

Scientific Literacy

By Joseph Agassi

The central end of all of my research activities was the effort to break down the walls of the academy. The wall is defended by the idea that not only do experts possess knowledge beyond the ken of lay people, which is trivially true, but that there is an unbridgeable gulf between the two. The aim of this presentation, then, is to discuss the possibility of building a bridge between the ordinary educated citizen and the expert. The tool for this is the famous effort to disseminate scientific literacy, or more generally, any specific sophisticated literacy. The subject-matter of this presentation, then, is scientific literacy, and the question is, how can it best be disseminated?

Now the word "literacy" in expressions like "scientific literacy" and "computer literacy" may be meant literally or metaphorically. As I will try to show later on, if time permits, profound ambiguity and ambivalence reside here. The significance of all this remains to be seen. Let me first contrast any specific sophisticated literacy with elementary literacy, and center first on the elementary. It is of course the one that is denoted by the first two of the three r's, reading writing and arithmetic, the three skills teachers of the lower grades of elementary schools are supposed to transmit to their charges. Before discussing scientific literacy or computer literacy or any other specific sophisticated literacy, I will discuss this elementary literacy.

My suggestion is that by advancing somewhat our knowledge of elementary literacy we can see what is specific to any specific literacy, however sophisticated it may be, but that there is more profit for understanding the nature of elementary literacy by examining specific cases. My thesis will be that any literacy, elementary or specific, is best achieved by guided, aided experimentation: the trainee should learn by trial and error

while helped by trainer now and then -- on the condition that the trainer tries to keep their intervention to the reasonable minimum. This thesis requires much elaboration; I will come to it as much as time permits. In any case, is not revolutionary; only its application is. Let me also add at once that the chief error in the distinction between elementary literacy and any specific sophisticated literacy is based on the oversight of the tremendous sophistication involved in elementary literacy.

Well, then.

The concept of elementary literacy is notoriously vague, and reference to the two out of the three r's seems helpful, as we all think we know what the three r's are. But this is only deceptively so: we do not know what the three r's are, and this is a famous fact. To see this, let us note that elementary literacy is usually -- and erroneously, it will soon transpire -- defined as the skill of deciphering signs, the ability to decipher signs, to translate a written text to and from a voiced message, to move to and fro between writing and reading aloud or even reading silently. This is generally admitted, as it sounds precise. It is both false and vague. What is clear is that the illiterate has no familiarity with the sign system most of us literates are familiar with and take to be the one referred to when we generally speak of elementary literacy. We cannot explain illiteracy without knowing what is literacy, and for this we have to specify the sign system in question that the literate is familiar with and the illiterate is ignorant of. This is no easy matter, since the term "literacy" is meant to refer to the sign system known as the written language, but the written language is one of the most sophisticated extant and we know of much more primitive ones, the most primitive of which we label "animal languages". Even if we take all body language, dance included, to be voiced signs by extension, animals still have signs that are by

extension clearly written rather than voiced, as they leave their signs behind; humans, including the preliterate, have much more elaborate signs systems than other animals. Let us leave all these without discussion, however, since we want to go from elementary literacy to sophisticated, specific ones, not to the more primitive ones. All I wanted to stress here is that even the most simple sign system is very sophisticated. This is no news, yet we forget it repeatedly at important junctions, as I will soon illustrate.

Let us then concentrate on the written language, though we still do not quite know how to characterize it.

To avoid being abstruse let me explain without debate the trouble with the characterization of the written language; the explanation need not be endorsed, and I will not defend it: my aim is simply to avoid sounding abstruse when saying that we do not know how to characterize a written language. Briefly, it is our inability to characterize language -- any language. We may refer to a language (spoken or written, it does not matter) by reference to its signs, such as words and phonemes, or the hieroglyphs and the alphabet. This brings us to the theories of signs and of codes, where language is not involved in the least, and so it will be only marginally relevant to our discussion. Indeed, the theory of signs and of codes will be relevant to that part of language that is shared by a native literate speaker of it and the utterly unfamiliar with it, who nevertheless can read it or recite poems in it. As example, we may take most literate English-speakers, and note that they can read Latin with ease without comprehending it at all. To refer to literacy proper the written language has to be in the sense of English for native speakers of English, not in the sense of Latin. Clearly, what is at stake here is meaning.

