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ABSTRACT

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The differential role of Physical Science and Biology in achieving scientific literacy in South Africa – a possible explanation

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ABSTRACT

A survey of the scientific literacy of selected high-school leavers at the secondary/tertiary educational interface in South Africa revealed that taking Physical Science in grade 12, in contrast to Biology, plays a more significant role in the achievement of scientific literacy by these students. An explanation for this result was sought by comparing Physical Science and Biology students' scores on the three subtest comprising the Test of Basic Scientific Literacy, *which was originally used in the scientific literacy classification. Students with Physical Science possessed a better understanding and awareness of all three dimensions of scientific literacy than students taking Biology. This result suggests a number of mechanisms through which Physical Science impacts on the achievement of scientific literacy: (a) the greater number of topics placed in an historical context in the Physical Science syllabus in comparison to Biology; (b) the greater, more obvious connection between technology and syllabus topics covered in Physical Science than in Biology; and (c) the comparative ease with which some understanding of concepts in the biological sciences may be obtained through informal and non-formal education in comparison with concepts in the physical sciences.*

Introduction

Scientific literacy has become an internationally well recognized educational slogan, buzzword, catchphrase, and contemporary educational goal. Scientific literacy "commonly implies an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas" (Jenkins, 1994: 5345). The term is usually regarded as being synonymous with 'public understanding of science' (Durant, 1993), and although the concept is for various reasons often regarded as controversial (Laugksch, 2000; Jenkins, 1994), the notion of scientific literacy is now commonly acknowledged to consist of three dimensions: an understanding of the norms and methods of science, an understanding of key scientific terms and concepts, and an appreciation of the impact of science and technology on society (Laugksch, 2000; Miller, 1983).

Education has consistently been shown to be the most important influence on scientific literacy in various national and cross-national surveys (see, for example, Durant, Evans & Thomas, 1989; Foundation for Research Development, 1993, 1996; Bureau of Industry Economics, 1995; National Science Board, 1991, 1993, 1996; 1998), particularly the level of science and mathematics education individuals have completed (see, for example, National Science Board, 1996, 1998). In South Africa the situation is similar: a recent survey of the scientific literacy of high-school leavers at the secondary/tertiary educational interface in the Western Cape - one of nine Provinces in the country - revealed that the number of science subjects high-school leavers take in grade 12 has an effect on the high-school leavers' level[1] of scientific literacy (Laugksch & Spargo, 1999). More significantly, however, it was found that specific science subject choices had an important influence on their literacy levels. Uni- and multi-variate analyses from this survey revealed that students who had taken only Biology in grade 12 consistently displayed the lowest level of scientific literacy of students who had taken at least one science subject in the senior secondary phase, whereas the level of students who had included Physical Science[2] in their science subject combination was at least twice as high as that of students who had not (Table 1) (Laugksch & Spargo, 1999; Laugksch & Dunne, in press).

Based on assesssments of scientific literacy using the *Test of Basic Scientific Literacy* (TBSL) (Laugksch & Spargo, 1996a), there is thus evidence to the effect that Physical Science, in contrast to other subjects such as, for example, Biology, plays a more significant role in the achievement of scientific literacy by South African high-school leavers. Why should this be so? The TBSL is not numerically biased with respect to test-items in the physical and chemical sciences. These items, in fact, constitute the lowest

1 By 'level' of scientific literacy is meant the percentage of scientifically literate students observed among any relevant total number (all students, male students, female students, etc.).

2 In South Africa, Physical Science is a school subject combining chemistry and physics that learners can chose to take from grade 10 onwards.

proportion of test-items in any content area covered by the TBSL (Laugksch & Spargo, 1996a), so that students taking Physical Science were not advantaged by the method in which their scientific literacy was assessed. Answers to the above question therefore need to be sought elsewhere. Clearly there are many different possible hypothesised causal sequences that could account for the South African survey results described above. These include the possibility that students taking Physical Science are more able, experience a greater 'science push' from their parents, have a greater interest in science than their Biology peers, and so forth. Perhaps one of the more proximal and parsimonious of the suite of possible explanations entails constructing a link between the syllabus content of Physical Science and Biology and scientific literacy, and assumes a causal relationship between subject choice and scientific literacy - as measured by the TBSL.

