



GEES Subject Centre Resource Briefing: Mathematics, Statistics & Quantitative Skills

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The Issue:

- **Quantitative skills are a fundamental element of undergraduate geography, earth and environmental science (GEES) degrees (e.g. Subject Benchmarking Statements, Quality Assurance Agency for HE, 2000, <http://www.qaa.ac.uk/academicinfrastructure/benchmark/>)**
- **They underpin many other core elements of GEES syllabi, including fieldwork, laboratory practical classes and computational modelling**
- **However, they are commonly found to be one of the most problematic areas of learning and teaching in the GEES disciplines: many current GEES students arrive in HE with insufficient quantitative skills and view quantitative material with antipathy**
- **This problem is likely to be exacerbated by the widening participation agenda**
- **Despite this gloomy analysis, as the efforts, skills and experience of many GEES teaching professionals have shown, quantitative material can be presented in inspirational and successful ways, and there are cures for “mathophobia”!**

This Briefing aims to ...

- provide a handy summary of:
 - key issues in developing successful strategies for enabling GEES students to acquire quantitative skills
 - suggestions for ways in which these successful strategies can be adopted and developed
 - resources, references and further reading related to these key issues
- act as a gateway to the GEES Subject Centre Resource Database
<http://www.gees.ac.uk/db/>
- make readers aware of the wide range of pedagogic research and development output in this area, and the extent to which it can inform and develop their teaching practice

This Briefing is aimed at ...

- staff new to teaching, or new to teaching in the GEES disciplines, as an introduction to these issues and resources
- experienced staff, as an *aide memoir* and to raise awareness of resources available

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Student Profiles & Diagnostic Testing

What are the issues?

- Ensuring that the gap between quantitative skills levels delivered by secondary education and those required on GEES degree schemes (e.g. Savage, 2000) is bridged for all students
- Coping with differences in entry-level students in their quantitative skill levels, background, motivation, expectations & learning styles (e.g. King, 1999a)

How can they be addressed?

- **Diagnostic tests** taken by students on entry to HE can help to identify the range of skill-levels in a student cohort.
- These can be **web-based** (see resource list) or **paper-based** (e.g. Agnew, 2000, p. 65).
- **Prompt and effective support** should be available to those students deemed to need it:
- **Formal “remedial” courses** can be laid on for weaker students – stronger/better performing students can be **exempted from assessments** to counteract the increased teaching load this will cause
- Quantitative courses can be **streamed** according to the test results
- Additional support can be made available through peers, tutors, web or paper-based aids

General Tips

- In your teaching, **recognise the range of approaches to learning**. (see, e.g. Agnew, 2000; Healey & Jenkins, 2000)
- **Be aware of, and act on, the diverse nature of student difficulties**, e.g. poor quantitative skill levels, poor understanding of underlying concepts, weak ability in applying these skills, inappropriate expectations of HE study, or antipathy towards material (King, 1999a)

Resource List

- Diagnostic tests on the web:
 - <http://www.keele.ac.uk/depts/ma/diagnostic/>
 - <http://www.staff.ncl.ac.uk/john.appleby/diagnopage/diagindx.htm>
 - <http://www.brunel.ac.uk/~mastmmg/>
 - <http://caroll.ugent.be:8080/aim/>
- Birnie, J. (1999) *Key Skills of Students on Entry to Geography in Higher Education*, GDN <http://www2.glos.ac.uk/gdn/confpubl/keystud.htm> has a section on numeracy and information on changes in the 16-19 key skills curriculum.

- Walker, G. (1996) What Students Think They Know, *New Academic*, 5(2) - discusses a diagnostic test of maths & physics for chemical engineering students
- Healey, M. & Jenkins, A. (2000) GDN website: <http://www.chelt.ac.uk/gdn/discuss/kolb1.htm> - discusses students' different learning styles
- Savage, M. (2000) 'Measuring the Mathematics Problem' provides an overview of the problem: http://www.engc.org.uk/documents/Measuring_the_Maths_Problems.pdf
- King, H. (1999a) 'Back to Basics: Ideas for Teaching Basic Maths and Science Skills Essential to the Earth Sciences', Staff Development in the Earth Sciences Workshop Series (case studies at <http://www.gees.ac.uk/essd/basic.htm>)

Course Design & Organisation

What are the issues?

