Skills in Mathematics and Statistics in Geography and tackling transition

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This report is one of a series of reports commissioned by the Higher Education Academy STEM team to look at mathematical and statistical skills in a range of discipline areas. The report seeks to contribute to existing knowledge about this area within the context of Geography.

At the start of the study a list of areas for consideration was provided by the Higher Education Academy. These encompassed the way in which mathematical and statistical skills form part of the discipline landscape, the signalling higher education provides about the need for these skills, sector requirements within the discipline (e.g. from accreditors and Quality Assurance Agency subject benchmark statements), the use of diagnostic testing and the support provided for students to improve and develop their mathematical and statistical skills. The methods used in the study in Geography consisted of (i) a literature review; (ii) survey work; (iii) telephone interviews; and (iv) a discussion event.

The mathematical and statistical requirements of a Geography degree can be quite demanding. However, the actual mathematical entrance qualifications for Geography degrees can be comparatively low. This disparity provides particular challenges in Geography which have been recognised for some time. Despite the development of many relevant teaching resources there has been relatively little research on this topic. The present study aims to address this issue and to provide a sound evidence base to inform future discussion, policy developments and teaching practice in the discipline.

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I Summarised findings and recommendations

1.1 Introduction

Geography is a discipline that bridges the natural sciences, humanities and social sciences. In 2014, based on data from the University and Colleges Admission Service (UCAS), 23,830 undergraduate students were enrolled in both BA and BSc Geography degree programmes. All programmes include quantitative methods. However, there is a large degree of variation, with some programmes covering just basic Statistics while others include advanced topics such as spatial analysis, numerical modelling and visualisation.

Geography has a long tradition of quantitative methods research and teaching. It was quick to adopt, develop and apply geographic information science (GIS) and earth observation technologies, and more recently “big data” and the development of new and creative methods of combining, visualising and analysing geographic information. However, quantitative methods did fall out of favour in the past in some parts of the discipline. Recent initiatives, notably the Q-Step initiative (Nuffield Foundation, 2013), have been implemented to address quantitative skills training for Geography undergraduates.

This report describes work that was undertaken within the Higher Education Academy (HEA) Science, Technology, Engineering and Mathematics (STEM) project for the Geography discipline. The work aims to gather evidence about approaches to the learning and teaching of quantitative methods within degree programmes in Geography and the issues related to quantitative methods that face students as they transition from A-level or equivalent to university level Geography.

A literature review was undertaken at the start of the study, and three surveys were developed to follow on from this. The HEA STEM project team developed three questionnaire-based surveys, to ensure that, as far as possible, a consistent approach was adopted to the work across the full spectrum of disciplines involved. Slightly broader Geography-specific surveys were written, and these were adapted to include questions from the HEA STEM surveys and tailored to the Geography discipline in terms of language and likely quantitative methods content. One survey was aimed at staff teaching within Geography and a second survey was directed to heads of department or those with responsibilities for organising teaching in Geography (taken together these form the HEA STEM staff survey in Geography). The staff survey was followed up with telephone interviews. The third survey was for students taking degree programmes within Geography. The surveys were in circulation in the Autumn of 2012 to Spring 2013. The last strand of the work was a set of HEA STEM Tackling Transition events for the various disciplines. The Geography event provided an opportunity for staff working in Geography in higher education to meet and discuss the areas of interest with colleagues in the pre-university sector and other key stakeholders in the discipline. The discussions were recorded and collated with the other data obtained during the work.

1 QM is sometimes used as an abbreviation for quantitative methods in this report.
1.2 Findings and recommendations

1.2.1 Notable findings

1 Based on reviews of online information about programmes and the responses from the HEA STEM staff survey, there is no evidence to suggest that any Geography degree programme, BSc or BA, is purely qualitative in nature; both BSc and BA programmes appear to incorporate some element of using or interpreting numeric data.