Table 1. The percentage of scientifically literate South African high-school leavers for the most frequent science subject combinations by population group (from Laugksch & Spargo, 1999). In each case the sample size is given in parentheses.

Science subject combination	African	Coloured	Indian	White	Total
Biology	5 (80)	14 (162)	- (6)	27 (326)	20 (574)
Biology & Geography	7 (91)	20 (119)	- (4)	34 (170)	23 (384)
Biology & Physical Science	18 (188)	40 (336)	61 (36)	53 (670)	44 (1230)
Physical Science	17 (12)	42 (24)	50 (10)	47 (549)	46 (595)
Biol. & Geog. & Physical Science	14 (58)	33 (273)	- (6)	72 (223)	47 (560)
Geography & Physical Science	- (4)	0 (0)	- (4)	60 (247)	59 (255)
Geography	- (8)	- (8)	0 (0)	31 (61)	25 (77)
other subjects or subject combinations	6 (66)	- (2)	0 (0)	36 (77)	23 (145)

In this paper, the scores of high-school leavers on the three subtest comprising the TBSL are compared, and possible explanations for any differences in the scores are discussed in the light of differences in the syllabus of the two natural sciences subjects.

Methodology

Student data collected in the recent survey were used to compare student scores on the TBSL subtests. The sample of that study consisted of 4223 students at the universities of Cape Town, Stellenbosch and the Western Cape and at the Cape and Peninsula technikons[3], who entered tertiary education for the first time in 1994 (i.e., were 'freshmen'), who completed their school-leaving exams either in 1992 or in 1993 in South Africa, who in 1994 were younger than 24 years of age, and had left fewer than 39 of the 110 TBSL test-items unanswered (Laugksch & Spargo, 1999). Data in that study were obtained by means of a questionnaire, that requested students *inter alia* to indicate which of the five natural science subjects widely taken in senior secondary school in South Africa the students had taken in grade 12: Agricultural Science, Biology, Geography, Physical Science, and Physiology.

Assessment of scientific literacy

Data on scientific literacy were provided by the 110-item *Test of Basic Scientific Literacy* which formed the Section B of the original survey questionnaire (Appendix G of Laugksch [1996]). This test, which consists of 110 test-items with a "True-False-Don't Know" item format (Laugksch & Spargo, 1996ab), is based on selected chapters of the 1989 American Association for the Advancement of Science overview report on literacy goals in science, mathematics and technology, entitled *Project 2061 - Science for All Americans* (American Association for the Advancement of Science, 1989). This report identifies the knowledge, skills, and attitudes that all students should possess, as a consequence of their total school experience, in order to be regarded as scientifically literate. The TBSL consists of three separate subtests, each corresponding to Miller's (1983) three constitutive dimensions of scientific literacy: the Nature of Science Subtest (NSST: 22 test-items), the Science Content Knowledge Subtest (SCKST: 72 test-items), and the Impact of Science and Technology on Society Subtest (ISTSST: 16 test-items). The test was marked dichotomously, with one mark being awarded per question for a correct answer, and zero for a wrong one. A "Don't know" response was considered a wrong answer. No negative marking was used. In order to be classified as scientifically literate, students needed to obtain at least 13 out of 22, 45 out of 72, and 10 out of 16, on the corresponding subtests of the TBSL, respectively. Characteristic features of this test with respect to validity, reliability, and derivation of the above performance standards have been reported in Laugksch and Spargo (1996b); the complete TBSL is given in the Appendix.

3 In South Africa, technikons are tertiary educational institutions where the emphasis in teaching and research is placed more on the practical, rather than the theoretical, aspects of a variety of disciplines.