- Defining the quantitative skills required by GEES students and graduates
- Deciding how to fit these skills into the curriculum – “bolt-on” or “embed”?
- Integrating quantitative skills teaching across the curriculum

How can they be addressed?

- King (1999a) gives an example of a basic quantitative skills list for Earth Science
- Agnew (2000) discusses such lists for Geography
- At one extreme, quantitative skills can be taught in dedicated “**bolt on**” **modules**
- At the other, skills can be **entirely embedded in the curriculum**, within specific contexts - for example in laboratory or fieldwork classes
- Purely embedded approaches tend not to lead to transferable skills
- Purely “bolt-on” approaches lack context and mean skills are soon forgotten
- The most effective approach appears to involve a **mix of these approaches**
- A **matrix that crosses desired outcomes with modules** can be used to integrate quantitative skills teaching across the curriculum (Macdonald & Bailey, 2000). Gaps or duplications can then be remedied

General Tips

- Weaker students list only **basic arithmetic, square roots and whole number powers** as quantitative concepts with which they are confident on entry (Folkard, 2004)

- Quantitative skills teaching design needs to **define the objectives for the curriculum, including only those skills that are going to be used** (King, 1999b)
- **Tasks which will achieve those objectives** should then be defined, and each task **associated with appropriate activities**

Resource List

- King, H. (ed.) (1999b) A Staff Resource Book to Support Earth Sciences Learning and Teaching in Higher Education', Earth Science Staff Development Project FDTL1
<http://www.gees.ac.uk/essd/>
- Folkard, A. (2004) 'Mathophobic students' perspectives on quantitative material in the undergraduate geography curriculum' JGHE, Vol. 28 No.2 pp209-288
- Macdonald & Bailey, 2000, Journal of Geoscience Education, 2000, 48, 4,
http://www.nagt.org/nagt/jge/sept_2000.html
- Teaching quantitative skills in the geosciences
<http://serc.carleton.edu/quantskills/>
- Quantitative Skills in Geoscience Courses
<http://www.ldeo.columbia.edu/~mwest/quant/>
- Wagner, J.R. (2000) Sneaking mathematical concepts through the back door of the introductory geology classroom. Mathematical Geology, Vol. 32, no. 2, pp. 217-229.

Delivery of Material

What is the Issue?

- Deciding what approach should be taken to delivering quantitative material

How can it be addressed?

- **Lectures, seminars, tutorials:** traditional & much maligned, but often effective ways of getting ideas across in authoritative and inspirational ways.
- **Computer aided learning (CAL):** popular & effective, either through web-based packages or fixed-time practical classes. These can use e.g. spreadsheets, GIS, numerical models or virtual field trips
- **Problem based laboratory or field classes** with quantitative skills embedded, studying unifying concepts such as density (Carlson, 2000; Nelson and Corbett, 2000), tombstone weathering (Roberts, 2000), and local rivers (Dupre and Evans, 2000; Keller et al., 2000)

General tips

- To enhance the value of lectures, Bailey (2000) uses a **question based approach** that

requires students to practice "back of the envelope calculations"

- Examples used in lectures need to be vivid and relevant. Building equations and relating them to processes using PowerPoint animation can be effective (although PowerPoint can become bland & soporific)

Resource List

- Cited papers by Bailey, Carlson, Dupre & Evans, Keller et al., Nelson & Corbett, and Roberts all available in Journal of Geoscience Education, 48, 4, pdfs downloadable from
http://www.nagt.org/nagt/jge/sept_2000.html)
- General Quantitative CAL Packages
 - <http://www.bham.ac.uk/mathwise/>
 - <http://davidmlane.com/hyperstat>
 - <http://physics.open.ac.uk/flap/>

Student Support & Guidance

What is the Issue?

