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Edited by David Green

The Higher Education Academy Maths, Stats & OR Network

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Contents

Quantitative skills in the social sciences: Identifying and addressing the challenges

Catherine O. Fritz[1], Moira Peelo[2], Andrew M. Folkard[3] and Alberto Ramirez-Martinell[1]

[1]Department of Educational Research, Lancaster University
[2]Centre for the Enhancement of Learning and Teaching, Lancaster University
[3]Department of Geography, Lancaster University

Abstract

Social science students are often surprised and dismayed by the requirement to develop statistical skills; many have avoided quantitative work and find the topic to be unfamiliar and frightening. Often these students lack basic numeracy skills and the confidence to develop them, but without quantitative skills their competence as graduates, job seekers and researchers is limited. Many students ask for, and expect they would benefit from, individualized tuition, but contemporary funding models preclude that level of resource for undergraduate teaching, especially in the social sciences where most courses are funded at the lowest level. Lancaster's recent university-wide study has identified two types of students who struggle with quantitative concepts and skills: those who struggle but can face it when encouraged and supported, and those who feel unable to seek help or use the support that is provided. A small set of interactive online statistics-teaching modules, and a system for constructing further modules, is being developed to support the teaching and learning of quantitative skills. A project to develop the system and a few pilot modules is being funded by the ESRC. The principles underlying the system are that students benefit from practice testing with feedback and customized, scaffolded tuition to help students monitor their understanding to guide the development of further understanding as well as the use of clear examples creating a clear purpose for the quantitative concept or skill and demonstrating its usefulness.

Quantitative skills in the social sciences: Identifying and addressing the challenges

The undergraduate study of social sciences, such as psychology, sociology, geography, politics, criminology, anthropology and social work, all include a research component. The data collection methods often used in the social sciences vary, but are likely to include observation (naturalistic, participant-based and ethnographic), experiments (laboratory and field-based), surveys and questionnaires, diary studies, interviews, focus groups, and case studies. All of these methods can yield data for quantitative and qualitative analysis. Key quantitative concepts covered in undergraduate courses generally include central tendency, variance, statistical and graphical description of a dataset, statistical hypothesis testing, significance levels, basic concepts of probability, Type I and Type II errors, effect size and power. The quantitative analysis tools that are often taught to undergraduates are likely to include:

- sign test, chi-square analysis and log-linear analysis for categorical (or frequency) data;
- *t* test, Analysis of Variance (ANOVA) and its multivariate extension (MANOVA), and correlation-based tools including Pearson's *r*, and linear and multiple regression for normally distributed data;
- Wilcoxon matched-pairs, Mann-Whitney *U*, Spearman's rho, and the Friedman test for non-parametric data.

In each domain the Quality Assurance Agency's subject benchmarks [1] require some degree of engagement with quantitative analysis and reasoning skills. Although the emphasis on quantitative description and analysis methods varies considerably among the social sciences, the requirement exists in all social sciences. Three major issues arise with respect to helping students develop the necessary quantitative skills, which will now be discussed.

Students lack confidence and motivation

Students who choose to study social sciences are often surprised and dismayed by the need for quantitative skills; some see the requirement to develop research expertise, and particularly quantitative skills, as unreasonable and unrelated to their studies [2]. This conflict between expectations and course requirements often leads to motivational problems, which may be aggravated by an *a priori* disinclination to engage with quantitative concepts and skills. Students who have avoided quantitative studies often lack confidence and may feel threatened by the need to build quantitative skills, especially if they have forgotten much that they once knew for a long-forgotten GCSE exam. Students who lack confidence in quantitative reasoning may neglect quantitative methods in favour of qualitative methods. So students' experience with quantitative concepts and skills should build their confidence and provide motivation for developing these skills.

Students' a priori numeracy skills vary widely

Social science students vary widely in their preparedness for quantitative topics. Although many students have avoided quantitative study beyond the minimum required at GCSE level, others have excellent A-level double-mathematics marks. Among the students with the lowest qualifications there are likely to be some with dyscalculia – a learning disorder that often goes unrecognized. This wide variability creates a special challenge for tutors and developers of curriculum materials. If too little scaffolding is provided, weaker students will be left behind, and likely will be demotivated, as described above. If there is too much scaffolding, better prepared students are likely to learn little from it [3], perhaps because it seems too easy; they may also resent the apparent waste of their time. Students recognize that their individual needs differ substantially across a cohort (e.g. [4] and [5]), but it is nevertheless necessary for tutors and curriculum materials to address their varied needs if students are to succeed. The widely variable level of prior achievement presents special challenges for teaching quantitative reasoning and tools.

