Background

Three fundamental problems encountered by statisticians in the training of undergraduate medical (MBChB) students and at a personal level, by qualified doctors are:

- poor retention of key statistical concepts such as confidence interval, absolute risk, relative risk, odds ratio, p-value, statistical power and significance level;
- a lack of efficacy in communicating notions such as relative and absolute risk and more generally, the findings of systematic reviews to patients;
- and
- a lack of professional training in the use the statistical findings presented in medical journals to make informed decisions on the optimal choice for the patient.

Aims and objectives of the project

With a view to confronting the above problems, the Maths, Stats & OR (MSOR) Network-funded project 'Statistics in medicine: a risky business?' was set up with the aim of addressing the following questions:

- how can we effectively steer undergraduate medical students through the conceptual maize of statistical concepts on the road to evaluating risk?
- how can we convince undergraduate medical students that the use and application of statistics is an integral part of good medical practice?
- and
- can we empower tomorrow’s doctors to identify and implement the correct statistical tools for evaluating patient risk so as to make the best choices for their patients?

With respect to the second of these questions in particular, it can be argued that the rationale for this project shares some common ground with the STEPS (Statistical Education through Problem Solving) project in that the philosophy behind the latter project was to ensure that students recognize “that statistical issues” arising from problems within other disciplines, including biology, business, geography and psychology, are “important natural parts of the process of reaching conclusions.” [1] However, it was also recognized that there was a dearth of available online resources to facilitate effective engagement with statistical notions of risk, and that within the context of clinical practice in particular, this had clear ramifications for patient safety in terms of communicating risk to patients and in ensuring informed decision
making based on statistically valid interpretations of research findings.

There is in turn an associated need for statistical teaching to emulate teaching in other areas of the undergraduate curriculum through ensuring that students are engaging with problems they are likely to meet in their professional lives in the absence of on-site experts to consult for reassurance.

"Irrespective of whether or not they should choose to pursue a career in research within the workplace, all practicing clinicians will be faced with the challenge of making clinical decisions through ‘interpreting the evidence’ in the available literature with a considerable degree of autonomy and with confidence. The requirements to differentiate between good and bad evidence and to be able to empower patients to make informed decisions based on good communication of findings are unavoidable. The General Medical Council (GMC), which is the regulatory body for the medical profession in the UK, has placed an increasing emphasis on the optimization of patient safety as a driving force for quality assurance of medical teaching [2], thus reinforcing the importance of the above recommendations.” [3]

The relevant work was to involve the development of a CAL (a sequentially arranged collection of Computer Assisted Learning objects). Through this medium it would be possible to link real-life case-scenarios with comprehensive eLearning activities which not only defined the underlying concepts of risk but also empowered students to perform their own calculations to evaluate risk. The rationale was that through involvement in these activities beyond the timeframe of the project, students would be equipped with better skills in assessing the quality of statistical procedures which were presented to them in medical literature before communicating knowledge to patients on medical or surgical risks. Moreover, they would learn to challenge published findings through developing the necessary skills to recognize and know how to correct statistical blunders within the constraints of their own working knowledge of statistics.

This paper provides a progress review of the project and introduces some of the underlying pedagogical tools which have been created to accomplish the above goals.

**Recent innovations aimed at enhancing effective student engagement and autonomy**

**Student-student dialogues to highlight common ambiguities concerning the best choice of statistical methodology**

In terms of encouraging learners to identify with the CAL materials and thus of promoting a deep approach to learning, it was felt that the provision of student-student dialogues involving discussion of potential areas of conceptual misunderstanding in statistics was desirable. Thus, a couple of bona fide undergraduate medical students were enlisted for a structured photographic session, and screen shots of the resultant image files were used during the ongoing CAL development work.

Printed cartoon strips served as a useful source of inspiration for the visual presentation of these dialogues (Fig 1) in so far as the participants in the dialogue are presented as images in sequence. However, unlike the cartoons we tend to engage with in newspapers, the content of these dialogues is designed to connect with the reader through engendering a sense of empathy rather than appealing to their sense of humour.