TBSL score comparison

A comparison of the two science subjects was obtained in the following manner. Students who took no natural science subjects (*n* = 383) and students who included only Physiology and/or Agricultural Science in their science subject choice (*n* = 31) were regarded as the control group against which the effects of Physical Science and Biology could be determined. In order to achieve meaningful comparisons, only students who included Physical Science but no Biology in their science subject combination were allocated to the Physical Science group. Similarly, only students who included Biology but no Physical Science in their science subject combination were assigned to the Biology group. As previous results indicated that the effect of Geography on scientific literacy may be similar to that of Biology (Laugksch & Spargo, 1999), students who took Geography were excluded from all three groups.

Results

The mean score (± *SD*) per subtest of the TBSL for the three student groups are presented in Table 2. Mean scores on all subtests were higher for students in the Biology and Physical Science group than in the control group, suggesting that both science subjects influenced the scientific literacy of students positively. In contrast to the Physical

Table 1. The mean score (± *SD*) per subtest of the TBSL for a control group and for students with science subject combinations that included Physical Science and Biology. Geography was excluded from all groups (see text for details).

Test of Basic Scientific Literacy Subtest	Control ($n = 414$)	Phys. Science ($n = 626$)	Biology ($n = 615$)
Nature of Science Subtest (NSST)	10.9 ± 4.0	13.7 ± 3.5*	11.5 ± 3.8
Science Content Knowledge Subtest (SCKST)	33.0 ± 13.2	47.2 ± 12.1*	39.9 ± 12.8
Impact of Science and Technology on Society Subtest (ISTSST)	7.9 ± 3.5	10.3 ± 3.3	8.2 ± 3.5

Note. Asterisks indicate significant differences (*t*-test) between the mean score of students with Physical Science and the control group ($\alpha = 0.05$).

Science group, however, no statistically significant differences existed between the Biology and control groups (Table 2). Nevertheless, it is the increase in mean scores as a result of taking different science subjects that is important here, as students were required to meet performance standards on each TBSL subtest in order to be classified as scientifically literate (Laugksch & Spargo, 1996a). Students needed to achieve a score of at least 13 out of 22 on the Nature of Science Subtest (NSST), 45 out of 72 on the Science Content Knowledge Subtest (SCKST), and 10 out of 16 on the Impact of Science and Technology on Society Subtest (ISTSST) in order to be classified as scientifically literate (Laugksch & Spargo, 1996a). As can be seen from Table 2, the mean score of students taking Physical Science was above the performance standard on all three subtests, whereas the mean score of students taking Biology remained below the performance standard on all subtests.

Discussion

These results are important as they suggest a mechanism through which Physical Science impacts on the scientific literacy of high-school leavers. Averaged over all students, individuals who took Physical Science are shown to have a better understanding of the nature of science than students who took Biology. The former group also has an increased awareness of the impact of science and technology on society compared with the latter group, despite a lack of a statistical significance when compared with the control group. In addition, students taking Physical Science in grade 12 are shown to have an understanding of a larger number of important concepts in science than students with Biology. What follows are possible explanations for the superior performance on each dimension of the TBSL of students who took Physical Science in comparison with students who took Biology. Each dimension is addressed in turn.

Firstly, the nature of science. In the classroom, teaching particular concepts in Physical Science is often approached from a historical perspective. For example, teaching the model of the atom in the South African syllabus requires a conceptual voyage from the single indivisible particle of Dalton to Thomson and the discovery of the electron, to Rutherford and his model of the nuclear atom, before ending with Bohr and the orbital model of the atom. During this teaching process, the ideas underlying a number of key experiments in physics need to be discussed and explained. It seems probable that through such a process pupils are likely to become more familiar with the way scientists think, how science proceeds, and what the limitations of science are (see, for example, Irwin, 2000). While this increased familiarity with the nature of science will in all probability be comparatively unsophisticated, the familiarity is nevertheless likely to be greater than that of pupils taking only Biology. Examination of the senior secondary syllabus in Physical Science and Biology indicates clearly that in the senior secondary phase a larger number of principles in the physical and chemical sciences are expected to be taught with at least some rudimentary historical perspective than in the biological and health sciences (personal observation). It is therefore possible that the greater historical contextualisation of topics believed to be occurring in Physical Science is responsible for the fact that students taking Physical Science have a better understanding of the nature of science than students taking Biology.

