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RESEARCH COMPUTERACY

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ABSTRACT

This paper describes the concept of computeracy as it applies to research workers and argues that research will be improved if the level of computeracy can be raised.

1. COMPUTERACY AND RESEARCH BACKGROUND

At an educational conference held some two years ago the concept of Computeracy was suggested as a useful tool for structuring educational programmes [47]. This concept has subsequently been discussed at a number of seminars, both local and overseas and as a result certain ideas have been clarified and developed further [48]. This paper considers whether the concept of computeracy is a useful one in the research environment.

2. COMPUTERS AND RESEARCH

The development of computers has been stated by many authors (e.g. O'Brien, [44] page 7) to be the most important technological development of the 20th Century. It is claimed that the computer is now doing for man's mind what the industrial revolution did for man's muscle in the 19th Century. The term "computer revolution" has been applied to this change.

There is no doubt that the computer has significantly magnified our ability to analyse, compute and communicate thereby greatly accelerating human technological progress [23, 43, 54]. For this reason the "computer revolution" has also been called the "information revolution". There is nowhere that the possibilities of expanding man's mind through the use of computers can be better illustrated than in the fields of scientific , technological and social research.

As a simple illustration of this, the following table gives the cost of undertaking an analysis of variance for a large experiment involving a complex factorial design and unequal cell frequencies from 1950 to the present:-

Mid	1950's (vacuum tube circuits)	R	500,00
Early	1960's (transistor printed circuit)	R	90,00
Late	1960's (miniature circuits)	R	50,00
Mid	1970's (integrated circuits)	R	2,00
Mid	1980's (Large scale integration)	R	0,10

figure 1

Costs of Research Computing 1950s to 1980s

These costs are for the actual calculations and do not include the costs of collecting and encoding the data. For the average researcher today the actual costs of computation are usually only a very minor part of the research costs. The exceptions to this are in the "newer" research areas of computational mathematics, physics, in particular nuclear physics, and large scale simulations carried out in particular in biological studies.

Until 1945 a great deal of research in the "older" areas was limited either by the cost of computation or by the sheer impossibility of actually undertaking the calculations.

What is the limiting factor today? Campbell and Stanley [9] and more recently Benet [6] have listed some of the factors that are limiting research today. I submit that an additional and

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important factor is the computeracy of research workers. Even if this is not the prime factor limiting research, the concept of computeracy is nevertheless useful in considering why some research is still limited and why some areas that could be quantified have not been. (The similar problem in Management information systems was highlighted by Ackoff as early as 1967 [1].

3. WHAT IS COMPUTERACY IN RESEARCH?

Computeracy is a multidimensional concept. A simple measure of one of the dimensions is the rate at which people learn to use PCs and terminals. The time required to develop a specific skill has been found to vary by a factor of 10 even in fairly uniform groups [46]. This variation is found within all groups whether they are groups of university graduates or junior clerks with minimal education. Further references may be found in Pirow [47, 48]. Some statistics on this variable were originally obtained by observing the behaviour of students in the laboratories at the Wits Business School.

4. OBSERVATIONS

All students at the Wits Business School, whether undertaking the Higher Diploma in Personnel Management, the degree of Master of Business Administration or other higher degrees, make use of computer facilities. These facilities include 19 microcomputers and a 30 terminal laboratory operating in Virtual machine mode. Over 1 000 students have used these facilities in the past seven years. All MBA students study a course on Computers in Business and all HDPM students undertake a course on Computers in Personnel Management. All Ph.D. students undertake a course in Research Methodology which includes a number of courses on computers. All these courses and a number of executive courses which use the laboratory have provided an opportunity to observe the learning curve phenomenon which takes place. The reaction time to the more frequent stimuli typically decreases by a factor of ten over a period of six months. The variation is however great. For example the logged on time taken to get rid of a somewhat irritating message that I put on the screen varies from 1 hour 20 minutes to over 200 hours. The distribution is very negatively skew and is almost log-normal. There is a significant relationship between this time and the student's performance in the first computer course.($r = 0.68$ for a typical class) The vastly different learning rates achieved by these students raises the question of how the human mind functions in the computer environment. This leads us to study other parameters of computeracy.

4.1 The multidimensionality of computeracy

Computeracy and Information: Historically the development of computeracy may be regarded as parallel to and about 20 years behind the development of the idea of "information" as a concept [4]. The relationship of both to the overall development of Science may be assessed by consulting Sarton [53].