In the early twentieth century, the new logic was supposed to bring

about a radical revolution in philosophy, just because it introduced a new theory of meaning, or rather a few similar ones. The promise was fulfilled only in part, though an exciting one at that. In general, it proved premature: we still do not have any reasonable comprehensive theory of meaning. So let us take meaning as given and proceed with the written texts of a language as a set of signs in that given language that is the system of signs plus their usual meanings, whatever these are. Literacy, then, may mean the ability to decipher the signs in question in the sense of being able to manipulate them - like the Latin reading ordinary English speaker and like the computer which can translate a written text from one language to another or to a voice representation of the same text, now that reading computers are available. Or it may mean the ability to comprehend the signs as well.

Up until now I tried to characterize the sign system of a written language or of any language, and I admitted failure: I do not know how to characterize it because I do not have a theory of meaning. Yet we do have simple tests of comprehension, so we can repeat the question, is literacy the ability to translate or to comprehend? Here we come to a crucial junction, so please notice this.

When discussing elementary literacy the question does not arise, is the test of the ability to manipulate or to comprehend? For, the texts usually given in literacy tests are easily comprehended by all. This is where expressions like "scientific literacy" and "computer literacy" become metaphorical, since in tests there concern comprehension. This would not matter overmuch, except that the ambiguity between the two senses of literacy spills from the matter of the contrast between elementary literacy and specific sophisticated ones, to the matter of the contrast between the possession and the acquisition of elementary literacy and thus also the matter

of the contrast between the possession and the acquisition of sophisticated specific literacy. For, in our society, before the acquisition of literacy, the language that infants possess is notoriously limited; it is increased through the acquisition of literacy. Illiterate adults possess more comprehension than infants in the elementary classroom, though less than literate adults; because we know that literacy has to do with comprehension, when we test adults for literacy we give them simple texts to read, and then we forget that literacy has to do with comprehension. This is brought home when we test people, usually adults, for specific sophisticated literacy. And then we say, elementary literacy has to do with simple reading but scientific literacy or any other specific sophisticated literacy has to do with comprehension. Not so.

The problem aired here is not new; it is traditional. It is so well known that there is a repeated effort to bypass it by the attempt to reduce comprehension to the ability to manipulate. As we saw, computers are able to manipulate, better than humans in some limited contexts. So, if the effort to reduce comprehension to the ability to manipulate is possible, then we are computers. Are we? This is the mind-body problem, which is as commonly known in philosophy as any. But let us stay with the solution. We test comprehension by trying to eliminate mere memorizing. And we do so by rewording the question and looking at the candidate's ability to answer it despite the alteration. Consider the range of possible alterations as given and you can teach a computer to manipulate them all. Hence, a computer well programmed over a sufficiently wide range will fool the examiner who wants to distinguish comprehension from the ability to manipulate. The failure of the examiner is the failure to pass the Turing test, so-called.

The theory just propounded is the one known as materialism or rather

reductive materialism (as it reduces meaning to the ability to manipulate), and as the theory of meaning as use or usage. If one also offers a correlation between the message to be translated and its translation, then one achieves a version of behaviorism. It is interesting to see that, true or false, this theory presents literacy of any sort as a proficiency in manipulating signs, so that there is no difference between elementary literacy and any specific sophisticated literacy, no difference between the ability to read English and the ability to read Latin except that the one task is much more limited: the reader of the Latin text reader can only translate correctly written to spoke signs, yet the English text reader can also translate correctly some spoken sentences to other, equivalent ones. Is this idea feasible?

No. The trouble is that in the previous paragraph I spoke of correct translations, of correct manipulations, without noticing that the correctness in question is one we all judge easily because we have a sense of correctness that the computer does not. Yet there is a great merit to the theory, and it is that it is an attempt to bridge the levels of proficiency regardless of the question, is this proficiency linked to comprehension or not?

