A Knowledge Base for Internet as a tool in Statistical Education

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Introduction

Teaching statistics to undergraduate and graduate students in the empirical sciences from the point of view of research methodology would greatly enhance its impact.

The approach to applied statistics through realistic research problems is much more relevant to students, who did not choose to become statisticians, but who endeavour to be professional problem-solvers in biology, psychology or whatever discipline they chose. This approach would provide them the anchor-points they need to link statistical and methodological theory to reality.

Statistical consultants know how frustrating it is to communicate with scientists who are illiterate in experimental design, sources of variation or statistical modelling; and how fruitful and agreeable the conversation was with the 'rara avis' who had this basic understanding. Educating our students to be well informed discussion partners of the statistical consultant prepares them more adequately to tasks in their later professional life, than teaching them a thorough and systematic course in statistics, or training them to be do-it-themselvers-with-SPPS without much understanding of the consequences and significance of the resulting computations. And they will be grateful for it.

In many educational settings a problem-oriented approach is now favoured at the expense of a comprehensive and systematic teaching of statistics. And not only statistics: the same situation applies to comparable 'basic', often mathematically oriented disciplines. Statistics is seen as a skill, supposedly acquired by self-instruction and by exercising in a professional, although controlled situation.

At the same time our attitude towards information retrieval and processing has been changed fundamentally in the last decade through world wide web and by general acceptance of the digitalisation of everyday life. A 7 years old measurement of the attitude towards computers of 16-19 year old students, see e.g. Selwyn (1997), will surely be outdated by now. Media behaviour of young people influences school culture. Students of the present generation, when confronted with a problem they can't solve immediately, first ask a colleague by mobile, then consult Google and, only when no other option remains, are willing to open a book.

These young people have become used to collect their information on demand by zapping and searching a large number of different sources, i.e. in an associative way and by trial-and error. Their knowledge and skills are therefore constructed by associating them to practical problems and not so much by deriving them from a consistent system of reasoning. However, statistics *is* a coherent and deductive piece of knowledge. Exploiting statistics as a mere toolbox from which tools can be chosen as experience suggests often leads to serious errors and even misuse. Statistical knowledge and skills should be linked, not just to practical problems, but also to the principles of research methodology and to the essentials of statistical and probabilistic reasoning. Far better would be a situation where the student is confronted with real research problems, but where simultaneously the theoretical background is presented in a consistent and pleasant way.

Statistical knowledge base

In this type of teaching environment a *statistical knowledge base* for the internet could be an invaluable companion if it comprised an ordered overview of basic statistics and research

methodology, but at the same time competed with standard books by its easy handling, its interactivity, its compactness and good search properties, and its attractiveness to the internet-generation through the extensive use of hyperlinks, quizzes, simulations and animations.

The beta-version (in Dutch) of a statistical knowledge base with these properties can now be visited on http://www.wynneconsult.com. A translation to other languages would be welcomed.

The knowledge base contains 300 main windows, a glossary plus alphabetical index with 500 entries, a hierarchically ordered site map, the common statistical distributions in the form of simulated densities to replace statistical tables, and numerous figures, tables, passive and active animations and quizzes with feed-back to true and false responses. It contains the topics common in an introductory course in statistics at higher education level: *research methodology*, *descriptive statistics*, *probability and probability distributions*, *sampling*, *estimation*, *hypothesis testing*, *association*, *correlation* and *regression*.

A number of sites are available on the internet presenting statistical teaching materials of various kinds. Many of them are fragmentary offering e.g. animations of key concepts of statistics, or texts on some special topics. Some present complete statistical textbooks and are therfore more or less comparable to the statistical knowledge base discussed in this paper. These sites differ from each other as expected in numerous ways: in mathematical level of treating statistics, in sophistication of the use of multimedia, in programming efforts spent to styling of text, figures and formulas, and in style of presentation. This last most interesting aspect of the writing concept and the way hypertext is exploited to attain certain educational goals will be treated in more detail in the next two sections.