Computeracy and literacy: A useful analogy may be drawn between the way the mind functions when confronted with a computer and the way the mind functions when confronted with a book. In considering "literacy" no one would have any difficulty in recognising the subject involved and assessment of competence in the subject, at least at an elementary level,would be examined by means of a comprehension test. In computeracy the time taken to get rid of the irritating message is equivalent to an elementary comprehension test for elementary or functional literacy.

Computeracy and numeracy: In considering "numeracy" there would be slightly more difficulty in conveying an accurate description of the body of knowledge to be examined because a distinction would have to be made between "numeracy", meaning "acquainted with the basic principles of mathematics ", and numeracy as meaning " acquainted with the basic principles of science". Nevertheless there is still not a great deal of difficulty in designing examining procedures (though the multidimensionality of numeracy begins to present a problem) We all know that there are large differences between numerate people. We have on the one hand the person with the amazing, if not freak, ability to handle numbers, for example, the sub-teen child who can multiply two nine-digit numbers together and get the correct answer in a second. This ability has even been reported, if not substantiated in a person with an IQ of 46. On the other hand we have the mathematical logician who is brilliant at logic and theory but may be poor at mental arithmetic. Both are numerate. The computer equivalent of the former is the person with the rapid response time at a terminal who can make his system perform all the tricks. This is however only a mild extension of the child's ability at computer games. In this sense elementary computeracy has a high correlation with quick reaction times and keyboard dexterity. However, just as one would hesitate to call the child with freak mental arithmetic capabilities "numerate" in the broad sense, so the person with quick reaction times and high keyboard dexterity should not be regarded as computerate. The student getting rid of the message on the screen has to have a deeper understanding of the computer system, he has to locate the virtual disk on which it is stored and then call in an editing procedure to change or delete it. Achieving this objective may then be one very simple measure of elementary computeracy. If we define "computer literacy" as "being acquainted with the basic principles of computers" then computer literacy could also be regarded as the lowest level of computeracy.

5. COMPUTERS AND RESEARCH

Any research worker in this modern world would need to know that computers are valuable research tools where

1) There are large volumes of data to be handled
2) The data can be classified at least at the nominal level
3) There are a number of calculations to be made on the data
4) There is a limited amount of time available for undertaking the calculations.

figure 2

When computers can assist research

Research workers need this fundamental awareness simply to be able to determine whether a computer will further their research or not. Whether research workers need to go beyond this level will be dependant on the techniques they use for their research.

6. RESEARCH METHODOLOGY

There are many research methodologies and many excellent books which describe these (e.g. Yeomans et. al [59], Bailey [5] & WBS [58]). Whereas an increasing number of these is making use of computers (e.g. literature analysis) for purposes of this paper I will concentrate on those research methodologies which attempt to establish relationships between variables. (For other methodologies the reader is referred to Delbecq [18], Fusfield [21], Garfinkel [22] & Harrigan [25]) There are two approaches to research concerned with attempting to establish relationships between variables. (see e.g. Carlile et al. [12]) Both methods require increasing computeracy. The two methods have been termed experimental methods and multivariate methods. It should be noted that the names "experimental methods" and "multivariate methods" are not either exhaustive or mutually exclusive. Experimental methods are often multivariate as will be shown below. The terms are however more correct than "correlational studies" and "experimentation" which are often used as alternatives. In order to distinguish the two with more exclusivity the terms "directly controlled" and "indirectly controlled" may be used.

6.1 Experimental methodology (Directly controlled research)

6.1.1 Definition & Characteristics of an experiment

An experiment is the actual trial of a proposed course of action (or other hypotheses under consideration) so conducted that its effects can be observed (measured) objectively and distinguished from the effects of extraneous variables.

In an ideal experiment the experimenter has complete control over the environment. He therefore has complete control over all the independent variables and the ability to hold all extraneous variables constant. In an ideal situation he would also have perfect measurement of all variables (Independent and dependent)and, if groups are involved he will have perfect control over the control and experimental groups. Such an approach clearly meets the requirements of scientific method. Note however that, even under this ideal situation a successful experiment need not necessarily establish causation.

Experimentation is nevertheless a particularly desirable method where research questions take the form of hypotheses which state that "if (a) then (b) follows", rather than those hypotheses which seek to describe a phenomenon or where the primary purpose of the research is to develop or verify theory. It is not especially useful in exploring a field, describing phenomena, and suggesting or generating hypotheses for testing.