To see this we may want to examine the further ambiguity of the term "elementary literacy" that is left after we ignore all our failures to say what it is that we speak about when we speak about elementary literacy. The literate in the sense of being in possession of elementary literacy, it is well known, may be familiar with the sign system of the written language to different degrees. Thus, literacy may be the ability to sign one's name, or to read one's prayer-book, or the newspaper's headlines, or also the small print, and so on. The degrees of ability to manipulate signs resemble the degrees of the ability to comprehend. it is not surprising then that some thinkers want to identify them, and leave the "and so on" in the increase of comprehension on a par

with the "and so on" on the increase of the ability to manipulate signs. For, this "and so on" is the challenge to computer simulators whose work in the effort to increase the scope of their commutators is supposed to shed light on the growth of comprehension.

The subject-matter of this presentation is this "and so on", since when we go far enough in the direction of the "and so on" we will reach the level of scientific literacy or of any other specific sophisticated literacy; the problem of this presentation is, how is the more specific sophisticated literacy best achieved? and if we see that elementary literacy and specific sophisticated literacy are on a gradation of sophistication, we will be more respectful to the difficulties met in the effort to acquire elementary literacy and tend to be less enigmatic about any specific sophisticated literacy; we will thereby be more compassionate and more helpful to both kinds of students. If computer simulators will be able to help us in this respect, their contribution should be most welcome. Yet, thus far they offer a distant promise of a solution for a very urgent problem.

The question is very important, how is elementary literacy to be achieved? It was given new life by Caleb Gattegno: he said, just as infants acquire the ability to speak, they may be able to acquire the ability to read and write. That is to say, if we had a good applicable theory about the acquisitions of the spoken language, we would be able to transfer this knowledge to literacy and achieve the required gradation between the acquisition of the spoken and the written language. This is contestable, of course, and so the question is, what is the way we acquire the spoken language and why is it or is not, applicable to the written word?

To show you that this is very very commonsense, let me mention one theory that explains the breach, the gulf, the chasm, between the spoken and

the written language. It was suggested that the culprit is the alphabet, since in the spoken language the elementary sign is the word and the word is meaningful, yet in the alphabetically written language the elementary sign is the letter that is devoid of meaning. If this were so, then there would be no chasm between the spoken language and the hieroglyph. So, the effort to bridge the spoken and the written language should be successful if the alphabet were replaced by hieroglyphs. Now it is too much to expect ordinary teachers in the modern world to be able to teach hieroglyphs. So, the idea was invented to consider words written alphabetically as wholes, thus viewing them as hieroglyphs of sorts. Moreover, some words, like "elephant" seemed to be more pictorial than others. So the project of implementing this idea was launched. The idea was deemed so convincing that it was launched with no pilot. This is unbelievable and may be taken as evidence for the recklessness of some innovator, but that takes us away from our topic. What is at the heart of our topic is the fact that the result of the failure of the reckless experiment led to stagnation, whereas the question, can the gulf between the written and the spoken language be bridged and if so how? For the next question in line is of course, can the gulf between specific sophisticated literacy and elementary literacy be bridged and if so how?

The literate may be able to write or not, and to write a brief message, a diary entry, a brief essay, a book. It is an interesting fact that in the nineteenth century, when the level of literacy in the western population was still low, the literate used to write regularly -- letters and diaries and journals, at the very least. In the twentieth century the widespread reading ability was not yet complemented by any writing ability, though the establishment of electronic mail and of fax machine made it a bit more

widespread. Thus, in the most elementary case of literacy there is the vagueness as to the level of competence and as to the different dimensions involved.

The dimensions involved are no simple matter. The famous New-York linguist Mario Pei reports that, being bilingual, he was asked by a bank to translate a text from Italian to English, but he could not: he was not literate in banking matters. This is my paradigm case.

When we speak of any specific sophisticated literacy, such as computer literacy or as science literacy that is today's agenda, the vagueness concerning degrees of competence in literacy proper is assumed to be irrelevant, as students are supposed to be reasonably literate, but the matter of literacy in the specific subject is raised forcefully. This is reasonable when the problem is examined, but not when a solution is sought. For, only the properly literate can face intelligently the question of how to acquire computer literacy or science literacy, and find their way in the effort to acquire it.

