consisting of technologists, who use science but are not committed to it. They are *uninvolved.* They behave like spectators.

A similar phenomenon perhaps occurs in the field of computers and particularly computer games. How easily youngsters become addicted to computer games! They seem to be thoroughly involved. But are they really? Surely those asteroids tumbling across their monitor screens, and laser beams flashing their destructive paths, are mere simulations, flickering images obediently following the programmed co-ordinates? The eye predicts, the hand presses a button, a high-speed digital calculation occurs, and the asteroid is destroyed in a gigantic explosion. But the pieces of shrapnel whizzing past are not real. It is only a game. And it is passive, and the player essentially uninvolved.

We contend that computer games are prime examples of the instrumentalist attitude. This struck us one evening in 1987 when we were using a BASIC program we had written to predict the position of Halley's Comet on any given night. It was only a calculus, like Ptolemy's, for prediction. Data and images could be manipulated in a purely geometric way, with little or no reference to physical reality. The computer was isolated in time and space from everything else in the universe. It had no relationship with the user, or the Cosmos, except in a superficial, instrumental way. It was not interested in the real physical gravitational forces pulling on real masses. It merely computed the mathematical models of Newton's Laws, and came up with the right answer. It was a spectator, and it made the user a passive spectator as well. And therein lay its danger.

Powers (1982) encourages us to take a realist stand in science, for we can easily be deceived by the escapism and superficiality of the instrumentalist approach. Realism

> requires us to take very seriously the question of the consistency of the assumptions our theories make. A recipe-book instrumentalism carries with it no such injunction. Phenomenalism (or submicroscopic phenomenalism) provides a way of brushing problems of intelligibility aside, but if the implication is that we are simply investigating experimental effects we produce in our apparatus and that these can tell us nothing about "what is there," then the whole enterprise may seem like a costly hoax we have played on ourselves; and it will be hard to believe a positivist who claims that this makes no difference. When experimentalists "bombard" protons with electrons they have to "believe" in both their missiles and their targets; though it seems "hard-headed," phenomenalism is a theory for spectators rather than actors. (Powers, 1982, p. 164)

The deliberate lack of commitment to a serious realism suggests that instrumentalists are playing games. For Berne,

> a game is an ongoing series of complementary ulterior transactions progressing to a well-defined, predictable outcome. (1964, p. 44)

Games are substitutes for real living. They are governed by rules, and involve activity and fantasy. Games are directed toward the manipulation of reality, and are evaluated by their effectiveness or pay-off. Games may not be intended to convey information, but merely to follow a predetermined course to an expected conclusion. Games are basically dishonest, for they tend to be cosmetic and superficial, shelving the important issues of life. They can be manoevres to attain pragmatic, utilitarian goals.

The parallel of games with instrumentalism is more than mere coincidence. For, like games, instrumentalism is also basically dishonest, as Koestler (1959, p. 65) says, for this reason: it deliberately ignores whole areas of non-empirical reality. It is a pretence.

Instrumentalism and Pragmatism

Commenting on the recent cut-backs in the American space-research program, Lago (1983) observes that contemporary Western society's emphasis on practicality and financial success has led to utilitarian values. Nothing is worth doing unless it is useful. Since a space-probe to Neptune has no obvious usefulness, the American exploratory space program will probably languish.

> Practicality has created America's greatness, but we have paid a dear price for it — and in the space age, that price is paralysis. (Lago, 1983, p. 28)

There are unquestionably certain human enterprises which are justifiable *in themselves*, without having to be obviously useful. But the instrumentalist attitude tends to blind us to this, and encourages the passivity syndrome which permeates so much of modern society.

Commenting on Dewey's instrumentalism, Bertrand Russell says, "In all this I feel a grave danger, the danger of what might be called cosmic impiety" (1979, p. 782). For Russell, the instrumentalist view of truth about the world lacks the necessary element of humility. It is a step

> on the road towards a certain kind of madness. . . . I am persuaded that this intoxication is the greatest danger of our time, and that any philosophy which, however unintentionally, contributes to it is increasing the danger of vast social disaster. (Russell, 1979, p. 782)

Instrumentalism and Science Education

As science educators, we should not allow our pupils to leave school as passive spectators, able only to turn switches, adjust voltage levels, check instruments. Rather, they must learn to become involved and care about what they do. They should be full-blooded realists, joining in the fruitful, productive quest for knowledge. They must reject sterile, passive, instrumentalist spectatorship and gamesmanship. We believe, with Pirsig, that it is somewhere in this strange separation of realist from instrumentalist, of what man is from what man does, that we may have a clue as to what has gone wrong in this 20th century.

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