Let us consider the requirements of a researcher undertaking an experiment. Such a researcher obviously needs a high level of literacy in order to establish whether his experiment is worth while. He will have undertaken some form of literature survey before he starts. In order to establish his validity he will have to have read and understood work done by his peers and will have to describe his work in terms that can be understood by his peers. If his experiment involves measurement he will also have to have sufficient numeracy to use statistical techniques to test his hypotheses. If his experiment involves more than a trivial amount of data or requires anything except trivial analysis he will require in addition at least sufficient computeracy to determine how to use a computer to achieve his objectives. In many cases this implies that he must have the ability to select the correct analytical package for his analysis of variance or analysis of co-variance or whatever. He will then require sufficient computeracy to capture the data accurately, to undertake his analysis and to present his findings in the most appropriate form For this some knowledge of the relevant input and output hardware would be desirable in addition to the software knowledge.

It may be argued that such a researcher does not need to be computerate as he can call in the advice of a computer "expert". I submit that the dangers of doing this are at least as great as the dangers of calling in an "expert" statistician to analyse his results without the researcher having a basic knowledge of statistics.

Generally the researcher studying the interaction of two or more variables by experimentation needs a more limited level of computeracy than the multivariate researcher.

6.2 Multivariate methods (Indirect control)

Here the researcher has far less control over the environment. He has to rely on other techniques to obtain his results. He may be working with data that have long been removed from the point where they were collected. The data may be stored in computer records or in some other format. In such a case the researcher's control is limited almost entirely to methods for selecting the variables and subsequent statistical data manipulation. The research worker will in all probability have:

1) Large volumes of data to be handled
2) Data which is classified at least at the nominal level
3) A number of calculations to be made on the data
4) A limited amount of time available for undertaking the calculations.

figure 3

Characteristics of Research with Indirect Control

Many statistical techniques allow one only to establish symmetrical relationships between variables and do not attempt to establish causality while other techniques do attempt to establish causality [3, 20]. The multidimensionality of computeracy is illustrated by the close correspondence between statistical expertise and computeracy at this higher level.

In order to understand what is involved in computeracy for the research worker applying multivariate methods we can again draw the analogies with literacy and numeracy. Just as in reading a book, we are not communicating with the book but with the author of a book, so in using computers we are not communicating with the computer but with the authors of the software on the computer. The researcher using multivariate analysis firstly may need sufficient computeracy to communicate with databases, both local such as CATS and the JSE, and international such as are available through ARPANET, in order to assemble his variables. He will then need sufficient computeracy to determine what system he is going to use to collect his data[10, 11]. Does his data require manipulation ? If so he may have to be sufficiently computerate to evaluate Databases or, at least to consider the merits of the more popular systems as follows :-

6.3 Database structures for research

6.3.1 Network Data Base Systems

This system follows the recommendation of the Data Base Task Group [13, 14]. Network systems available in South Africa include IDMS and DMS 1100. ADABAS provides an inverted network-orientated data base. The fundamental concept in these systems is the 'set' which is an association between two record types one of which is the owner and the other number.

6.3.2 Hierarchical Data Base Systems

This system is essentially a tree-like structure of relationships where a segment or record at one level has a parent-child relationship with segments at the immediate subordinate level. The most frequently used system of this type in South Africa is IBM's Information Management System.

The fundamental unit in the system is the 'physical data base record'. Flexibility is provided by the concept of a logical data base which is defined as a hierarchy of one or more existing physical data bases. A hierarchy does not exist in its own right, but only exists if the physical data base does not have its own pointers or segments, and pointers or segments are added to the physical data base to provide the required structure.

6.3.3. Relational Data Base Systems

The unique feature of relational data base systems is that all the data is regarded as residing in tables or relations. The Relational Task Group of the American National Standards Institute (ANSI) has given the following minimum criteria for a relational data base.

1) The data base is represented in the form of two dimensional tables.
2) The user has no navigational constraints.
3) Any number of tables may be joined or projected dynamically.

Three systems in use on mainframes in South Africa are Rapport from Logica, Oracle from Oracle and Ingres from Relational Technology. There are over 100 PC data base management software products on the market. DBASE III, PC/Focus and RBase are three of these which are relational.

A process of normalisation should be used to break down the overall body of data so that each table contains data for a single sub-area.

Normalisation can be regarded primarily as a discipline by which the data base designer can capture a part of the semantics of the real world enterprise that the data base represents ([17], p. 265).

E.F. Codd[15, 16] who in many respects may be regarded as the founder of relational databases, defines normalisation as "a step by step process of replacing a given collection of relations by successive collections in which the relations have a progressively simpler and more regular structure. The simplifying process is based on non-statistical criteria." (Statistical techniques such as cluster analysis can, however, assist.)

The phrase "non-statistical criteria" indicates that subjective judgement is still involved in the process. (For an overall management view see Martin [35, 30]).