In other words, what makes the use of the word "literacy" in the expression "scientific literacy" metaphorical is the fact that when testing for elementary literacy we forget comprehension, yet we do not consider the ability to read Latin incomprehensibly literacy. If we iron out this matter, then we will see that the illiteracy of the illiterate is not a matter of the inability to manipulate signs but the inability to comprehend something. Once this incomprehension is overcome and the opportunity to read is offered, literacy is acquired. This is why some infants learn to read faster than others.

The thesis of this presentation, then, is that in order to help individuals to acquire scientific literacy -- or any other specific sophisticated literacy --

it is best to train them in the highest level of literacy proper. Let me discuss, then, the idea of literacy proper and the idea of any specific sophisticated literacy, scientific, computer or any other, and how they interrelate.

The three items just mentioned, elementary and particular literacy and their interrelations, are very closely linked, simply because in the context of this presentation the idea of literacy is very broad.

In the narrow sense, literacy is tied to the ability to manipulate a very specific set of symbols, namely the alphabet. Literate persons in the narrow sense of the word can read a text even if it makes no sense to them as long as it does not involve specific symbols. Let us leave our example of a Latin text and choose instead a chemistry text. A person with no familiarity with chemistry will be able to read a plain chemical text as long as they are allowed to read the names of the elements in letters, such as H, O, C, and so on. But if it is required of them that they read H as hydrogen, O as oxygen and C as carbon, then they will not perform as well as the scientifically literate. This simple example is much more significant than it seems. One reading a foreign text can fare well enough until one bumps into common abbreviations, e.g., e.g., i.e., etc. Some will get stuck when they fail thus, others will show initiative and seek in the dictionary the table of chemical elements or a list of common abbreviations or anything else that is required. More than that. Not all dictionaries offer the items required, and some people who look up a dictionary will lose heart after one or two failures, and others will go on until they meet with success. Still further, if they fail all the way, some of them will give up and others will seek help. It seems to me, let me say outright, that much of what we deem as literacy, elementary or scientific, is the simple ability to consult others when one gets stuck. This is all that there is to the matter at hand, I propose, unless one moves to a higher

level of literacy that requires some familiarity with the background knowledge that Mario Pei was missing and without which he could not perform the task at hand. I will come to this matter later on; before that let me elaborate a bit on what has been observed thus far.

The literature on literacy is defective in one way that needs immediate correction: it presents as literate on this or that level in this or that dimension one who meets with no problems while performing the task that requires the literacy under discussion. Perhaps the field may be slightly increased: it may very well include some problems of the kind that the literate who bump into them may overcome them with the use of very common and readily available techniques. Yet here we have the inkling of a new dimension of literacy, one that is hardly discussed as it has to do with initiative, but which should be explicitly discussed, as it is related more to skill than to initiative.

Let us take the skill of consulting a dictionary, since it is much simpler than that of consulting people if a library is around the corner. Most people, including graduate students, are surprisingly limited in their ability to exercise this skill, simply because they are not in the habit. This is a major block to the growth of knowledge and to the development of intellectual and moral independence, since it is a symptom of the popularity of a different skill, of trying to navigate as best one can without understanding a word or an item of information while timidly covering up for this lacuna.

This is a skill, for sure, even though it is not one that we wish to train our students to acquire, much less to use. This is an error: the best way to train people NOT to employ a certain skill, is to train people in it and to show them how easy it is to employ it and yet how poor its results are as compared with those of better skills. The skill at hand, of concealing a lacuna in one's skills and/or background knowledge, is one that is really

epidemic these days, as the number increases of students from home with little or no literacy. This change is of course wonderful, and we should help facilitate it in any way possible, and indeed the this presentation is offered in the spirit of helping people overcome the traumas of the transition from an illiterate social milieu to a literate one. It is clear that the transition is traumatic, at times leaving big scars, and in my experience the absence of notice of it, let alone investing some study of it.

