THE FUTURE OF INTERACTIVE, ELECTRONIC RESEARCH: AN EXEMPLAR FROM PROBABILITY EDUCATION

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In the topic study group on probability at ICME 11 a variety of ideas on probability education were presented. In an international, collaborative, electronically supported project after the conference, many of these papers have been developed much further, incorporating electronic techniques. Following McLuhan, the medium of research has influenced the message (massage) of the results and–not surprisingly–the research has changed its character during this process. This presentation comments on future possibilities of electronic communication. This will enable developments relevant for other areas of research too. Hyperlinks are included.

INTRODUCTION

This paper is intimately related to another one (REVIEWING AND PROMOTING RESEARCH IN PROBABILITY EDUCATION ELECTRONICALLY) but the two papers serve rather distinct purposes. The other one presented current research efforts in the teaching of probability across the world, linked to ICME. This one goes on to discuss the influence of new technology in how research is presented and how this may change even the nature of research. The results of this project by Borovcnik & Kapadia (2009) in IEJME may encourage more collaborative and interactive approaches across countries, languages, and cultures. This paper presents some of the novel and interesting aspects which arose. Links within the text are to the full papers including their annexes, which have emerged from this electronic project. Hence this paper exemplifies some of the ideas it is promoting. Readers may wish to read the other paper first, where the main ideas of current research in probability education are summarised. This paper shows how features of electronic publication have been used to enhance all the published papers in IEJME: it is of note that all the papers contain some use of electronic media, be it a link to an interview, a reference or the inclusion of abstracts in several languages. Reference will be made to specific papers where a particular idea features, but the same ideas are also used in other papers. The key elements presented are on how to present pertinent information, enhancing investigations, providing more details, and solutions to technical problems, building on the ideas of Borovcnik (2007). The paper ends with some perspectives for the future.

New tools have always changed concepts. Mathematics has been changed by the advent of numerical methods, facilitated by the increasing capacity of computers. In probability, the possibility of simulating complex models to replace almost impossible analytic derivations has revolutionized the methods. It has led to new branches of the discipline like resampling methods, or bootstrap. To design a resampling study in order to give a valid "proof" of properties is no longer dismissed as a non-mathematical or non-scientific approach. The new tools have also–less rapidly–changed the teaching of mathematics including probability.

Multi-media teaching is now enriched by various forms of visualisation, e. g., animations, which show sequences of relations and enhance the underlying concepts. The internet provides more diverse information than any conventional book. Graphs, animated teaching sequences, and authentic videos are motivating and enhance understanding of concepts. The mass of information possible requires new methods of learning or working with it. The internet also provides more possibilities for collaborative work.

Interestingly, the style of communication in research has not yet been much affected by these developments. Scientific journals still focus on presentation of results via language, scarcely enriched by graphs. Original data, on which conclusions are based, is rarely available; the reader is left over to believe the conclusions of the authors. There are some ideas, which the scientific community could copy from existing examples of good hypertext textbooks, or from the better e-learning projects. The scientific community is in a pilot phase of electronic communication. Few researchers are aware of the categories of problems of electronic publishing, and some lack the

imagination to utilise such a medium. One perspective is to make the communication of research results more authentic. One can supplement the presentation of ready-made final results with the process of emergence, to a status nascendi from where the results came from. This would allow the recipients to re-analyse the issues, to draw their own conclusions, to evaluate and appreciate the author's way to model the problem.

Extensive projects on electronic communication would show the potential and thereby develop categories to reflect the ways in which research communication could be improved by the new tools. The present project presents substantial material and initiates a discussion of relative advantages of the approach. As it is often the case, the tools themselves do not reveal their potential; they are bound to a context. We present the new tools in the context of research on probability education as it was developed after ICME 11. The actual content and development of ideas is dealt with elsewhere; here we focus on the potential of electronic publishing.