Students' numeracy skills are generally lower than university courses expect

Many students are substantially unprepared for the quantitative aspects of their course. Some have avoided quantitative work and describe themselves as "rubbish at maths". Bynner and Parsons's [6, p. 103] data suggest that self-report may seriously underestimate the number of students with deficits in their ability to effectively use even basic quantitative concepts and skills, so the skills gap may be worse than students think. Furthermore, modern pre-university education appears to develop relatively lower levels of mathematical fluency than in decades past [7] [8]. Although university tutors may be well versed in the teaching of particular quantitative concepts and skills at the undergraduate level, they may be unprepared to teach basic mathematics, and undergraduate courses typically lack the time and resources to do so. Extra working sessions and surgeries are welcomed by students (e.g. [4] and [5]), and are often provided in the physical sciences and engineering, but social sciences are typically funded at the lowest band, D (except for psychology and geography at band C), by the Higher Education Funding Council for England (HEFCE) [9, see Table 1 for information about funding bands]. Whereas physical sciences, typically funded at band B, can draw upon additional resources to provide surgeries, social sciences cannot. It can be counterproductive to teach undergraduate statistical concepts when tuition in basic mathematical concepts and relationships is needed for many students, but there may not be resources to provide that tuition.

Band	Weighting factor	Example subjects
A	4.0	medicine, dentistry, veterinary science
B	1.7	physics, chemistry, biosciences, engineering
C	1.3	information technology, mathematics, arts, languages
D	1.0	social studies, humanities

Table 1: Summary of the Higher Education Funding Council for England (HEFCE) funding bands, effective 2004-5. The weighting factor is applied to the basic amount that HEFCE pays universities to fund undergraduate students. The complete report is available online [9].

The minds of the students

To address the needs of social science students with respect to learning quantitative concepts and skills, it is necessary to identify and understand their strengths, weaknesses and perceptions of the relevant teaching and learning environment.

Focus groups with Psychology in Education students at Lancaster University were conducted during the 2006-7 academic year. First- and second-year students were recruited from statistics classes. Sessions were run by two people who did not teach on the course but were familiar with it. Students reported that statistics worried them because they generally understood the gist of their other courses at first encounter, but often did not immediately understand the statistical concepts. They responded to their own confusion with statistics by withdrawing, whereas when they experienced confusion with the other parts of their course they were more likely to seek clarification. Students were especially frustrated by the often greater effort required to understand statistics, because they saw statistics as being simply a matter of "automatic rules," a view similar to that reported by Ben-Zvi and Garfield [10]. Ben-Zvi and Garfield went on to note that based on this perception of an arithmetic-like approach, students were loathe to engage in interpretation; this observation was appropriate to the students in this programme as well.

Other recent focus groups, surveys and interviews at Lancaster University have asked students to comment on how to make teaching and learning of the quantitative components of their courses more effective [4] [5]. Most students argue for more individual or small group tutorials and labs, many stating emphatically that they cannot learn the concepts and skills from written material. They express frustration at tutors and materials that assume skills and knowledge which they lack – and many argue that they should not be expected to remember what they learned for GCSE mathematics exams. Many students suggest that they need more elapsed time when learning quantitative concepts and skills, explaining that a 10-week term is not long enough to take the material on board. The use of examples was important: Students found the use of real examples useful, but were confused when too many examples were used or when an example was not taken from a clear starting point to a reasonable conclusion. Students were confused by equations and said that they would prefer verbal explanations. They were resistant to the idea that they might learn from a text, but offered some suggestions for making a text more useful. Although they were in favour of assessment within their classes, they argued against formative assessment exercises as being too much work for both tutors and students. In general, weaker students disliked a problem solving approach as being too challenging and preferred working through worked out examples, but recognized that merely following examples might not lead to understanding.

Evidence for the mathematical skills that social science students bring to university was obtained from 77 first year students at Lancaster University who studied Psychology in Education as one of their three subjects; they took an online basic-level mathematics quiz at the beginning of academic year 2006-7. Students were generally competent at many basic arithmetic tasks involving whole numbers, but roughly half of the students made errors when decimal fractions were introduced (e.g., put numbers in order from smallest to largest: .3, .13, .20). They could read graphs reasonably well, but roughly half of the students could not handle very simple algebra questions (e.g., solve for X: $A + X = B$).

The world of the tutors

For the students, research methods, including quantitative and qualitative analysis methods, are often seen as separate from the content of the discipline [2]. Whereas other parts of the discipline are reasonably likely to be presented in an interrelated way with occasional comments that connect separate modules, the modules addressing other aspects of the discipline rarely make substantial reference to the research methods involved and almost never refer to the types of quantitative analysis employed. Even within modules addressing research methods, it is often the case that quantitative and qualitative methods are taught separately, sometimes as incompatible alternatives. This problem can be exacerbated when the tutor for quantitative skills comes from outside the discipline.