6.4 Analysis

Having determined how to collect his data the computerate researcher must now concentrate on the analytical techniques to use. The decisions relating to the database and to the analytic technique are not necessarily independent. For example if the analytical techniques to be applied are only available in one of the statistical systems available to the researcher, e.g. SAS, then this may prescribe the data base structure. For example the following packages all have their own data base structures:-

S.P.S.S. - Statistical Package for the Social Sciences
S.A.S. - Statistical Analysis System
OSIRIS III - Organisation and analysis package.
BMDP - Biomedical data processing library.

See Pirow and Hnizdo[50] for a method of linking the databases.

7. COMMUNICATION

It should be noted that neither in accessing the database nor in using an analytic technique is the researcher communicating with the computer. Even in the early days of using computers [49] we were never communicating with the machine. When we punched binary cards, used adders and nand and nor gates, etc. we were really using the cards to communicate with the designer of the computer to achieve the joint objective of furthering our research. Today the communication problem is vastly compounded in that the computer user wishing, for example, to use a fourth generation language to access a database for his research is using the computer to communicate with:-

a) The authors of the language used to access the data base.
b) The authors of the data base system.
c) The data base administrator or systems analyst who constructed the data base.
d) The authors of the compiler used to compile any programs involved with *a, b & c*.
e) The data processing manager who designed the configuration of the hardware on which the application is to run.
f) The authors of any other systems software that may be involved.
g) The designers of the hardware used to run the application.

The extent to which any person is able to do this is a measure of his computeracy. Understanding of computers must therefore involve some understanding of the communication process between the user and all the above people. (Mason [37], Mowshowitz [38], Mumford [40-41], Murdick [42], Reisner [49], Shannon [54], & Siedel [56] all have interesting comments to make on the problem of communication which can occur at any of the above stages)

8. THE LEVEL REQUIRED BY RESEARCHERS

8.1 Data capture

The first problem that has to be faced by the researcher is how to "capture" the data for the computer. As mentioned above, until voice and touch become common input media for computers, the typewriter keyboard will remain the primary input for research data. If data capture can be automated, e.g. by attaching say pulse reading instruments to measure the pulse rate of stressed executives coupled to automatic recorders, then of course time, effort and probably costs will be reduced by doing this. Let us assume that this is not possible and that the typewriter keyboard has to be used.

The most frequently used form for data is based on the now antiquated punched card and is called "card image". Whereas there are some restrictions to card image data the benefits of using this form generally outweigh the penalties imposed by the restrictions.

Advantages:

- Data interchange is facilitated. Much of the data in the world is already in card image form.
- Physical punched cards can be used to transport the data from one geographical site to another.
- Practically all the packages that may be used will accept data in this form
- Many data checks have been developed and checking is easy (e.g. OSIRIS field checks).

Disadvantages:

- Data is limited to 80 columns.
- The full 2**8 = 256 "characters" are not available. Data is usually limited to numbers, capital letters and some punctuation.
- Full screen editing of Card image data requires the creation of a separate screen.

figure 4

Advantages and Disadvantages of Card Image Data.

Free card image format is the one most frequently used by our students and has the easiest conversion facilities. Many of the systems available to research workers have full screen editing facilities available to them and many students making use of these do not bother to relate the full screen to card image format. This does not matter provided the researcher is sure of the accuracy of his encoding and that he will not want card image format for other reasons. Some of the full screen editors have facilities for checking the field contents and these should be used in all but the simplest data collection exercises.

In the case where a full screen editor is not used one drawback to using 'free' format, i.e. designating the break between one variable and another by a space or a comma, is that it is difficult to check if the lengths of the input variables differ. Fixed format means that one variable always occurs in one column and can therefore be more easily checked. Free format also requires room for the delimiter so that fixed format enables more data to appear on each 'card'.

8.2 Data analysis

There are today many integrated systems of computer programmes suitable for the analysis of research problems. Examples of unified and comprehensive packages that are available on most of the large computers at universities and other research centres are:-

S.P.S.S.	- Statistical Package for the Social Sciences
S.A.S.	- Statistical Analysis System
OSIRIS III	- Organisation and analysis package.
IMSL	- International Mathematics & Statistics Library.
BMDP	- Biomedical data processing library.

figure 5

Some statistical packages for mainframes.

All of the above, and a system to link them [50] are available at the computer centre at the University of the Witwatersrand. All of the above packages can accept data in a great variety of forms, and if by any chance your data is not in a suitable form it is easy to reformat it using the above or many other systems.