With respect to science content knowledge, it is hypothesised that a higher proportion of test-items in the biological and health sciences may be easier to answer correctly without formal education in these areas than in the physical and chemical sciences. Tamir (1991), for example, investigated the acquisition of functional knowledge and understanding of selected concepts in physics, chemistry, and biology in a study of 554 Israeli 10th grade (year 8) pupils. He found that biology was the only subject in which functional knowledge was significantly related to non-formal science activities such as, for example, watching television science programmes, listening to radio science programmes, and reading on science topics. Some of the concepts addressed in the content area of the biological sciences in the TBSL are of an ecological and environmental nature (e.g., ecosystems, the importance of species diversity, greenhouse effect), and it is believed that such topics receive fairly regular coverage on television and in newspapers. It is similarly believed that topics in the health sciences receive frequent airing in broadcast and print media. Although there are no data in this area available for South Africa, these assumptions are to some extent supported by studies in the United Kingdom, which show that medical issues, ecology, and the environment dominate newspaper coverage of science (Hutton, 1996; Wellington, 1991). It thus seems possible that items in both the biological and health sciences may be answered correctly not only because of exposure to formal education in these areas but also because of non-formal involvement in science through, for example, reading newspapers. Concepts in the physical and chemical sciences, on the other hand, are more abstract and theoretical in nature (e.g., energy, motion, forces), and are likely to receive less coverage in any of the news media. Both Hutton (1996) and Wellington (1991) found that issues related to physics and 'pure science' received much less newspaper coverage than medical issues, ecology or the environment. Test-items in the physical and chemical sciences are therefore less likely to be answered correctly without exposure to formal education than items in the biological and health sciences. It is thus hypothesised that Physical Science students are able to correctly answer a greater proportion of test-items in content areas related to the biological and health sciences than Biology students are able to do in areas related to the physical and chemical sciences.

A comparison of mean scores of Physical Science and Biology students for the test-items in the physical and chemical, as well as biological and health, sciences lends support to this argument. Converting mean score to a percentage, Physical Science and Biology students correctly answered 69% and 46% of the 14 test-items in the physical and chemical sciences, respectively. The percentage of items answered correctly for the 43 items in the biological and health sciences was 64% and 60% for the former and latter group, respectively. The percentages of correctly answered test-items thus fit the hypothesised pattern. Although mean scores for Physical Science and Biology students for each group of sciences were not statistically significantly different (in each comparison the *p*-value was greater than 0.05), these results provide support for a hypothesised explanation that accounts for the fact that students who took Physical Science as a science subject in grade 12 scored higher on the SCKST than students who took Biology.

A considerable number of test-items in the Impact of Science and Technology on Society Subtest are related to technology (Appendix). In fact, the words "technology", "technologies", and "technological" appear in nine of the 16 test-items of the ISTSST. Reasons why Physical Science students do better on the ISTSST than Biology students may be related to the greater obvious connection at a first glance between technology and Physical Science than between technology and Biology at school science level. It is not being argued here that biological concepts do not have any connection to technology - clearly this would be erroneous - but rather that such connections may be more obvious without teacher intervention to students in Physical Science than in Biology. For example, there are many everyday examples of technology that are based on physical concepts covered in the South African Physical Science syllabus. Such concepts include waves, light, sound, electricity and electrical current, chemical reactions, heat and work, motion, radioactivity, and so forth. However, the relative number of obvious everyday examples of technology which are based on biological concepts covered in the Biology syllabus are lower than in the Physical Science syllabus (personal observation). Examples of such biological concepts are largely related to health and may include aspects of human anatomy and physiology, genetics, and nutrition. It is thus speculated that because of differences in the syllabus content, Physical Science students will in all probability have a comparatively clearer understanding of technology and the issues surrounding its application than Biology students. It therefore follows that compared to Biology students, Physical Science students have an advantage in answering the test-items related to the impact of science and technology on society, and hence are likely to achieve a higher score on the relevant subtest.