A survey of existing sites can be found on David Lanes' (Rice University) HyperStat Online Textbook (http://davidmlane.com/hyperstat/index.html).

Hypertext

A digital knowledge base is not a book. It is not sufficient to digitalize the contents of a book, because lengthy texts on the screen are difficult to read and will be printed out to read them on paper. However this is precisely what happens in many cases, where a school or department decides to put its course content 'on the internet', probably under the umbrella of some integrated e-learning system like WebCT or Blackboard.

To exploit the advantages of electronic content it should be developed as such from scratch. Well-written electronic content is presented as *hypertext*, i.e.:

- the style of presentation is *nonlinear* and *multidimensional*. Various short texts are presented at the same time supporting each other. Extensive use is made of *hyperlinks* to create a web of coherent interconnections;
- *multimedial:* information and explanation is offered not only as text and frozen figures, but also as passive (user cannot interfere, like in a movie) and active (user interruption and manipulation is possible) animations, simulations and if budget permits even as videos and spoken word;
- *interactive:* exercises and quizzes are provided with immediate support and feedback.

Hypertext as a way of communicating information through the computer screen is a much debated issue. The main characteristic of hypertext is, that through appropriate hyperlinking a web-like information-structure is created. The user can utilize this system by associating and zapping, skipping what he already knows or doesn't want to know, and clicking to what he does not yet know and wants to know. However, this overwhelming supply of choices and information may easily cause what is called *cognitive overload* en *disorientation*.

Particularly for novice students orientation is crucial and confusion about the structure of the learning material may seriously hamper the process of constructing knowledge. From the point of

view of constructivism, learning to handle a new technique or aquiring new knowledge is a process of encapsulation: integrating new phenomena into existing mental structures and adjusting these structures to fit the observed environment.(Crowe and Zand, 2000a) This doesn't proceed by transferring pieces of knowledge from a source (the teacher) into a container (the student), but by an active process of mental self-organization of the student, stimulated bij well chosen learning tasks and a carefully structured presentation of the subject matter. Hypertext may support this process by permitting and at the same time stimulating the student to choose freely the blocks he thinks useful to construct his own building.

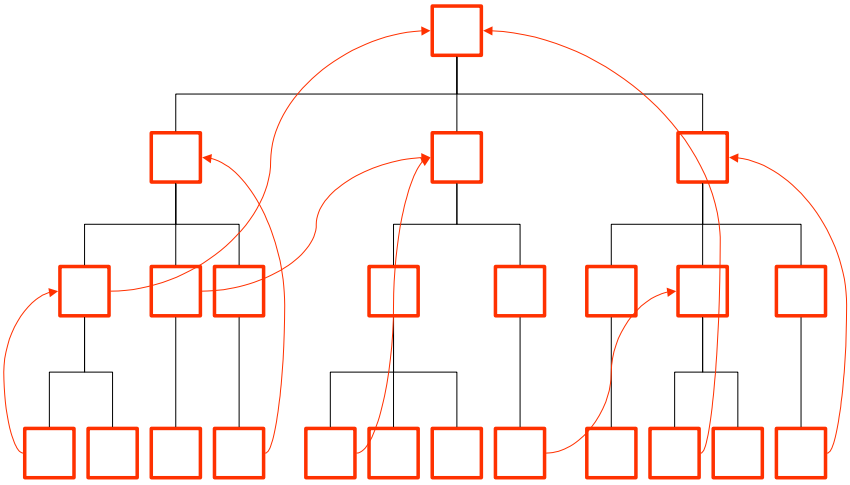

Figure 1. Hypertext structure of the knowledge base: basically hierarchical, enriched with a secondary referencing network.