COLLATING PERTINENT INFORMATION

A research paper has to make choices on how information is presented, particularly relating to experiments performed or tests administered. For example, in studying the difference in the solution behaviour between two groups of people, items may be ordered by the concepts involved, or by relevance in the factor analysis (by explained variance) used, or by difference in success. Electronic presentation allows for each of these ways to be available via hyperlinks which can give the same information in a table in various ways. One can focus on different aspects of a test, such as typical wrong answers and then on typical correct answers. But then one can also switch easily to the other type of solution, or to a general analysis of the complexity of the item. This is facilitated by pop-ups with the required information (Diaz & Batanero). This approach helps in understanding the authors' conclusions, the difficulty of the item, or the difficulty of the students to work on the item. Grouping items by different categories (items, for which instruction helps easily, or for which instruction does not help and why this is so) may help to find a contextual structure in the empirical findings. One can also refine batteries of items, as one may see "unexpected" difficulties to use the results of one item for the research question. Such regrouping and re-analysis from the context of the items and the other items corroborate the findings about the research questions. Moreover, it allows the reader to do his/ her own analysis of the items as convenient.

Wherever possible (as with this paper), references used in each paper are included as hyperlinks to the full papers, which can be immediately accessed. This allows an easy access to background and more in-depth analysis of the authors. This is major advantage from a time when a few weeks may pass before a reference became available via an inter-library loan.

ENHANCING INDIVIDUAL INVESTIGATIONS

Much is gained from authentic material to illustrate how research is done, not least to enhance one's own research. Such material is available in many of the papers in the IEJME project: complete test items in Huerta, or Diaz & Batanero, or Kapadia; complete interview protocols and screen videos in Ireland & Watson; a video of an in-depth interview in Abrahamson; PowerPoint animations of the experimental setting in Chiesi & Primi; authentic material used in the project work in Vancsó or Trevethan et al.

Thus, the research situation is "visualized and enriched" for the reader; the available material can serve for a re-analysis, or in probing the authors' conclusions; or, understanding the point of problems encountered in empirical research. Younger and even experienced researchers may well welcome access to the detailed material such as a questionnaire or a collection of items, or with respect to the potential methods, and a specimen interview (by a video) and thereby support their own work. Such material is offered electronically; in conventional publications, there would be no space for such details. It is daunting to start research where long-term projects have been done; access to the detailed material can prove to be vital for those with less experience in the field.

Authors are not always able to give a full account of their research and may have to omit specific results. However, they might have ideas on relevant ways to proceed and how the community could make progress. To give a plan of how to shape the intuitions of naïve probabilists (as Pratt & Kapadia do), and to offer specially designed Software (ChanceMaker, which is freely accessible via a link) might encourage researchers to become engaged.

PRESENTING MAIN IDEAS WITH SEPARATE LINKS AND SUPPORTING DETAILS

To offer more detailed analysis, e.g., in categorizing items, links to full tables are inserted. This allows more discussion of features from various viewpoints (contextual analysis, concepts involved, type of problem) (Huerta). Moreover, frequently used, and less well known concepts are explained in a glossary, which is linked to the text (Huerta, Vancsó, Martignon & Krauss).

One wants to separate technicalities from the flow of reading to get an overview and yet offer the interested reader the possibility of extra details. For this purpose, links to informative tables of all involved concepts, or from static graphs to dynamic animations are built in (Martignon & Krauss). Thus trinomial graphs as a means to describe types of problems and methods of solutions, and complexity of problems is shown by graphical animations of the growing solutions graph. The complexity of the solution graph illustrates the complexity of the item used (Huerta).

EXCEL sheets show the results of the methods used and graphs can illustrate the results. The representation in a spreadsheet allows readers to explore the ideas (Vancsó).

Research papers may not show how the authors refer to related publications. How are the ideas embedded in the existing research? Some authors give (too) many references. The text may then become cluttered and difficult to follow for the reader. To cut references, on the other hand, might leave the text anecdotal. Often references are of the type that, e.g., Borovcnik (2007) has done some research on the same topic, without revealing why this and not another author is selected. The reference does not reveal the tradition or school in which the referenced author works and how this may differ from the background of the current author. With one of the papers, the editors performed an "experiment" in scientific communication and referencing. We developed with the author (Abrahamson) a companion paper, which extracted the intellectual background from the main text and consolidated and expanded it in notes that could prove useful for readers who wish to delve deeper into the underlying issues. These companion research notes are accessed by links at the position of referencing. It is like footnotes, yet much more flexible and powerful. The notes *justify* the research methods used and *connect* the ideas and results to the broader scientific debate. They also serve as an *introduction* to research literature on the specified topic. This experimental article format could therefore be viewed as an attempt to broaden the report on the comprehensive results of conducting research.