The choice of which package to use will depend on the recourses available to the researcher and on the objectives of his research. Practically any statistical package today will provide simple descriptive statistics. If this is all that is required then the researcher should probably make his decision on the output he requires. For example does he want to present graphs in his report and , if so , what should they look like. Does he require the power of e.g. SASGRAPH or will the CHART procedure provide him with what he wants. In this day and age however it is unlikely, though not impossible, that simple descriptive statistics will provide the researcher with sufficient power to make a significant contribution to research. In this case the researcher must determine whether the package he wishes to use contains the statistics he requires. This is not always as straightforward as it may seem, as, even if the index to the package contains an entry for say 'cluster analysis' the researcher may find that this is limited to one dimensional analysis when he requires multidimensional analysis. A computerate researcher who has a mental picture of the way the package organises the data would make the correct decision whilst the non-computerate researcher might choose the wrong package.

9. THE LEVEL OF COMPUTERACY

As can be seen from the above, If the researcher can determine what he wants to do, he will also determine the level of computeracy he requires.

Any researcher whose field of investigation involves research which involves non-trivial data and is concerned with attempting to establish relationships between variables will require at least some computeracy. In order to establish 'how much' computeracy, ten levels are suggested. The lowest level of computeracy may be limited to keyboard dexterity and reaction time. These are, and will be until voice and touch become universal inputs, the fundamentals of computeracy just as reading and writing are the fundamentals of literacy and simple arithmetic is the fundamental requirement for numeracy. Developing reasonable response times and typing skills can be equated to the literary equivalent of learning simple words and joining them in very simple sentences or the numeric equivalent of adding two single digit numbers. An example of this is:-

"The cat sat on the mat"	— Elementary Literacy
" 2 + 3 = 5 "	— Elementary Numeracy
"Press the enter button when asked"	— Elementary Computeracy

figure 6

Equivalents of Elementary Computeracy

Elementary literacy is demonstrated if the student knows the meaning of cat, sat and mat. Elementary numeracy is demonstrated by checking "5". Elementary computeracy can be demonstrated by checking that the student knows which button to push.

As computers are steadily becoming easier to use [7], it would seem to me that in the future developing elementary computeracy will be as important for the research worker as developing literacy and numeracy. There are of course excellent research workers who are innumerate. (Consider an ethnomethodologist for example as described in Garfinkel [22]) Probably in the future there will be many excellent researchers who are non-computerate, or "computer dyslexic" to use a phrase coined by one of my colleagues. Many researchers will however require a higher level of computeracy and it is worth while trying to quantify a higher level.

As soon as we move above the lowest level we encounter definitional problems similar to the definitional problems in trying to determine higher levels of literacy and numeracy. One parameter of the level above that of elementary computeracy,(also called computer literacy), involves the ability to communicate with one other person through the computer. This could be regarded as the literary equivalent of being able to read a nursery school book or the numeric ability to do simple multiplication.

The researcher operating at this level could be communicating with say the author of a statistical package which the researcher is using to describe the results of his findings. Experience with researchers using both our PC and mainframe laboratories indicates a great deal of frustration while they remain at this level generally followed by a 'eurica' effect and a flurry of highly productive work as soon as the barrier is overcome and they move to the next stage of computeracy. What accounts for the frustration at the lower level ? Lack of 'user friendliness' of the computer system is frequently cited as the cause.

I really hate this damn machine
I wish that they would sell it
It never does quite what I want
But only what I tell it.

figure 7

Computer Frustration

The problem is that because of the newness of computers the authors of computer packages do not as yet know what is required from a system in terms of "user friendliness". In order to establish the requirements many more controlled experiments, such as those described in Pirow [45], and Rushinek, Rushinek and Stutz [52], involving actual use by representative end-users will be required. (For a treatise on end user involvement see Briefs et al. [8])

How do we find a theoretical framework on which to base such experiments? Is there such a framework? We could start with the most frequently cited framework of Shannon [54] and his mathematical theory of communication, but I have some difficulty in interpreting this in the man-machine interface environment. Some more recent work on the theoretical requirements of a friendly interface has been carried out by Halstead [24]. Halstead's unit of measurement is the ratio of the number of unique operators and operands to the total numbers of operators and operands. This is useful in studying the ability of the user to manage complexity but does not assist in the interface structure problem. Reisner [51] has defined an interface in terms of a Backus-Naur Form description of the grammar the user needs to know in order to use the interface. Some of the cognitive problems involved in learning to use any interface have been described by Mack et al. [34]. None of these really fits the problems.

The paucity of published work in this field indicates that we are in the very primitive stages of computeracy, probably equivalent to pre-hieroglyphics in terms of literacy or pre-arabic in terms of numeracy. (Imagine inverting a large matrix using Roman numerals without having a zero!) At this stage it is probably difficult to define the other dimensions of computeracy. The analogy with numeracy may assist.