Conclusion

The fact that selected South African high-school leavers taking Physical Science in grade 12 were found to possess a better understanding and awareness of all three dimensions of scientific literacy compared with students taking Biology is important, as it suggests a number of possible mechanisms through which Physical Science impacts on the achievement of scientific literacy by high-school leavers. These mechanisms are hypothesized to include (a) the greater number of topics placed in an historical context in the South African Physical Science syllabus in comparison to Biology; (b) the greater, more obvious connection between technology and syllabus topics covered in Physical Science than in Biology; and (c) the comparative ease with which some understanding of concepts in the biological and health sciences may be obtained through informal and non-formal education in comparison with concepts in the physical and chemical sciences.

These possible mechanisms for the differential role of Physical Science and Biology in achieving scientific literacy both in a South African and international context are largely unexplored, and thus represent interesting and relevant directions for further research in an important area of science education.

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APPENDIX

TEST OF BASIC SCIENTIFIC LITERACY

Instructions: The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T), FALSE (F), or whether you really DON'T KNOW (?) the answer. ***Please place an "X" in the appropriate box.***

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. **Please take this sentence to be TRUE!** The statement to which you are asked to respond refers to this true sentence.

Please work as quickly and carefully as possible, and respond to *all* the statements.

	Your response:		
1. The earth is as old as the universe.	T	F	?
2. Our galaxy only contains a few thousand stars.	T	F	?
3. Light from the nearest star to our sun takes only a few minutes to reach us.	T	F	?
4. In the universe there are many other bodies similar to our sun.	T	F	?
5. Most of our knowledge of the universe comes from looking at very small slices of space and small intervals of time.	T	F	?
6. Compared to the earth's diameter, a very thick blanket of air surrounds the entire earth.	T	F	?
7. Many of the planets and moons in our solar system appear able to support life as we know it.	T	F	?
8. There is no liquid water at the surface of planets other than the earth.	T	F	?
9. *The earth's axis is tilted, i.e. slanted.* This tilt produces seasonal changes in the earth's climate.	T	F	?
10. Varying radiation from the earth's hot interior is the basic cause of changes in climate on earth.	T	F	?
11. The earth's climate has changed very little over thousands of years.	T	F	?
12. The oceans and atmosphere can only be changed by a limited amount before affecting human activities unfavourably.	T	F	?

Source: Laugksch RC & Spargo PE (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science*, 5(4), 331-359.