The need to study this epidemic rests on the fact that the process of auto-immunization against it is very slow. This is so because the older one gets and the higher the status one achieves as a scholar, the worse the illness and its symptoms. If you want to see an example of it, look at the writings of leading intellectuals such as the famous hermeneuticist Hans Georg Gadamer. He studies the meanings of texts, yet any perusal of his writings will show that he is a great expert in concerning up for his illiteracy concerning anything to do with science or mathematics. I am not discussing now his scientific or mathematical illiteracy, let me stress: I have met some great scholars who are scientifically and mathematically illiterate, and they are simply very capable of avoiding discussion of anything to do with science. I am speaking of the fact that Gadamer is not clever enough to dodge items that have to do with science and mathematics, yet he compensates for this by cleverly masking this fact. The masking comprises a certain vagueness of style characteristic of a whole scholarly tradition, if one may call it that. I will not discuss examples of this as time is very short, and so I will direct the curious to my essay "Gadamer Without Tears". Let me mention that here Gadamer follows a tradition that goes back to Hegel: in Popper's classic *The Open Society and Its Enemies* Hegel's writings on the natural sciences are quoted, and this is considered a slight on his -- Hegel's --

character, though, it is well-known, Russell has said before that Hegel's writings on mathematics are sheer nonsense, and his -- Russell's discovery of that fact was important for his liberation from the charm of Hegel's philosophy.

Literacy in the sense somewhat broader than the ability to translate written to voiced messages, then, includes some unintended assets, such as the spotting of pretentious writings. But here we have to center on its contribution to the ability to move in unknown territory, beginning with the dictionary. As this sounds very low-level, let me brag and tell you that when in my first book, which is on the writing of the history of science, I used materials I had found in old encyclopaedias, this amazed some colleagues of mine whose scholarship I greatly admire. The reason, incidentally, for this absence of uses of encyclopedias among historians of science is that they follow the requirement that books should be read from the first page to the last. I found it amusing that a number of scholars have complained in print about the dwindling of "the time honored custom" of reading from the first to the last page consecutively. My complaint is in the opposite direction: it seems to me that one is not properly literate unless one can browse effectively. Why then is browsing discouraged? The answer is clear: browsers are tempted to pretend to have read the books they only skimmed through, and this is a part of the already mentioned epidemic of pretense and covering up for lacunae. The fact that people browse instead of reading is easy to document by reading some reviews of familiar books, since it is the duty of a reviewer to read the book under review or else to tell the reader that this is not the case.

When as graduate student I read in a very prestigious philosophical journal a review of Karl Popper's already mentioned classic, in which the

reviewer says he likes the final chapter of the book as it discusses nature and convention, I was amazed, as the book's fifth chapter is about this topic and is so labeled. Evidently I was naive, but also, evidently, the famous reviewer was incompetent, as he did not study properly the books' table of contents. This is evidence, if evidence is needed, that forcing people to read boring books from a to z is only further incentive to use the base technique of pretending to have read what one has not read. I applaud the observation of the once famous philosopher Rudolf Carnap, who complained that he often had to read whole boring books in order to find some items in them; he said so when he explained his own method of writing that greatly facilitates browsing through his books. And I repeat the observation, that a reviewer is exempt from reading the whole book under review on the condition that the reader is properly informed about the facts of the matter. Of course, the question always is, is a book worth reviewing that the reviewer could not read thoroughly. But this is a different question.

The art of browsing is essential for literacy in the broad sense. And it begins with the simple observation that the browser should read carefully the book's front material so-called, namely the table of contents, the preface, and the introduction. The reason that people skip this material, incidentally, is very different from the one that makes browsing unpopular: it is the stricture of the standard high-school, textbooks. I cannot begin to tell you how loathsome the very idea of a textbook seems to me, but let me sketch only the major ways in which this cursed institution impedes the acquisition of literacy in elementary and scientific literacy in particular. Briefly, it makes one's scientific literacy on the level with the literacy proper of one who can read only one's prayer-book. This last sentence must be qualified: one need not discuss the desirability of reading one's prayer-book and even the

priority this book has over the newspaper. Indeed, if we must have textbooks, then I know of no better ones than Holy Writ -- indeed this is the only text I recommend, though I am not religious, in addition to Homer and perhaps Shakespeare as well. But the standard textbook, especially the science textbook, elevates scientific doctrine to the level of dogma, which is an insult to both science and dogma. I would advise the interested to study the response of some school superintendents or inspectors to the fundamentalist demand to teach creation in biology classes. That the fundamentalists are dogmatic and dishonest becomes them; that school superintendents take the same liberties is more dangerous.