10. NUMERACY

A great deal of work has been done over the ages in studying mathematical ability and the teaching of mathematics. As some of you may remember a vast jehad occurred during the 1960s and early 1970s when a large number of countries attempted to reform their school mathematics criteria. (Remember Tom Lehrer?) There have been a number of studies attempting to quantify the benefits that resulted from this change and some of these have shown many negative effects [28]. One positive effect that has been identified is not related to the new maths but to the fact that mathematics courses became far more practical. We must learn from this and not let our computer courses become impractical. (This is one reason why I have not used the the theoretical frameworks discussed above in my own research)

There are other areas in which the studies of mathematics may help us in studying research computeracy. Aiken [2] discusses the inherent ability and creativity in mathematics which could be analogous to inherent ability and creativity in computeracy. Dienes [19] identifies six stages in the learning of mathematics as follows-

1 Free play exploring the environment.
2 Finding the restrictions or rules relevant to the environment.
3 The establishment of isomorphism,i.e. separating out the common structure between environments together with the ability to discard non-relevant parts.
4 Acquisition of the ability to represent the isomorphism, for example, by means of Venn Diagrams, Graphs or Cartesian Systems.
5 Examining the representation and the use of a language to describe this representation.
6 The ability to enclose the multiple properties and dimensions of representations in a finite domain using a finite number of words.

figure 8

The Six LearningStages of Numeracy

The parallels between this and becoming computerate are striking:-

1 Exploring the computer
2 Finding the restrictions or what can't be done
3 The establishment of isomorphism,i.e. separating out the common structure between the computer and the real world with the ability to discard non-relevant parts.
4 Acquisition of the ability to represent the isomorphism by, for example, relevant data structures or data-base design.
5 Examining the representation and the use of a language(4GL) to manipulate this representation to further the objectives.
6 The ability to enclose the multiple properties and dimensions of representations in a finite domain using a finite computer program.

figure 9

Six Learning Stages of Computeracy

Computer literacy as commonly used is confined to the first stage, or at best to the first two stages.

An overall picture of developments in mathematical education which could parallel future developments in computer education is given in Howson [27] and the reader is referred to his excellent book should he wish to study this in greater depth. (See also Hofstetter [26]).

11. LITERACY

In order to study computeracy at a deeper level it may be useful to take the analogy between literacy and computeracy further. For many generations a minimal standard of literacy (the ability to read and write one's name) served a valuable purpose. With the increasing complexity of life however it became apparent that this limited ability did not equip adults to meet many of the requirements of daily life. To designate a higher level of competence the term "Functional Literacy" was coined. Functional literacy is now defined as being able to read and write as well as children who have five years of schooling. The 1984 Encyclopaedia Britannica Book of the Year claims that applying this standard, some 55% of the population of the world are now functionally illiterate as compared with 99.99% in the 12th Century.

The term functionally literate can be regarded as having sufficient literary ability to communicate ideas in writing to others. If we define the term functionally computerate as having sufficient computer ability to communicate with others using computer systems, then, at this stage probably 99.99% of the population of the world are not functionally computerate. Using this parameter functional computeracy is 800 years behind functional literacy. Becoming functionally computerate is therefore a target that any researcher should achieve in the interests of broadening his education.

The analogy is with the literate researcher who can now understand the body of knowledge associated with his research or the numerate researcher who is comfortable with a wide range of statistical techniques. At this level the computerate researcher is able to find his way round all the databases of whatever structure that may effect his research and extract and analyse data from these at will. A good example of this is the way computerate researchers at the business school extract and analyse data from the CATS and JSE databases available at the Wits Business School. As far as I am concerned these students are functionally computerate and have achieved level 2 computeracy.

12. HIGHER LEVELS

Because of the primitive stage of our 'Information Society' and the multidimensionality of computeracy it is very difficult to define the higher levels.

The analogies with literacy and numeracy may obviously be developed much further but this is probably not strictly relevant to the theme of this paper.

A one dimensional snapshot of the ten levels could be:-

Level	*Name or type of person at this level* Literate	Numerate	Computerate
1	Kindergarten	Standard 1	Arcade games player
2	Standard 2	Standard 4	Fully computer literate
3	Standard 5	Standard 7	Qualified programmer
4	Standard 7	Matric maths	Functionally computerate
5	Matric English	1st yr univ.	Computer science master
6	2nd yr univ.	Maths major	?
7	English major	Maths master	?? James Martin ?
8	English master	Maths Ph.D.	???
9	Trollope	Ramanujan	????
10	Shakespeare	Newton	?????