The merits and risks of hypertext have been evaluated in a number of published investigations. (Calvi and De Bra, 1998; Nimwegen et al., 1999; Mohageg, 1992; Verheij et al., 1996; and many others). The effects on learning of hierarchical, traditional linear or network structures depend strongly on the type of learning task (e.g. factual recall, problem solving, information retrieval), the learning style of the student, working memory of the participating student or reading time. Hierarchically structured hypertext seems advisable for complicated learning tasks, while pure network structures as expected have inferior orientation properties. On the other hand, a traditional linear (book-like) structure seemed to favour factual recall of pure texts, although this effect disappeared partly when reading time was controlled for. (Lee and Tedder, 2003)

Writing concept

In designing the statistical knowledge base we have adopted a number of definite starting points. These are partly of a hypothetical nature and will have to be examined in subsequent evaluations or comparative studies.

The hypertextual structure is defined by the unity of the screen as a monograph, the primary hierarchical and secondary networked hyperlink-structures. See also figures 1 and 2.

- A screen with its supporting elements (glossary, figures, animation, quizz) is a small monograph, which should be readable and comprehensible as such.

  This is achieved by a careful design of the contents of the window: the texts in connection with graphical and other elements. To avoid browsing, which hinders the user to have an immediate insight into the way a window is organised, contents of the windows were kept compact in order to fit them to a screen of 768 by 1024 pixels, which was successfully accomplished in the majority of cases.

- Orientation is best warranted by a consistently hierarchical design. Grasping the intrinsic and logical structure of the subject matter is an essential objective of learning and is strongly promoted by a hierarchical presentation.

  In the knowledge base the hierarchy is provided by hyperlinks permitting the user to go up and down in the tree of windows, supported by an ordered site-map, which gives an overview and from which also new windows can be called (see figure 2). This should not be seen as a mere facility: it also forces the user to make a deliberate and well-considered choice how to continue after having read the content of a window.

- In addition to the primary, hierarchical hypertext structure a network structure should link keywords in the text to a short explanation in a glossary and to an exposition in full detail elsewhere in the knowledge base. This secondary network structure is introduced for two reasons. First it is an invaluable aid in rehearsing and comprehending the material. Second, a knowledge base of this type is meant to be used not as a stand alone introduction to statistics, but as a reference source to be used in various teaching environments.

  Using the secondary network structure ensues possible disorientation because the user leaves his intended study-path for a temporary excursion following a different path. Therefore, when the cursor goes over a hyperlinked keyword, the glossary, which is always visible on the screen, gives a short explanation. The user then has the opportunity to decide whether this explanation is sufficient for the present moment, and to continue regularly, or not sufficient, and to decide to pursue more detailed information by mouse clicking (see figure 2).