From the tutors' standpoint, there can also be isolation. The social scientists who teach statistics may be somewhat anomalous within their department. In this case tutors may feel the lack of colleagues with whom to discuss the teaching issues that arise and share good practice. Statistics tutors from outside the social science may not have colleagues who share the concerns of the programme or familiarity with the students.

A sense of isolation and frustration can also arise from resourcing issues. Successful teaching of research methods and especially quantitative concepts and skills typically requires different teaching methods and usually requires special rooms (e.g., computer labs) and additional time and teaching staff (for workshops and practical activities). Because most social sciences are funded minimally, there is often strong competition for resources to support teaching. Tutors on modules that are not awarded additional resources sometimes resent modules that are and the tutors who teach them. Alternately, where recognition of the need for additional resources has not been forthcoming, conscientious tutors who provide additional tutorials or surgeries from their own research time may resent their situation.

A SIMPLE tool to support statistics teaching

Research commissioned by the Economic and Social Research Council (ESRC) (e.g., [11] and [12]) identified a specific need to develop more and better quantitative skills among UK social scientists. The Mills *et al.* report [11] suggests that this training needs to begin at the undergraduate level, and it needs to change the way that these budding social scientists relate to quantitative methods. SIMPLE (Statistics Instruction Modules with Purposeful Learning Emphasis) is one of the undergraduate curriculum development projects funded by a recent ESRC initiative to improve and encourage undergraduate research training.

The project is developing a teaching tool and materials that can be used at an introductory level in any social science department to provide students with effective and engaging tuition that is cost effective and easy to administer and customize. The SIMPLE system includes four pilot modules and the software, examples and instructions to enable tutors to use the pilot modules, modify the modules, or to construct their own. Modules are intended to supplement existing statistics modules, primarily as exercises introduced in class and completed outside of class. SIMPLE is designed to stimulate effective learning for the students, enable tutors to modify or develop modules using familiar file formats and clearly documented procedures, and enable tutors to monitor students' progress and be aware of students requiring special help.

Figure 1 illustrates an example of flow in a SIMPLE module. Each module can be designed to require as much or as little mainstream tuition as the tutor determines is appropriate. Where questions are asked, error handling options include both progressive error handling, as illustrated for the first question in Figure 1, and specific error questions for multiple choice, as illustrated for the second question.

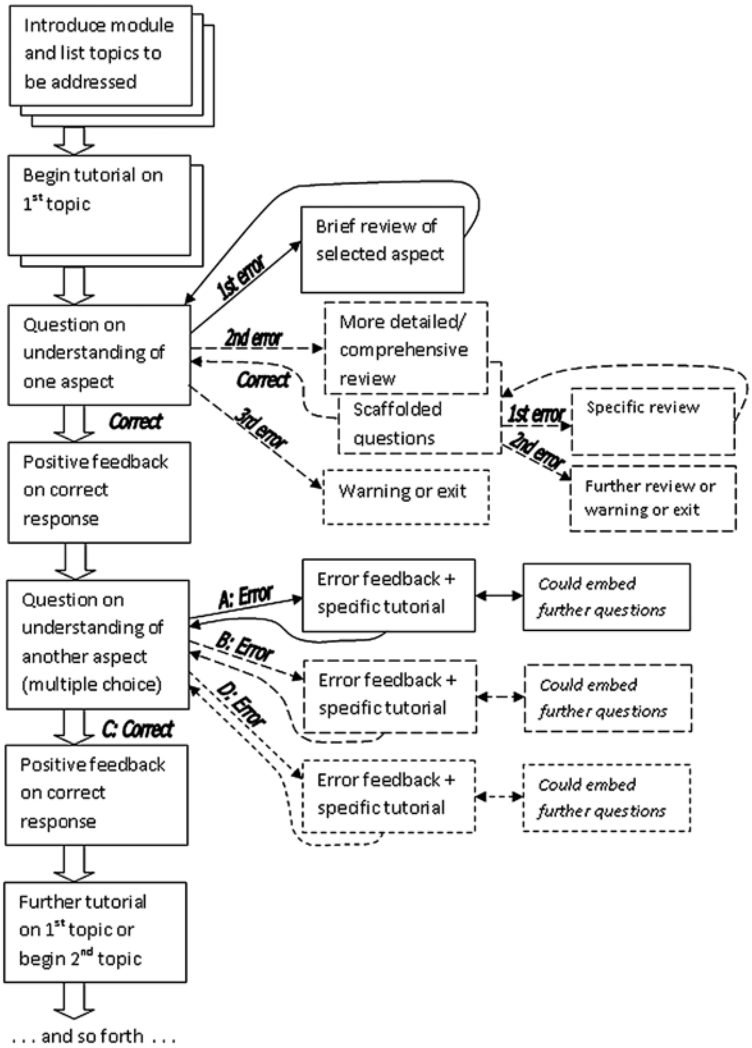

Figure 1: Example flow in a SIMPLE tutorial. Boxes represent one or more slides; block arrows represent main-line flow through the module; line arrows represent optional flow, based on students' responses.