Note that the levels relate to current ability and not to any qualification. E.g., a maths master may currently be at numeracy level 4 or even 3 due to lack of practice. A person could be rated on all three, e.g., James Martin might score 7,5,7.

figure 10

Ten Levels for Literacy, Numeracy and Computeracy

13. CONCLUSION

I submit that the researcher using non-trivial data volumes to relate variables has to reach a minimum of level two. There are of course many other types of research for which computeracy is not essential. Interested readers may refer to Hodge [25], Jolson [29], Katler [30], Linstone [31], Lutekal [32] and Schiffman [53]) for further reading.

REFERENCES

1. Ackoff R.L., [1967], Management Misinformation Systems, *Management Science*, **14**, 4, pp B 147-156.
2. Aiken L.R., [1973], Ability and creativity in mathematics, *Rev. Educational Research*, **43**, pp 405-432.
3. Alwin D.F. & Hauser R.M., [1975], The decomposition of effects in path analysis, *American Sociology Rev*, **40**, pp 37-47.
4. Aspray W.F., [1985], The scientific conceptualization of information — A survey, *Annals of the History of*

Computing, **7**, 2, pp 100-116.
5. Bailey K.D., [1982], *Methods of Social Research*, MacMillan Publishing Co, New York.
6. Benet R., [1983], *Management Research, Guide for Institutions and Professionals*, Management Development Series No 20 I.L.O. 1983, Geneva.
7. Branscomb L.M. and Thomas J.C., [1983], Ease of use — A System Design Challenge, *Proc. 9th World Computer Congress, Information Processing '83*, Mason R.E.A. Ed. North-Holland, Elsevier Science Publishers, pp 431-438.
8. Briefs U.,Ciborra C. and Schneider L., [1983], Systems design for, with and by the users, *Proceedings of a W.G. 9.1, IFIP conference*, Riva del Sole, North Holland, Amsterdam.
9. Campbell D. &. Stanley J. [1966], *Experimental and Quasi Designs for Research Chicago*, Rand McNally, Illinois.
10. Canning R.G., [1976], Toward the Better Management of Data, *E.D.P. Analyser*, **14**, 12, pp. 13-26.
11. Canning R.G., [1978], Installing a Data Dictionary, *E.D.P. Analyser*, **16**, 1. pp. 1-13.
12. Carlile K., Dent N., Morais M., Rodriques J., Van der Westhuizen, B. van Wyk D, and Warden A, [1985], *The experimental Method*, Project for a course in research methodology at the Graduate school of Business, University of the Witwatersrand.
13. Codasyl [1971], *Data base Task Group Report*, Association for Computing Machinery, New York.
14. Codasyl [1971], *Data base Task Group Report*, British Computer Society, London.
15. Codd E.F., [1970], A Relational Model for Large Shared Data Banks, *Communications of the Association for Computing Machinery*, **13**, 6, pp 377-387.
16. Codd E.F., [1972], Further normalisation of the Data Base Relational Model, *Data Base Systems*, Courant Computer Science Symposia Series, **6**, Prentice Hall, Englewood Cliffs.
17. Date C.J., [1983], *An Introduction to Database Systems*, Addison-Wesley, Systems Programming Series, New York.
18. Delbecq A.L., Van de Ven A.H. and Gustavson D.H., [1975], *Group techniques for program planning*, Scott Foreman, Glenville Ill..
19. Dienes Z.P., [1973], *The six stages in the process of learning mathematics*, N.F.E.R, Slough:.
20. Duncan O.D., [1966], Path Analysis: Sociological examples, *Amer. Jnl. Sociology*, **72**, 1 pp. 1-16.
21. Fusfeld A.R. and Foster R.N. [1971], The Delphi Technique: Survey and comment: Essentials for corporate use, *Business Horizons*, Time Inc, New York.
22. Garfinkel H. [1967], *Studies in Ethnomethodology*, Prentice Hall, Engelwood Cliffs N.J..
23. Gotlieb C.C., [1985], *Economics of Computers*, Prentice Hall, Englewood Cliffs,N.J..
24. Halstead J.M., [1977], *Elements of Software Science*. Elsevier, New York.
25. Harrigan K., [1983], Research methodologies for contingency approaches to Business strategy, *Academy of Management Review*, **8**, 3, pp. 398-405.
26. Hodge B.J., [1970], *Management and Organisational Behaviour:a multidimensional approach*, Wiley, New York.
27. Hofstetter F., [1982], *Seventh summative report on computer based education*, University of Delaware, Delaware, Virg..
28. Howson G., [1983], *Mathematics at work*, Heinemann, New York.
29. Howson G, Keitel C. and Kilpatrick J., [1981], *Curriculum Developments in Mathematics*, Cambridge University Press, Cambridge.
30. Jolson M.A. and Rossow G.R., [1971], The Delphi process in marketing decision making, *The journal of market research*, **8**, 3, pp. 443-448.
31. Katler P., [1980], *Principles of Marketing*, Prentice Hall International Edition, New York.
32. Linstone H.A. and Turoff M. [1975], *The Delphi Method: Techniques and applications*, Addison Wesley, New York.
33. Lutekal D.J., [1982], *Marketing Research*, Prentice Hall.
34. Mack R.L., Lewis C.H. and Carroll J.M. [1984], Learning to use Word Processors: Problems and Prospects. *ACM Transactions on Office Information Systems*.
35. Martin J., [1982], *Application development without programmers*, Prentice Hall, Englewood Cliffs, N.J.
36. Martin J., [1983], *Managing the Data Base environment*, Prentice Hall, Englewood Cliffs, N.J.
37. Mason R.O. and Mitroff I.I. [1973], A programme for research on management information systems, *Management Science*, **19**, 3, pp 475-487.
38. Mowshowitz A. (ed.), [1980], *Human Choice and Computers 2*, North Holland Press, Amsterdam.
39. Mumford E. and Sackman H., (eds.), [1975], *Human Choice and Computers*, North Holland Press, Amsterdam.
40. Mumford E., Land F. and Hawgood I., [1978], A Participative Approach to the Design of Computer Systems, *Impact of Science on Society*, 3, 2, pp 235-253.
41. Mumford E., [1979], Consensus Systems Design — An Evaluation of this Approach, in *The Design and Implementation of Computer Based Information Systems*, Edited by Szyperski and Grochia., Sijthoss and