2 The amount of quantitative methods content taught in degree programmes in Geography varies considerably between institutions. Similarly, there is considerable variation in terms of the inclusion of emerging topics, the use of innovative teaching methods and whether content is organised into standalone modules or embedded in other modules.

3 The perception of most instructors who responded to the survey is that students underestimate the skills in quantitative methods that will be required in their Geography degree programmes.

4 There is a difference of opinion between students and academic staff on how well prepared students are in terms of quantitative methods. Almost three-quarters of staff said students are not very well or not at all prepared in terms of Mathematics/Statistics skills; in comparison under a quarter of students responded that they were poorly or very poorly prepared.

5 The Quality Assurance Agency (QAA) subject benchmark statement for Geography clearly identifies quantitative methods and familiarity with the associated technologies as key skills in a Geography degree, but the statement lacks specificity in its definition of quantitative methods and the related skills and methods of particular importance.

6 Fewer than half of Geography degree programmes surveyed online explicitly state a Mathematics-related entry requirement, but a common minimum expectation is GCSE grade C (or equivalent) in Mathematics. In practice, many students exceed this minimum.

7 Diagnostic testing to determine the level of students’ Mathematics and Statistics knowledge and skills is uncommon in Geography degree programmes in UK higher education institutions.

8 More than 90% of staff respondents stated that for those students that struggle with quantitative methods, Mathematics and/or Statistics anxiety is an inhibiting factor. A high proportion of institutions implement at least one form of additional support in Mathematics and Statistics for students undertaking Geography degree programmes.

9 Nearly all teaching of quantitative methods in Geography degree programmes is delivered by members of the Geography department, but specific training in the teaching of quantitative methods for such staff members is not widely available.

10 Prior to coming to university, students on Geography degree programmes have studied a diverse range of subjects and are likely to have encountered Mathematics in A-level and equivalent qualifications in Geography, Mathematics and other subjects.

2 In this report the term ‘module’ will be used to refer to a single unit which is distinctly listed within a programme specification, has its own assessment and carries a specified number of CATS points. In some institutions such units may be referred to by other terms e.g. ‘course’.
The participants in the HEA STEM surveys and events were self-selecting and in some cases the sample sizes were quite small. Detailed information on sample sizes and the response rates for specific questions is given in Section 4.

1.2.2 Recommendations

1. Key stakeholders in the Geography discipline should work to disseminate existing and developing good practice from institutions and from initiatives supporting quantitative methods in the discipline, including resources to support the learning and teaching of new and emerging methods.

2. Higher education institutions and professional bodies in Geography should provide clear signalling to the pre-university sector about the mathematical and statistical skills needed to undertake a Geography degree programme. Staff with responsibility for Geography degree programmes should provide clear information about the quantitative methods content in their degree programmes.

3. Staff with responsibility for Geography degree programmes should review their entrance requirements to ensure that their introductory courses reflect the quantitative skills students entering university will have from their A-level (or equivalent) studies in Geography and other subjects.

4. The QAA subject benchmark statement for Geography should be revised at the earliest opportunity to include information specifying the type and level of quantitative methods that should be present in degree programmes in Geography and to emphasise the importance of numeracy across the discipline.

5. University staff with responsibility for managing degree programmes in Geography should review their approach to, or consider introducing, diagnostic testing of students’ mathematical knowledge and skills at the start of Geography degrees, and use the results to inform feedback and other follow-up actions (e.g. student support).

6. Key stakeholders in the higher education sector should develop specific training in up to date approaches to the teaching and learning of quantitative methods, especially for postgraduate teaching assistants. Such training should also be available to teaching staff at all stages of their careers.