Important characteristics of the modules that stimulate effective learning include:

- Combining instruction with practice, which informs subsequent instruction. The practice questions provide diagnostic and formative assessment. Where students show a lack of understanding, the modules provide simpler instruction, as an individual tutor would. Where students succeed, the modules move along. Tutors can design parts of modules to allow students to select a path through the module based on their own assessment of their prior knowledge. It is possible to offer students with substantial prior knowledge an initial set of questions so that students who perform well can skip the module or select only parts they need. At the other end of the spectrum, it is possible to offer students who lack prerequisite knowledge access to appropriate tutorial and reviews of that knowledge. In this way, each student receives individualized instruction.
- By asking questions at early stages and monitoring students' profiles, the modules help students to build confidence and learning skills. Carefully thought out, well designed modules avoid unwarranted assumptions about students' prior knowledge. Modules may ask students if they want a review of a basic topic before moving on, allowing students to guide their own learning and encouraging them to monitor their understanding. Each screen can include links specified by the module designer to supporting materials (e.g., slideshows, webpages).
- The modules can be introduced in class, where students might obtain help getting started, but they can be completed from any computer linked to the internet. This practice allows students to work at their own

pace. This flexible approach, combined with online resources, can also encourage students to work in small study groups even when it is not convenient to be in the same place. Students can share comments, questions and support via email or synchronous discussion tools external to SIMPLE. In this way, SIMPLE encourages the development of cooperative work and effective learning skills.

Tutors interface with the system in developing or modifying modules and in monitoring students' progress:

- Modifying modules, especially the examples, is easy. The original materials are mostly PowerPoint slides, and tutors merely need to change the context of the example to adapt a module developed for one discipline to fit squarely within another. In many cases, though, this adaptation may not be necessary as the original examples are intended to engage the students by addressing student issues.
- The development of modules is not easy from a conceptual standpoint: The designer must imagine a plethora of one-on-one tutorials, anticipating students' errors and misunderstanding and designing appropriate interventions for these imaginary students. But having done that, the development of materials is relatively simple in that it requires no special, new or unfamiliar skills. In its simplest form, a module can be built from PowerPoint slides and an Excel file to direct the flow of the module and provide links to supporting material.
- The system maintains records of students' progress for tutors to review and alerts tutors whenever a student has exhausted the tutorials available in the system without appearing to understand the topic.

Pilot modules have been developed and trialed at Lancaster University during 2007-8. The system and modules will be available to all interested parties during the summer of 2008.

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Supplementary Information

Correspondence to:

Catherine Fritz
Department of Educational Research
County South
Lancaster University
Lancaster
LA1 4YD

c.fritz@lancaster.ac.uk

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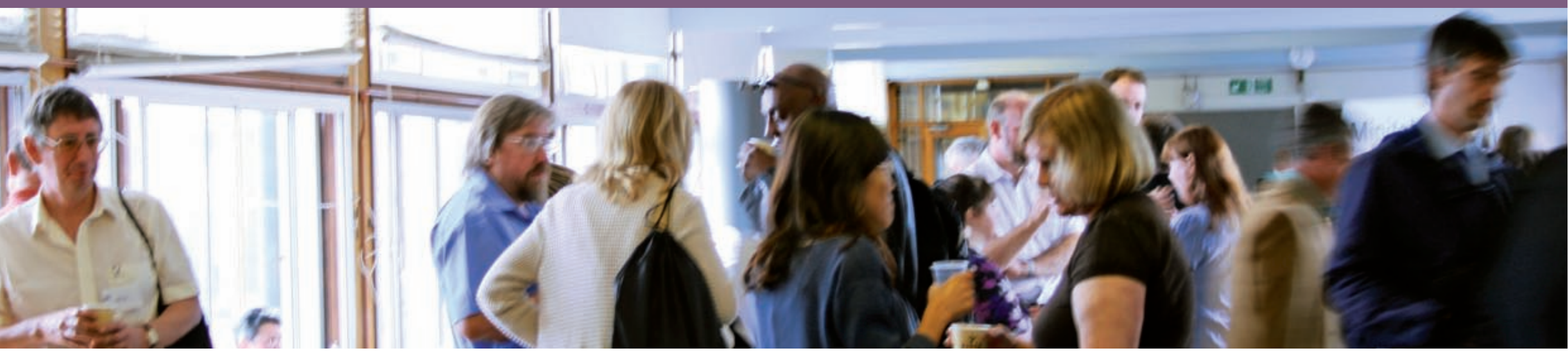

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University of Birmingham,
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