13. *Elements such as carbon, oxygen, nitrogen, and sulphur, move slowly through the land, oceans, and atmosphere.* While doing so, elements change their chemical combinations.	T	F	?
14. The earth's atmosphere has been unaltered by the presence of life.	T	F	?
15. Human activities have hardly changed the earth's land surface, oceans, and atmosphere.	T	F	?
16. Scientists share certain beliefs and attitudes about what they do and how they view their work.	T	F	?
17. Science takes for granted that the things and events in the universe do <u>not</u> occur in consistent patterns.	T	F	?
18. Science assumes that the basic rules about how the universe operates are the same throughout the universe.	T	F	?
19. There are many aspects of our lives that cannot be usefully examined in a scientific way.	T	F	?
20. There are fixed steps that scientists always follow to lead them without fail to scientific knowledge.	T	F	?
21. Sooner or later, the validity (i.e. truth) of scientific claims is settled by referring to observations of phenomena.	T	F	?
22. Scientists disagree about the principles of logical reasoning that connect evidence with conclusions.	T	F	?
23. The process of putting forward and testing hypotheses (i.e. provisional explanations) is <u>not</u> one of the chief activities of scientists.	T	F	?
24. *Scientists try to make sense of phenomena by inventing explanations for them.* These explanations rarely use currently accepted scientific principles.	T	F	?
25. Scientific theories should explain additional observations that were <u>not</u> used in developing the theories in the first place.	T	F	?
26. Scientific evidence can be biased (i.e. distorted) in the way that data are interpreted, recorded, reported or selected.	T	F	?
27. Scientists may, because of their background, personal beliefs and values, emphasise different interpretations of evidence.	T	F	?
28. Scientists try to identify possible bias in the work of other scientists.	T	F	?
29. In carrying out an investigation, no scientist must be made to feel that s/he should reach a particular result.	T	F	?

Source: Laugksch RC & Spargo PE (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science*, 5(4), 331-359.

30.	Even though science is an activity carried out by many different people, science hardly ever reflects values and viewpoints related to society (e.g. views on women, political beliefs).	T	F	?
31.	The spreading of scientific information is unimportant to the progress of science.	T	F	?
32.	Scientific fields such as chemistry and biology have fixed boundaries or borders.	T	F	?
33.	The bodies (e.g. the different government departments) which supply money for research influence the direction of science (i.e. which research to undertake).	T	F	?
34.	Because of strongly held traditions in science, most scientists behave professionally and ethically (i.e. in a moral and honest way).	T	F	?
35.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harm that could result from scientific experiments.	T	F	?
36.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harmful effects of applying the results of research.	T	F	?
37.	Scientists can seldom bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment).	T	F	?
38.	*Biologists classify organisms into groups and subgroups.* This is done in a manner that is unrelated to the structure and behaviour of the organisms.	T	F	?
39.	Keeping a great variety of species on earth is unimportant to human beings.	T	F	?
40.	In obtaining the energy and materials necessary for life, human beings are independent of food webs (i.e. interlinked food chains).	T	F	?
41.	Each gene is one - or more than one - particular segment of a molecule of **DNA**.	T	F	?
42.	The "mixing" of genes in sexual reproduction results in a great variety of gene combinations among the offspring (i.e. young) of two parents.	T	F	?
43.	Many of the basic functions of organisms, such as extraction of energy from nutrients, are carried out at the level of the cell.	T	F	?
44.	The genetic information encoded in DNA molecules plays no role in the assembly of protein molecules.	T	F	?
45.	The chemical processes in the cell are controlled from both inside and outside the cell.	T	F	?
46.	*Most organisms have many different cells.* In such organisms, most cells perform only the basic functions common to all cells.	T	F	?

Source: Laugksch RC & Spargo PE (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science*, 5(4), 331-359.

47. In an ecosystem, every species depends, directly or indirectly, on all other species in that system.	T	F	?
48. The interdependence of organisms in an ecosystem often results in an almost stable system over very long periods of time.	T	F	?
49. Ecosystems cannot avoid changing when the climate changes.	T	F	?
50. Ecosystems cannot avoid changing when very different new species appear.	T	F	?
51. Living organisms do <u>not</u> share with other natural systems the same principles of the conservation of matter and energy.	T	F	?
52. Only a small proportion of life on earth is basically maintained by transformations of energy from the sun.	T	F	?
53. The elements that make up the molecules of living things are continuously recycled.	T	F	?
54. Coal and oil were formed millions of years ago.	T	F	?
55. *Carbon dioxide was removed from the atmosphere over millions of years.* By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at a much faster rate than at which it was removed from the atmosphere.	T	F	?
56. The earth's present-day life-forms have evolved from common ancestors over many millions of years.	T	F	?
57. Life on earth has existed for only a few thousand years.	T	F	?
58. New combinations or mutations of parents' genes do <u>not</u> result in new characteristics which can be inherited.	T	F	?
59. Natural selection is likely to lead to organisms with characteristics that are well adapted to survival in particular environments.	T	F	?
60. Evolution is <u>not</u> a ladder in which the lower life-forms are all replaced with superior forms.	T	F	?
61. The modern concept of evolution provides a unifying principle for understanding the history of life on earth.	T	F	?
62. New instruments and techniques being developed through technology make little contribution to scientific research.	T	F	?
63. Technology just provides tools for science - it seldom provides motivation and direction for theory and research in science as well.	T	F	?