7. Key stakeholders in the Geography discipline and university staff with responsibility for managing degree programmes in Geography should actively engage with developments in post-16 qualifications in both Geography (quantitative methods content) and Mathematics (e.g. “Core Maths”).
2 Background

2.1 The situation generally

The skills deficit in quantitative methods in the UK is well documented and the focus of substantial investment from research councils including the Economic and Social Research Council (2012) and Natural Environment Research Council (2012), from the Higher Education Funding Council for England (2011), and from charities, professional bodies, government departments and other organisations (Advisory Committee on Mathematics Education, 2012a, b; British Academy, 2011, 2012, 2013; Department for Business, Innovation and Skills, 2011a, b; Hodgen et al., 2010, 2013; Nuffield Foundation, 2012a, b; MacInnes 2009, 2013; Parker et al., 2008; Porkess, 2011; Vorderman et al., 2011).

The British Academy position paper “Society Counts” (2012) identifies a number of the causes behind the skills deficit in quantitative skills, specifically in the social sciences:

1. The long-term vulnerability: A consequence of ageing of the cohort of quantitative social scientists who had led work in this area, in addition to a lack of appropriate training in the 1990s.

2. The schools gap: The low numbers of students who beyond the age of 16 formally study Mathematics, which may result in students entering university with poor quantitative skills, little confidence in their skills, and a lack of appreciation of their relevance.

3. The teaching of quantitative methods: Insufficient attention in degree programmes to methodology; quantitative methods modules that are often taught in isolation and can appear irrelevant to the core discipline; and a lack of academic staff (resulting from (1)) able to teach quantitative skills in ways that are relevant and exciting to students.

4. Signalling to students: Students are not aware of how useful quantitative skills will be to their employability and other aspects of their lives (as informed and participating citizens).

2.2 The situation in Geography

The discipline of Geography bridges the natural and social sciences and the humanities. It has a long tradition of quantitative methods research and teaching, and led the development of spatial statistical approaches and process modelling in the late 1960s and early 1970s. It was quick to adopt, develop and apply GIS technologies, especially in the late 1980s and early 1990s. More recently, the discipline has also embraced earth observation technologies and numerical modelling as techniques for studying the planet’s surface and subsurface, along with geocomputation, the harnessing of “big data” and the development of new and creative methods of combining, visualising and analysing geographic information.

The ESRC International Benchmarking Review of UK Human Geography (2013) states that “in many sub-disciplines it [Human Geography] is world leading, setting the intellectual agenda ...” but identifies “a relative weakness in quantitative methods and GIS” due to “the relative neglect of quantitative methods in undergraduate and postgraduate training.”
Concern about the status of quantitative methods in the discipline is, however, not a new phenomenon. A century ago, Wallis (1912; 110) documented the same problem, writing: “It has long been a standing reproach that no effort is systematically made to prepare the pupil for later life by teaching him [sic] how to discuss and appreciate the constant numerical appeals to his intelligence which face him then both as a worker and as a citizen.”

For Geography, the “quantitative revolution” of the 1960s and 1970s represented a period when economic theory and appeal to physical principles such as laws of gravity were used to model and to explain social process and the patterns of migration, trade or development. Beginning in the 1970s, such “positivist” approaches fell out of favour (Thrall, 1985; Philip, 1998; Barnes, 2011) as part of the “cultural turn” (common to other social science disciplines too). This resulted in less training in quantitative methods in many undergraduate programmes and the overt rejection of quantitative methods by some human geographers (Cosgrove, 1989). Physical Geography, in contrast, tended to follow the path of the natural sciences, continuing to base research on quantitative techniques (Bodman, 1991).

The geographic literature is full of discussion concerning this issue. For example, the Population Geography Study Group of the Royal Geographical Society (with the Institute of British Geographers) (RGS-IBG) convened a session at the RGS-IBG annual conference in May 1996 on “Multi-method research in Population Geography”. The debate continued in The Professional Geographer with the editor of the papers expressing his regret at the divide between quantitative and qualitative methods—"a form of intellectual hardening that closes minds, restricts insights and undermines our collective understanding" (Hodge, 1995). Another session at the same conference, jointly convened by the Quantitative Methods and Social and Cultural Geography Research Groups, entitled “Reconsidering Quantitative Geography: Social and Cultural Perspectives” aimed to throw the spotlight on Quantitative Geography. These conversations continue today; for example, the session “Do geographers count? Potentials, pitfalls and peer support for teaching QM in Geography” was convened at the RGS-IBG Annual Conference in 2012, with a parallel session at the Association of American Geographers Conference in New York.