- Ensuring that student support & guidance mechanisms offered are of the greatest benefit to students and use staff time most effectively

How can it be addressed?

- By **tutors or teaching assistants**. This is the preferred form for many students - tutors can be interrogated and answer specific questions more effectively than support material
- Through **paper-based material**. Good texts starts with clear definitions and motivations; mix text, algebra and graphics; use boxes for supplementary material; and use interesting examples. Terminology needs to be clearly explained - via a **glossary**, for example.
- Through web-based sources. **E-noticeboards and web-based discussion spaces** may be useful student support mechanisms. Elliott (pers. comm.) reports that these have been effective in large introductory classes, and encourage support from within the student cohort as well as from tutors
- **Peer tutoring** can be beneficial to peer tutors as well as tutees: explaining concepts helps clarify them in one's own mind

General Tips

- The key to supporting students is recognition of the nature of their difficulties (see above)

Resources

- Coventry University have a Mathematics Support Centre for all students: it can be used as a drop-in centre or on-line
http://www.mis.coventry.ac.uk/mathcs_centre/

IT Resources

What is the issue?

- Identifying sources of data and courseware that will help support quantitative skills teaching

How can it be addressed?/Resources

- **IMAGE** (Interactive Mathematics & Geoscience Education) provides a suite of self-study modules, which focus on placing maths in a geologically relevant context. <http://www.es.ucl.ac.uk/undergrad/geomaths/front.htm>
- **QELP** provides on-line access to a wide variety of GEES-related data sets. <http://www.seattlecentral.org/qelp/>
- Digital library for Earth System Education <http://www.dlese.org/>
- The **UK Earth Science Courseware Consortium** covers various issues, not just maths. Most of the topics dealt with use worked and set examples. <http://www.ukescc.co.uk/>

Learning Outcomes & Assessment

What are the Issues?

- Defining what **students are expected to achieve**
- Determining **the extent of their achievement**

How can they be addressed?

- Assessments in which quantitative skills are **embedded in problem solving tasks** are reported as being more popular and successful than those which stress quantitative techniques in isolation. For example, Shosa et al. (2000) use real world problems that require **hypothesis development, data collection, data processing, uncertainty analysis and hypothesis testing**.
- For **weaker students**, problem solving is found to be too challenging an assessment mode
- Instead, **assessment tasks closely related to worked examples** are preferred. These could **increase in difficulty** through a course

General References

- Good Practice in Earth Science Learning and Teaching: set of held articles at: <http://www.gees.ac.uk/essd/goodpractice.htm>
- Case Studies from the GEES Subject Centre (Abstracts 122, 135, 154 & 164 are of particular relevance: <http://goodpractice.gees.ac.uk/>
- Agnew, C. (2000) 'Improving students' numeracy skills', Geography Discipline Network (GDN) Key Skills in Geography in Higher Education Series, GDN, available for purchase from <http://www2.glos.ac.uk/gdn/guides/dfeepubl.htm>
- Booklets on teaching quantitative skills, including "Support for Students" and "Maths for Engineering and Science". Available in hardcopy, or downloadable as pdfs from <http://itsn.mathstore.ac.uk/mathsteam/>

This briefing is intended to act as a starting point. The resources listed here are just a few of the many available. Many more can be found within the **GEES Subject Centre Resource Database** <http://www.gees.ac.uk/db/>

A further key source of ideas is **Planet** - the bi-annual publication of the Subject Centre, which contains many useful short articles on pedagogic research & development in GEES disciplines in each edition.

What you need isn't in this list? Contact the GEES Subject Centre – let us do the searching for you!

<http://www.gees.ac.uk>

Email: info@gees.ac.uk

Finally, some watchwords to remember in teaching quantitative skills:

- Make it **RELEVANT** to students and their other studies
- **CLARITY** is paramount
- Use **VIVID** examples
- Provide **THOROUGH** explanations
- Don't just rely on a rhetorical style in lectures - use **NARRATIVE** - tell stories – & **DIALOGUE**
- Students need **EXAMPLES** and **PRACTICE**
- **DISCUSSION** is better than textbooks