Noordhof.
42. Murdick R.G., [1971], *Information Systems for Modern Management*, Prentice Hall, New York.
43. Naisbitt J., [1982], *Megatrends: Ten New Directions Transforming our Lives*, Warner Books Incorporated, New York.
44. O'Brien J.A., [1985], *Computers in Business Management*, 4th. edn Homewood, Richard D. Irwin, Ill..
45. Pirow P.C., [1966], Using Computers, *Business Efficiency*, Oct. 1966, pp. 12-15.
44. Pirow P.C., [1984], An Adaptive Response Algorithm, *Quaestiones Informaticae*, **3**, 2, p.21.
46. Pirow P.C., [1984], Examining Computeracy, *Proceedings of the 14th Annual Computer Sciences Lecturers' Conference*, 27th-29th June 1984, Sartori-Angus, A. ed., pp. 63 - 80.
48. Pirow P.C., [1986], *Effective Computer Applications,* Woodacres Publishers, Walkerville, South Africa.
49. Pirow P.C., [1986], Social aspects of computers, *Comparative Worldwide National Computer Policies*, Sackman, H. ed., North Holland, Elsevier Science Publications B.V, pp 363-394.
50. Pirow P.C. and Hnizdo, E., [1980], Note on the use of Statistical Packages for Processing Research Material, *Proceedings of the 10th Annual Computer Sciences Lecturers' Conference*, 25-27 June 1980, Riordan, D. ed., Grahamstown:Rhodes University, pp. 77 - 86.
51. Reisner P., [1981], Human factor studies of database query languages: a survey and assessment, *Computing Surveys*, **13**, 1, pp. 13-31.
52. Rushinek A., Rushinek S.F. and Stutz J.,[1984], A methodology for interactive evaluation of user reactions to software packages: an empirical analysis of system performance, interaction and run time, *Int. Jnl. of Man Machine Studies*, **20**, 2 pp. 169-188.
53. Sarton G., [1952], A history of science. Ancient science through the golden age of Greece, Harvard University Press, Cambridge,Mass.
54. Shannon C.E., [1948], A Mathematical Theory of Communication, *Bell Systems Technical Journal*, **27**, 4, pp 379-423.
55. Schiffman L.G. Schiffmann and L.L. Kanuk, [1983], *Consumer Behaviour,* Prentice Hall.
56. Siedel R.J., Anderson, R.E. and Hunter, B. (Eds.), [1982], *Computer Literacy*, Academic Press, New York.
57. Toffler A., [1980], *The third wave*, Morrow, New York.
58. WBS, [1985], *Research Methodology*, WITS BUSINESS SCHOOL, Student Course Pack MBA Programme 1985.
59. Yeomans K, Human L., Human P. and Pirow, P.C., [1986], *Research Methodology*, Juta(being published), Johannesburg.

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