There are few more recent papers in the literature on the teaching and learning of quantitative methods in Geography at university. Notable exceptions include comments in the text by Unwin et al. (2011) and the paper of Folkard (2004) who gathered data on students’ perspectives on modules covering quantitative techniques in Geography degrees, with the aim of improving the effectiveness of the modules. Recommendations from Folkard’s study focused on the need for “real world” applications, lots of practice questions, face-to-face tutorial sessions, active participation in lectures, good text resources, and assessments with clear feedback in terms of solution, interpretation and application.

Geography has a strong track record of peer support, knowledge sharing and enhancing pedagogic goals through institutions such as the Geographical Association (GA), the RGS-IBG, the Computers in Teaching Initiative (CTI) Centre for Geography, Geology and Meteorology, contributions to the JISC-funded Teaching and Learning Technology programme, the HEA subject level approach for the Geography, Earth and Environmental Sciences Discipline, and Spatial Literacy in Teaching (SPLINT), a Higher Education Funding Council for England-funded Centre for Excellence in Teaching and Learning. The discipline has always retained a strong desire to teach quantitative methods effectively (see, inter alia, Unwin and Maguire, 1990; Unwin, 1997). The Natural Environment Research Council has also focused attention on the skills deficit in quantitative methods in Environmental Science (Physical Geography) (Natural Environment Research Council, 2012).
Today, it is generally recognised as a mistake to associate quantitative methods only with positivism, to suggest that quantitative methods are necessarily antithetical to qualitative approaches, and to miss their use in critical social analysis (Sheppard, 2001; Kwan and Knigge, 2006; Barnes, 2009; Harris and Jarvis, 2011). Initiatives spearheaded by the Economic and Social Research Council have resulted in more quantitative methods training, particularly for doctoral students, and mixed-method approaches to research either by individuals or through collaborative partnerships are increasingly common.
3 Research objectives and methodology

This report describes research undertaken to investigate the Mathematics and Statistics used and taught in the Geography discipline throughout undergraduate degree programmes and at the transition from secondary to higher education. The specific objectives were to:

- review students’ mathematical and statistical skills in Geography at degree level, highlighting the current challenges in this area;
- document key findings of a survey of university teachers about their experience, familiarity and understanding of mathematical and statistical skills;
- explore the expected level of competency of school leavers commencing university undergraduate degree programmes, from the perspective of teaching staff in both schools and universities;
- highlight opportunities for interventions to address critical gaps/issues;
- identify and share key recommendations.

To achieve this, a combination of a literature review, analysis of UCAS and Higher Education Statistics Agency (HESA) data, online reviews of undergraduate programmes, surveys, interviews and focus groups were undertaken. Throughout this report these different sources of data are used. Particular emphasis is placed on the responses from the surveys and focus groups to answer questions regarding: the mathematical and statistical knowledge and skills of students entering Geography degree programmes; the confidence levels and training of university instructors teaching quantitative methods and the challenges they face; how and where quantitative methods are taught in university degree programmes; and examples of student support and quantitative methods teaching practice in universities.