Source: Laugksch RC & Spargo PE (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science*, 5(4), 331-359.

64.	Engineers can design solutions for all our problems.	T	F	?
65.	In the short term, engineering affects societies and cultures more directly than scientific research.	T	F	?
66.	*Engineering decisions without fail involve scientific judgements*. These decisions also involve social and personal values.	T	F	?
67.	*In engineering, a design takes into account all the constraints (e.g. physical laws, economics, politics).* An optimum (i.e. "best") design arrives at some reasonable compromise (i.e. balance) among the different constraints.	T	F	?
68.	Engineering designs almost always need to be tested.	T	F	?
69.	*The effects of large numbers of relatively simple objects (e.g. refrigerators or solar cookers) may be individually small.* However, these effects may be collectively significant.	T	F	?
70.	In spite of the great complexity of modern technological systems, all side effects of new technological designs are predictable (i.e. can be forecast).	T	F	?
71.	People's psychological reactions to risk (e.g. their fear of flying or driving) match the reality of the risks involved.	T	F	?
72.	No matter what precautions are taken or how much money is spent, any technological system can fail.	T	F	?
73.	Social and economic forces within a country have little influence on what technologies will be developed within that country.	T	F	?
74.	Technology has had little influence on the nature of human society.	T	F	?
75.	The relevant technical facts alone usually do <u>not</u> settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the decision.	T	F	?
76.	The total effect of decisions by large numbers of individual people can influence the large-scale use of technology as much as the pressure on decisions by government can.	T	F	?
77.	Most decisions on technology-related issues have to be made using incomplete information.	T	F	?
78.	All things of the physical world are made up of different combinations of about 100 chemical elements.	T	F	?
79.	Depending on temperature and pressure, every substance can exist in a number of different states (i.e. a solid, liquid, or gas).	T	F	?

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80. The way atoms bond together is determined by the arrangement of the outermost electrons in each atom.	T	F	?
81. A low level of background radiation exists naturally in the general environment (i.e. the world around us).	T	F	?
82. In the universe, energy appears only in one particular form.	T	F	?
83. Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by an equal amount.	T	F	?
84. Arrangements of atoms in molecules are unrelated to different energy levels of the molecules.	T	F	?
85. Energy as well as matter occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms.	T	F	?
86. Nothing in the universe - from atoms to living things to stars - is at rest, but is always moving relative to something else.	T	F	?
87. Changes in motion are always due to the effects of unbalanced forces.	T	F	?
88. Things appear to have different colours because they reflect or scatter visible light of some wavelengths more than others.	T	F	?
89. Every object in the universe exerts gravitational forces on every other object.	T	F	?
90. The *electromagnetic* forces acting between atoms are vastly stronger than the *gravitational* forces acting between them.	T	F	?
91. Magnetic and electric forces are unrelated to one another.	T	F	?
92. In most *biological* respects, humans are unlike other living organisms.	T	F	?
93. In spite of variations in features such as size and skin colour, humans are a single species.	T	F	?
94. Technology has been of little use to us in overcoming our biological disadvantages in our day-to-day lives.	T	F	?
95. The death rate of infants is independent of factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care.	T	F	?
96. Technology has added greatly to the choices which people have in controlling when, and how many, children they have.	T	F	?

Source: Laugksch RC & Spargo PE (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science*, 5(4), 331-359.