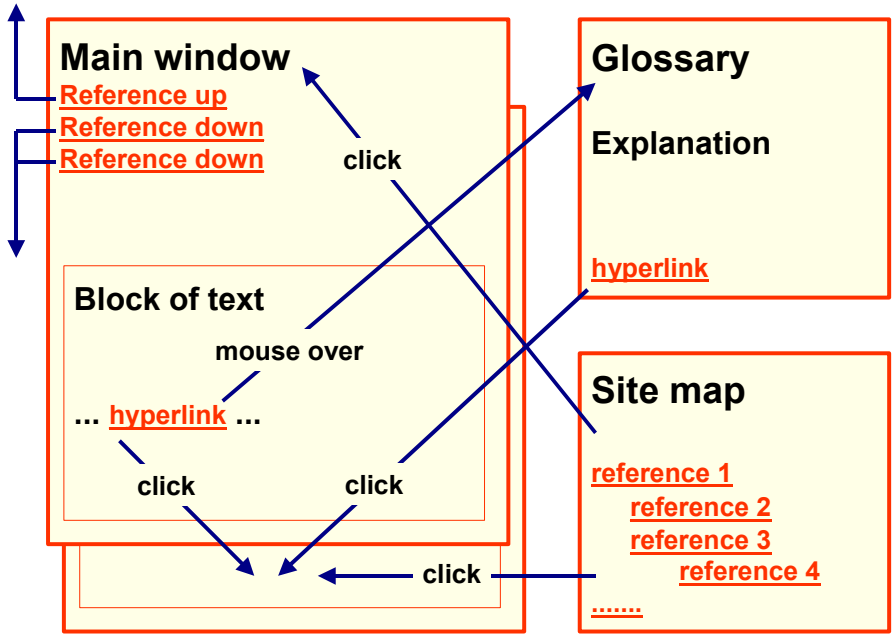

Figure 2. Hypertext structure of the knowledge base: hierarchical references under the header in de main window and network references through hyperlinks in the text. Mouse overs give short explanations of terms in the glossary, and mouse clicks give complete explanations in a new window.

The statistical knowledge base is supposed to be used 'embedded' in a problem oriented course in applied statistics, epidemiology, or research methodology. Didactic presentation is adjusted to this goal, seeking to find a good compromise between a well-organized and insightful exposition and the conciseness of an encyclopedic source of reference. The knowlege base has been designed to find quick solutions for actual problems *and* to provide insight in a specific situation, that is of interest to the user.

- Within each window treatment is from the exemplary to the general, starting wherever meaningful with an example, rather than by formal deduction with an example to finish. This again aids the student to identify the statistical or methodological concept as a model for the solution of common research problems and enables him to compare the structure of his own problem with the example given.
- Mathematical notation has been used to keep texts short and correct at the same time, not to derive or proof the results of mathematical probability and statistics.

  Statistics (and more generally research methodology) is seen by many as of superior abstraction. To some extent this may be true, but the common believe (by non-statisticians) that this is a consequence of the mathematics involved is certainly not true. Abstract thinking is a characteristic of science in general. Statistics (and research methodology) is needed as a language to enable people to discuss scientific problems. To make progress every scientific discipline has to adopt or even to construct his own language, which to the outsider may have an abstract or even occult appearance. In teaching statistics to future scientists we initiate them into this language. Mathematical notation is part of this language and its use is mandatory to explain complicated statistical concepts in a clear and unambiguous way. However, this is not equivalent to presenting mathematically rigorius derivations or proofs. A good teacher knows how to simplify without becoming incoherent.

Technology

The development of computer courseware is expensive and economically feasible only when a sizeable number of potential users is available. This requirement is satisfied in the case of statistics, which forms part of the curriculum of all empirical sciences.

Moreover the technology used for this internet production provides a relatively inexpensive method to produce book-competing knowledge bases and is usable for most types of content. Batchwise production of the website is accomplished by a compiler program, that transforms the authors' MS Word texts directly to the correct code and constructs all hyperlinks using a database. Using standard web-technology proper styling can be achieved even for the mathematical formulas. Flash and gif-animations, and Java-applets can be easily included. The author can concentrate on creating texts and additional material, receiving instant feedback to show him the resulting structure and consistency of the hypertextual presentation he has created.

Evaluation

In many instances proper evaluation of novel initiatives is lacking. This is a real problem, for their is often a serious mismatch between what the teacher intends, and what the student actually does. (Crowe and Zand, 2000b). Evaluation is also important to persuade teachers of the value of the new application. Teachers' (and students') mindsets are of prime importance in order for on-line course resources to be used (as compared to be implemented) successfully, as are their technical competency and the level of perceived IT infrastructure and technical support. (Benson et al, 2001)

The statistical knowledge base has been set up as a website. Students and teachers are accustomed to the common web-browsers and feel at home with their 'look-and-feel'.

After a review of the knowledge base for obvious errors with respect to content, and after a simple study to assess how the knowledge base is used and appreciated by students we are planning to embark on a series of studies to evaluate this knowledge base with respect to its learning effects in various 'real life' course types. Also, the way the knowledge base is produced makes it easy to construct various copies with different types of hypertext structure in order to compare their learning properties in appropriate study-designs.

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