The HEA STEM project team developed three questionnaire-based surveys, designed for use across several disciplines, with minor changes for subject specific wording. Slightly broader Geography-specific surveys (these included opportunities for free text answers, for example) were written by the authors, and these were adapted to include questions from the HEA STEM surveys and tailored to the Geography discipline in terms of language and likely quantitative methods content. The first survey was aimed at instructors in Geography departments in universities. The second was aimed at Geography heads of department or heads of teaching. Taken together, these two surveys comprise the HEA STEM staff survey in Geography. The instructors’ survey was made available online using the SurveyMonkey platform. Hard copies were also handed out at higher education events at the RGS-IBG. The heads of department surveys were conducted as interviews either over the phone or in person. A total of 74 instructors responded to the online survey and 16 interviews with heads of departments were completed. Inevitably this means there is more than one response from some institutions, with the data in this report coming from respondents rather than institutions. The range of responses covered 50 different institutions, Russell Group and non-Russell Group, geographically distributed across the UK. Quotations from the survey responses and interviews in the report text are not attributed so as to maintain anonymity.
The third survey (the HEA STEM student survey in Geography), was aimed at students and was distributed via: (i) student Ambassador events at the RGS-IBG and at UK institutions; (ii) online via heads of departments, with a request to forward on to their students; and (iii) hard-copy hand-outs by instructors in their home institutions and at events at the RGS-IBG. This yielded 795 responses reported here.

For each of the surveys, not all respondents answered every survey question which accounts for the varying number totals for each question in the results section.

It is important to note that the content of degrees which have the title “Geography” may vary widely between universities. Most Geography degrees, whether designated BSc or BA, offer combinations of individual human, physical and environmental Geography modules in each year of study. A number of institutions also offer Joint Honours Geography degrees with a diverse range of subjects. A Geography department is defined in this report as a department that offers a degree programme in Geography (as listed by UCAS). Such departments might be called something other than Geography. There are approximately 65 departments that fall into this category, teaching a total of approximately 24,000 undergraduate students. Of these, 82% are taught in England, 10% in Scotland, 6% in Wales, and 2% in Northern Ireland.

The data do not constitute a random sample and their analysis is limited to simple descriptive statistics. To complement them, a literature review of the current policy, initiatives, papers and reports related to quantitative methods in Geography was undertaken, using keywords including variants of teaching and learning; quantitative methods, skills, Statistics, Mathematics, GIS content; and searches in selected pedagogic journals in the discipline. In addition, an online audit of university Geography departments was carried out to review entrance requirements, and find out more details about how and where quantitative methods are taught in the degree programmes. This captured information on entrance requirements and Geography degree programme module names. Data were also analysed from UCAS on the qualifications held by students and on the A-level subjects taken by students enrolled on a Geography degree programme in the UK.

An HEA STEM Tackling Transition event was convened at the University of Reading in February 2013 to facilitate a discussion between secondary school teachers and higher education academics to consider the transition between the two sectors. The discussion focused on how and where quantitative methods are taught, what quantitative methods knowledge and skills students are expected to have, and what can be done to ease the transition. In total there were 21 attendees: 6 were school teachers, 7 were university instructors and the others were representatives of school examination boards, postgraduate students (who acted as note takers), the authors and staff of the HEA.

The perspective on quantitative methods used in the HEA STEM project in the Geography discipline is broad. Quantitative methods include, but are not limited to, data manipulation, presentation and analysis, visualisation, mapping, cartography, Statistics, GIS, and modelling. Throughout this report, the term quantitative methods is used to encompass all these methods, except where Mathematics and Statistics are explicitly referred to in survey questions and responses.

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3 The Geography Ambassadors scheme run by the RGS-IBG recruits, trains and supports undergraduate, postgraduate and graduate geographers from universities and businesses to act as ambassadors for Geography in the classroom and beyond.

4 The dataset lists the proportion of accepted applicants to institution subject areas who are recorded as holding the listed qualifications.
4 Main findings

4.1 How quantitative are Geography degree programmes?

Based on the responses from the interviews, instructor surveys, focus groups and online reviews, there is no evidence to suggest that any degree programmes in Geography are purely qualitative in nature. However, the amount of quantitative methods taught and how it is taught in the degree programmes varies considerably. At one end of the spectrum, there is very little quantitative methods content in the degree programme and data analysis is covered only in the fieldwork skills module or similar, the software used is Microsoft Excel™, and no inferential statistics are taught. Such instances are rare and associated solely with BA programmes. At the other extreme, quantitative methods are embedded into most BA and BSc modules of the degree programme, with a wide and in-depth range of quantitative methods taught, including inferential statistics, GIS content, spatial modelling, and visualisation.