Cartoons, as intended here, should also be distinguished from the interactive graphical animations which Bowman employs in his innovative use of the tckt package within R (a free downloadable software system with programming functionality for statistical computing and graphics construction). [4] Bowman’s use of cartoons in this sense is intended to encourage students to take some preliminary and indeed, intermediary steps in the spatial visualization and exploration of statistical distributions and concepts. Here, Bowman traces his use of the term ‘cartoon’ to that assumed during the Renaissance to refer to preliminary drawings created by experienced artists as a basis for a future painting or tapestry. When one considers the design of frescoes in particular, this early usage of the term does however bare some similarity to that intended in the risk CAL insofar as within this CAL, cartoons are presented as sequential images which are merged together. However, here, the motive is to steer the reader through a student-student dialogue rather than to wet their aesthetic appetite!

**Fixed effects model**

![Fig 1 – Start page from a student-student dialogue](image)

It is implicit from the content of each dialogue that it is a natural occurrence for medical students to find statistics hard and that this should not preclude the possibility of these same students engaging in valuable discussions relating to best statistical practice in interpreting clinical findings. The dialogues are therefore intended to improve levels of self-efficacy in less confident students. However, they are also designed to discourage naivety or apathy concerning the complexities involved in the use of statistics at a professional level. Thus, an emphasis is placed on the matching of different types of research design with optimal statistical procedures for the analysis and interpretation of clinical outcomes. Where appropriate, cautionary notes are also included elsewhere in the CAL to highlight the
importance of involving a professionally trained statistician within a research team where analyses demand a higher level of statistical expertise than can be reasonably expected from the non-specialist.

Use of informed strategies for rendering learning materials inclusive for dyslexic learners

On account of the stiff competition for admission to medical school and subsequent specialist training to meet their career aspirations, medical students may choose not to disclose specific learning difficulties. A learning environment in which provision for such students is made at the outset rather than in retrospect is not merely a strategy for efficiency in the use of resource development time. Rather, such an environment is also fundamental to removing potential obstacles to learning whilst respecting individual student privacy regarding disability.

The risk CAL contains many design features which are aimed at inclusivity for dyslexic students. However, for illustrative purposes only a few of these features are introduced below. These particular features are based on the recognition that in many cases, dyslexic learners have a preference for seeing the bigger picture prior to considering individual concepts in depth. [5]

Integration of optional online ‘story books’ with CAL materials accessed by all students

The story books are intended to provide a means of empowering the learner to choose their preferred learning styles within the context of essential learning material. They take the form of extensive notes on specific concepts (such as the Number Needed to Treat) and may be referred to once a general picture has been acquired of risk notions in context. Thus, within any one CAL page, the books are presented as learning objects which students may immediately access or skip to return to later if they sense that an overview of the more general topic of study would be preferable in the first instance (Fig 2).

On opening a story book, students are able to skip forwards, backwards or start again. This functionality acknowledges the short-term memory problems which are frequently encountered by dyslexic students [5], [6], [7] and which may also prove a barrier to other categories of learners. Pages within individual books also include links to published papers in peer-reviewed medical journals which can be immediately accessed and read in conjunction with the book to confirm the relevance of learning outcomes to clinical practice. The story books can also be closed after use, enabling the learner to navigate to alternative sections of the CAL.

It is hoped that the relaxed ambience characterized by the reader in the visual presentation of the story books (see Fig 2, for example) will strike a chord with learners, empowering them to go where medical students normally fear to tread!

It is implicit from these observations that the story books have also been designed with the fearful learner in mind, particularly with respect to avoiding information overload, whilst encouraging deep approaches to learning in the longer term. There are times, however, when learning materials contain a level of technical difficulty which ought to make them immediately identifiable by the learner as purely optional. The corresponding design feature within the risk CAL must therefore take a different form from that of the story books.

Use of ‘Want to check the technical details?’ boxes

Occasionally, the non-specialist learner will on intrinsic grounds, including intellectual interest, wish to view the complex technical justification for formulae assumed or results presented. Such interest ought to be cultivated whilst acknowledging the potential vulnerability of other learners. Thus, for example, where calculations of confidence intervals are particularly complex and involve algebraic skills of manipulation beyond those which should be required of a medical student or clinician, the reader needs a clear, instantly recognizable and non-threatening warning that they are approaching challenging territory. Moreover, they ought to be able to find a convenient means of escape without having been exposed to the technical detail alluded to. It is from this perspective on learning that the ‘Want to check the technical details?’ boxes have been introduced within the risk CAL.

These boxes, which are scattered throughout the CAL, have a defining icon (Fig 3) to facilitate ease of recognition.

But how do we obtain the confidence interval for the NNT?