The need to choose one's own text to read forces one to browse: browsing is then akin to window-shopping. The alternative to window-shopping the compulsory uniform, school or any other, and the analogue here is the school textbook. The school textbook is compulsory, it limits one's horizon, and it discourages all reading for fun. It is no accident that those who read for fun often read something that they had not encountered in school. The early days of the personal computer, the computer's golden age, took place before teachers developed computer literacy.

I do not know how many of those present have purchased textbooks with prefaces written for teachers, explicitly or otherwise. Even some of the best mathematics textbooks that I have read for fun have such prefaces. And of course, some of the front material of a book is of necessity comprehensible only to one familiar with the background to that book, and no teacher discusses the idea of front material. I have myself discussed this matter with a number of authors who asked for my help and advice about the way they should go about it. Most of them simply did not ask themselves, why is the front material there, and what is its role?

The textbook that is in any way comprehensive, even slightly, cannot avoid inconsistencies. When these are in a sacred text, the matter requires specific studies that will not be discussed here except to say that they are called apologetics, and that they may have their proper place in religion and even in law, but not elsewhere, yet they are very common. Like weed. Even if a textbook is free of apologetics, it rounds off inconsistencies, so that each page, even each chapter, of the textbook is consistent, but not it as a whole. This is unavoidable, as the only logical way to avoid such inconsistencies is to label them properly as different views. Thus it is inconsistent to say, there are 355 days in a year and there are 365 days in a year, and if these two estimates are placed in different parts of a book the inconsistency does not disappear. It is much easier to say, the solar year is 365 days but the year compounded of twelve lunar months has 355 days. This already gets one out of the inconsistency, but not well enough: to do so one has to ask, why does one include twelve lunar months in a solar year? For this one has to note that the word "month" signifies a lunar period and the word "year" a solar one (or terrestrial, to be precise), and face some question that invites a combination of the two periods. Only then are we prepared to some degree to understand the two estimates of the year, as 365 days and as 355 days respectively. Another inconsistency arises when the estimate of the length of the solar year is improved. This point is so obvious that it need not be discussed. That textbooks do not respect it is a matter of empirical fact that I suggest that you examine: check your textbooks for their consistency.

The point is quite general. High-school pupils learn that Euclidian geometry is the last and unquestionable word in geometry, and they are taught otherwise in college, but these two facts are seldom put together. I have a better example: arithmetic. The arithmetic we are taught in school is

not revised in college. Even non-standard arithmetic does not replace ordinary school arithmetic. Yet the rules learned for large operations, of addition, subtraction, multiplication and division, are less sacrosanct than the basics, even though they are faultless. I have found out empirically that some mathematicians, who can easily justify these complex rules, and it is easy to do that, have not done so until I challenged them to do so. This I find remarkable.

I have to finish this presentation, and I wish to end with one observation. It concerns a popular yet neglected item: problem-orientation. That learning is problem oriented has been shown repeatedly, but methodology and education theory do not notice this. Surveys of learning theories, concerning learning in school and in scientific research, often fail to mention problems and even trial and error. Trial and error is task oriented, obviously. Not all tasks are problems, and most tasks used in trial and error experiments in psych labs relate to tasks that are not quite problems, as do text-books. There is a reason for this: computers can generate answers to given questions if they are taught how to do so; but they cannot generate problems or improve upon given ones, as observed by arch-cyberneticist Norbert Wiener. It is clear that simply from the pragmatic point of view learning by trial and error is advantageous. The great linguist Otto Jespersen cites a Russian proverb: you do not learn a language unless you murder her in all possible ways. This is the bridge I see between elementary literacy and scientific literacy or any other specific sophisticated literacy: we cannot be experts in all fields, but we can make forays to any field we like given the time, effort, opportunity and help.