Of the 55 instructors who responded to the relevant question on the HEA STEM staff survey in Geography, 38% (21) said the degree programme they teach on is evenly balanced in terms of qualitative-quantitative training; 42% (23) that the programme is either more qualitative than quantitative or mainly qualitative; with only 20% (11) indicating the programme is more quantitative than qualitative. It is important to caution here that instructors from different institutions may have different interpretations of what is meant by the term quantitative methods. Although all institutions will use or show numeric information in some way, it is clear that the level of teaching and complexity of the methods taught vary greatly.

4.2 The learning and teaching of mathematical and statistical skills

Based on a review of 65 Geography department websites, to determine how Geography degree programmes are structured, the majority (89%, 58 of 65) include a standalone module in the first year that contains a component of quantitative methods teaching. The vast majority of these modules are not explicitly named “Quantitative Methods” but are called, for example, “Key Geographical Skills” or “Research Methods in Geography”. Only 11% (7 of 65) of the programmes include “Quantitative Methods” or “Statistics” in the title of the module.

Overall, the results from the interviews with heads of departments or heads of teaching in the HEA STEM staff survey are consistent with the insights from the online audit. From both it is clear that where and how much quantitative methods is taught in a degree programme varies considerably between institutions. Of 16 respondents, 88% (14) replied that in their institution quantitative methods are taught as part of standalone modules in the first and second year of the degree programme and such modules are compulsory for all Geography students.

The extent to which quantitative methods are embedded into the rest of the degree programme also varies considerably, but it is very common for data and quantitative methods to be heavily embedded in Physical Geography modules, but with very little or no data or quantitative methods embedded in some Human Geography modules. This is the case in 69% (11) of institutions (based on interviews with 16 heads of department or heads of teaching as part of the HEA STEM staff survey).
When asked about which quantitative methods are taught in the standalone modules in the degree programme, of 56 responses from instructors and heads of departments, a sub-set of all those who responded, 80% (45) stated “Statistics” (Figure 1). The range of Statistics again varies between institutions: 48% (27) specifically mentioned descriptive statistics and 25% (14) mentioned inferential statistics. Not all respondents gave more details about the type of Statistics used. Some respondents went further to describe specific methods such as regression, correlation, parametric and non-parametric tests, and specific examples such as the t-test. One-third specifically stated GIS content was taught. Spatial analysis, Mathematics, and using secondary data, such as the census, also were mentioned.

5 This list is unlikely to be definitive.
Table 1: Software used for quantitative methods. Data from HEA STEM staff survey (N=56).

The HEA STEM staff survey showed that Microsoft Excel™ and SPSS™️ are the most commonly used software for descriptive statistics (Table 1). Of 56 respondents, 21% (12) also use additional types of software for descriptive statistics including Minitab®, Stata® and R®. 59% (33) use SPSS for inferential statistics. Most institutions only use one type of software for each quantitative methods module, such as SPSS for Statistics and ArcGIS for GIS content. However, there are a few institutions that use a wider range of software. The widest range of software reported by a single institution included seven components: Microsoft Excel, Stata, SPSS, Minitab®, MATLAB®, R and ArcGIS®️.

In undergraduate degree programmes, skills in quantitative methods are also developed through fieldwork and final year dissertations. Fieldwork allows students to gain an interactive learning experience and enables them to understand the methods of acquisition and limitations of field data (see further elaboration by Butler, 2008). The final year dissertation, a requirement for most students, provides special opportunities for enhancing application of, and training in, quantitative methods.

Some examples of approaches to teaching quantitative methods at higher education institutions in the UK that were identified during the work include the following.