It can be shown that the 95% CI for the ARR is (0.054, 0.156).

As the NNT is the reciprocal of the ARR, it would seem to make sense to take the reciprocals of the confidence limits for the ARR.

Let’s try this idea!

Fig 2 – Inclusion of a story book to suit different learning styles

Fig 3 – ‘Want to check the technical details?’ box to support optional learning
This characteristic icon is one of a variety introduced within the CAL with the realization that difficulties in organizing learning materials can create barriers for particular categories of learners, including dyslexics. Through use of ALT tags, terms within these boxes are linked to pop-up boxes, mini-CALs and earlier CAL pages, thus providing various mediums, not only for presenting the requested optional learning materials but also, for linking with previous knowledge and accessing definitions of terms used.

The ‘Want to check the technical details?’ boxes protect specific types of learner, including dyslexics, who have a tendency to experience extensive sequencing problems, as might be encountered with symbolic forms of argument which are non-essential to their learning. The above intervention may therefore serve to guard against disaffection towards statistics which might otherwise have arisen through trauma or learner fatigue.

**Dissemination of learning objects**

The risk CAL has been created within EROS (Edinburgh Reusable Object Sequencer), which is an online sequencing engine owned by the University of Edinburgh. EROS has many capabilities, including that of facilitating online progression through pages of content, forming CALs. It is expected, however, that learning objects from within the risk CAL will be packaged as ShockWave Flash files which can be conveniently viewed or run on an Internet-connected PC or Apple Mac using Adobe-Flash Player and easily accessed through the MSOR Network website. Thus, further to research evaluation activities, many of the CAL materials are to be made accessible on an international scale to teachers of statistics who may wish to reassemble them for use within their own CAL systems and Virtual Learning Environments (VLEs).

**Future plans for curriculum development**

**Modularization**

As with the STEPS modules [1], the risk CAL materials are not intended to be self-contained learning objects or to represent surrogates for other styles of teaching. However, in their current form they constitute an individual CAL of approximately 100 pages which invites modularization into individual chapters for convenient integration throughout medical teaching programmes at the University of Edinburgh. Given the intensive nature of these programmes as it currently stands, it is pragmatic to complete the above extension to the project work prior to negotiating with programme developers concerning future plans for learning and assessment activities in statistics.

**Extension of available examples and exercises**

The CAL already includes clinically contextualized examples and MCQs with detailed feedback, including hints and the opportunity to try again. The examples explicitly address the challenge of developing skills in recognizing bad statistical practice through inviting students to compare the outcomes of alternative types of statistical analyses and contrasting the nature of the advice to the patient forthcoming from these analyses. Through use of images of simulated patient-doctor dialogues the implications for patient safety and hence the relevance to future clinical practice is unmistakable.

Nevertheless, there is considerable scope for expanding this content both in terms of question styles and the variety of clinical contexts within which risk notions are seen to be relevant. This next step awaits the outcomes of the collaborative discussions highlighted above.

**Research activities**

The learning materials which constitute the risk CAL are intended for use in pedagogical research at the University of Edinburgh, particularly in assessing their value in addressing aspects of the three fundamental problems defined at the start of this paper. The delivery of CAL modules to individual student cohorts will therefore ideally be controlled by means of one or more web-based VLEs.

In the longer term, it is anticipated that once the findings of the above research have been analysed and responded to, individual risk CAL modules (or revised versions of these modules) will become a permanent feature of medical teaching programmes at the University of Edinburgh. As such, it is hoped that they will serve as powerful formative assessment tools in preparing students to evaluate, choose between and where appropriate, implement, statistical methods for assessing patient risk in a variety of clinical scenarios similar to those they can expect to face in the workplace.

**References**


**Acknowledgements**

I wish to extend my appreciation to the MSOR Network for providing the necessary funding to support the development of the risk CAL. The modularization of the CAL to facilitate its use in teaching is currently being funded by part of a grant awarded by the University of Edinburgh Principal's eLearning Fund, which I gratefully acknowledge.

My colleague Jackie Aim (eLearning Developer) deserves a special mention for her dedication to the eLearning development work and her constant willingness to embark on new adventures.

A number of very able volunteer actors have helped to bring the CAL to life. These include Lesley Anne Lancastle and Stephanie Dunkeld Wills (undergraduate medical students), John M MacPherson and Michael Ross. Thank you all very much for being so patient!

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