TECHNICAL PROBLEMS AND SOLUTIONS

There is much to say in favour of both of the choices of *pdf* and *html*. IEJME has chosen the option of *pdf* format for the obvious reasons that it is more secure and easier to implement for authors. The journal collects the authors' results and checks whether the formatting conditions are fulfilled and builds it into its website. The work required to use html format is more intensive, and may even necessitate a different way of finance. Nevertheless, in *html* format it is easier to build links and to follow the links, or to integrate animations directly. But *html* appears in each of the browsers differently and there is hardly a control over the visual representation on the screen by different browsers. Since authors establish the prime part of the publication, they use slightly different formats, which are never accurately reproduced later. The navigation between the linked documents is unfamiliar and may also cause some (solvable) problems to Mac users, as Mac's philosophy on pdf documents is different. We have offered some links for help in such a case.

ELECTRONIC PUBLISHING: PERSPECTIVES FOR THE FUTURE

Finally, we discuss how electronic publishing affects the research and paves the way for future research, especially for younger researchers. According to McLuhan (1964), the medium of research influences the message (massage) of the results and–not surprisingly–we can report from our venture, it has changed completely the nature of the research in this process of electronic publishing. This project may show a way that ideas can be developed in the future.

One key element is the availability of abstracts in three languages to help readers across the world. It is hoped that those for whom English is a second or even third language can be engaged by this approach. It can be off-putting to begin to read a research paper (in English) when one is unsure of the thrust of the paper; here the abstract is accurately presented in Spanish or German, using the skills of a native speaker who is also familiar with the research ideas. This combination will, we believe, encourage much more international readership for these papers in IEJME.

Another possibility which has been exploited is to offer background material to the underlying research. For readers who are especially interested, they can analyze such material themselves. This gives a deeper insight into the research approach taken in the paper. Even the availability of direct links to a reference in the paper enables immediate access to ideas which are quoted. Sometimes this can be a book, sometimes it will be a paper in another journal, sometimes it is material on the internet. Occasionally there is a link to related software, or even to games, as referred to in some papers. The point is to separate the justification and referencing of ideas, as well as referring to literature beyond the normal citations. A reader may also explore why an author cites a particular source. One might also wonder how a source is embedded in a wider spectrum of research, as well as alternative approaches. This enables a balanced evaluation of how and why to cite, which is valuable for researchers.

There is also extra-material such as video-recordings or taped interviews; this is a much richer source than simple transcripts which cannot convey tone or visual expressions and interactions. These form the basis of some of the research and enables a reader to draw his/her own conclusions, as well as understand the author's conclusions more fully. Interactive ideas are no longer only formulated but are explained by visualizing, as well as by graphs and animation. Communication in research comes hereby closer to "communication" and not delivering results by only text. Like a good hyper-textbook for students, this is a hyper-textbook for researchers.

These aspects will be particularly valuable to new researchers who could also see the material in the background as specimen for their own future work. One cautionary remark is also in order: electronic publishing in this way takes much more time and effort, both for the author and also for the editor. We are pleased to confirm that every paper includes some minimum aspects of electronic publication: abstracts in three languages; some references which can be accessed directly; hyperlinks between different parts of the paper. Finally, the articles in this special issue speak for themselves about probability education.

A traditional paper journal could not cope with all that. However, it is only a first step, hopefully, into a new era of disseminating ideas and results in research, which exploits the full potential of an electronic publication medium. The possibilities referred to here are only an exemplary summary of those used in the electronic project; they may be regarded as some of the emerging potential of Web 2.0 publication, which may well be the future of academic output.

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McLuhan, M. (1964). *Understanding Media: The Extensions of Man*. New York: Mentor. (Reissued 1994, Cambridge, MA: MIT Press). Table of contents, retrieved October 31, 2009.

LINKS
International Electronic Journal of Mathematics Education (IEJME): www.iejme.com/
11th International Congress on Mathematical Education (ICME 11): Topic Study Group 13 on "Probability": tsg.icme11.org/tsg/show/14; Topic Study Group 14 on "Statistics": tsg.icme11.org/tsg/show/15; see also: www.stat.auckland.ac.nz/~iase/publications.php
Joint ICME/IASE study "Statistics Education in School Mathematics: Challenges for Teaching and Teacher Education": www.ugr.es/~icmi/iase_study/

SOFTWARE
ChanceMaker (n. d.) people.ioe.ac.uk/dave_pratt/Dave_Pratt/Software.html
Fathom (n. d.) www.fathom.com
Tinkerplots (n. d.) www.keypress.com/x5715.xml