97.	Organ systems of the human body have unspecialised functions.	T	F	?
98.	The immune system plays an important role in the self-protection of humans from disease.	T	F	?
99.	*Internal control (i.e. co-ordination) is required for managing and coordinating complex organ systems in the human body.* Hormones play an important part in this control.	T	F	?
100.	Any new-born animal will show certain patterns of behaviour without having been taught such behaviour.	T	F	?
101.	The behaviour of different people results from the interaction between what they have inherited biologically and differences in the peoples' experiences.	T	F	?
102.	Much of learning appears to occur by linking a new piece of information with an existing piece of information.	T	F	?
103.	People's existing ideas usually do <u>not</u> influence learning even if the ideas affect how people interpret new facts and ideas.	T	F	?
104.	In order to operate normally, the human body does <u>not</u> need replacement of the materials of which it is made.	T	F	?
105.	The good health of individuals is independent of people's collective effort to take steps to keep their air, soil, and water safe.	T	F	?
106.	Abnormal genes do <u>not</u> affect how human body parts or systems function.	T	F	?
107.	Good mental health is unrelated to the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life.	T	F	?
108.	Ideas about what is good mental health are the same in different time periods (i.e. at different times in history).	T	F	?
109.	Biological abnormalities (such as a chemical imbalance in the brain) cause some kinds of severe psychological disturbance.	T	F	?
110.	Psychological distress (such as the death of a close family member) does <u>not</u> affect any person's chance of becoming physically ill.	T	F	?

Thank you - you have reached the end of the test!

Source: Laugksch RC & Spargo PE (1996). Construction of a paper-and-pencil *Test of Basic Scientific Literacy* based on selected literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science*, 5(4), 331-359.

Test of Basic Scientific Literacy (TBSL):

Scoring key

Each test-item is described by a unique 6-character code. The first digit identifies the chapter in *Science for all Americans*, the second identifies the subsection of the chapter, the third and fourth digits identify the paragraph within each subsection (numbered 01, 02, 03, etc.), and the fifth identifies the item number per paragraph. **A "T" or "F" distinguishes True and False items, respectively.**

TBSL#	Item Code	TBSL#	Item Code	TBSL#	Item Code
1	41011F	38	51011F	75	33071T
2	41013F	39	51051F	76	33081T
3	41021F	40	51052F	77	33091T
4	41031T	41	52022T	78	44011T
5	41091T	42	52031T	79	44031T
6	42015F	43	53012T	80	44051T
7	42021F	44	53031F	81	44071T
8	42031T	45	53051T	82	45011F
9	42044T	46	53061F	83	45021T
10	42051F	47	54011T	84	45061F
11	42071F	48	54041T	85	45071T
12	42101T	49	54052T	86	46011T
13	43041T	50	54053T	87	46031T
14	43051F	51	55011F	88	46091T
15	43062F	52	55021F	89	47011T
16	11011T	53	55031T	90	47021T
17	11021F	54	55041T	91	47041F
18	11031T	55	55043T	92	61011F
19	11061T	56	56011T	93	61031T
20	12021F	57	56031F	94	61061F
21	12031T	58	56061F	95	62032F
22	12051F	59	56071T	96	62071T
23	12061F	60	56081T	97	63011F
24	12081F	61	56091T	98	63021T
25	12091T	62	31031F	99	63031T
26	12101T	63	31041F	100	64011T
27	12103T	64	31081F	101	64021T
28	12111T	65	31091T	102	64051T
29	12121T	66	31092T	103	64071F
30	13031F	67	32012T	104	65012F
31	13061F	68	32041T	105	65022F
32	13072F	69	32081T	106	65061F
33	13091T	70	32091F	107	66011F
34	13101T	71	32101F	108	66013F
35	13111T	72	32131T	109	66041T
36	13121T	73	33011F	110	66051F
37	13141T	74	33022F		

/END

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