6 SPSS is a trademark of IBM.
7 Minitab is a Statistics package developed at the Pennsylvania State University.
8 Stata is a general-purpose statistical software package created in 1985 by StataCorp.
9 R is an open source software programming language and software environment for statistical computing and graphics.
10 MATLAB®️ is a high-level language and interactive environment for numerical computation, visualisation, and programming.
11 ArcGIS is the mapping and spatial analysis GIS software of Esri.
Embedding data in modules throughout the curriculum: Instructors embed techniques in many of the Geography modules, focusing on the use of contemporary and national examples to emphasise the relevance of data. This prompts students to think about issues and contextualise the data. There is a strong link to policy in the degree programme and the need for rich evidence is emphasised. During classes, examples of the work the instructors in the department have done for the clients using data and quantitative methods, are used. This also serves to help students at this institution understand that in a future job, they may well be dealing with data and its analysis.

“Convincing Stories”: A cross-faculty unit (across the social sciences) showcases the use of quantitative methods as evidence in the social sciences. The work looks at how numbers are used (and abused) to create “stories” in the media, public policy, and in social and scientific debate. Focus groups are organised with students to find out how students are responding to the module.

Dissertations: Programmes explicitly link the instruction of quantitative methods to student dissertations, with quantitative methods heavily embedded in a high proportion of the degree modules. Extra workshops on data handling and Statistics, led by students, are available prior to the dissertation module, both for human and physical geographers.

4.3 Mathematical and statistical requirements

The learning outcomes associated with a subject programme are outlined in a discipline’s QAA subject benchmark statement. At the time of writing (Spring 2014) the Geography subject benchmark statement (Quality Assurance Agency for Higher Education, 2007) is under review. The subject benchmark statement outlines that GIS content and remote sensing are distinct teaching areas that are incorporated in the breadth of subject matter covered by “Geography”. In the 2007 statement these are classified as a category alongside Human Geography, Physical Geography and Environmental Geography. The Geography subject benchmark statement outlines that a main aim of an honours degree programme in the discipline is to equip students with a range of academic and transferable skills including the ability to interpret and analyse information, with the use of appropriate information and communication technologies (ICT). Discipline-specific skills that relate to learning quantitative methods are “employing a variety of technical and laboratory based methods for the collection and analysis of spatial and environmental information (e.g. GIS content, remote sensing, statistical and mathematical modelling)”. Although the statement clearly describes quantitative methods and familiarity with the associated technologies as key skills in a Geography degree, the statement does not specify what constitutes quantitative methods. Other statements are somewhat open-ended. For example, “Students should be able to effectively and appropriately interpret and use numerical statistical information and apply basic numerical skills to geographical information”. In terms of assessment, the statement summarises that Geography students are likely to encounter practical work that includes quantitative and qualitative analysis as a form of assessment during their degree.

The QAA subject benchmark statement for Geography (Quality Assurance Agency for Higher Education, 2007) is similar to that of other social sciences (Quality Assurance Agency for Higher Education, 2014) in that it does not specifically outline the quantitative methods needed by Geography students. However, the statement for Geography is more detailed than most social science discipline statements (such as Politics and Sociology). The statement for Economics, in contrast, is much more explicit with specific reference to numeracy. In comparison, the Earth Sciences, Environmental Sciences and Environmental Studies subject benchmark statement has a specific section under key skills outlining the numeracy, computing and information technology skills students should have, including “preparing, processing, interpreting and presenting data, using appropriate qualitative and quantitative techniques and packages including GIS”. It also explicitly considers sampling.
4.4 Issues surrounding skills in Mathematics and Statistics

The key issues highlighted by the instructors and heads of department in the Geography HEA STEM staff survey are outlined below, illustrated with quotations that capture the essence of the points being made.

First, in terms of the lack of resources for instructors in universities, the issues highlighted included the lack of time, difficulty in finding teaching resources, and software and other issues such as lack of data storage space. As one respondent stated: "It is hard to find good resources for instructors, and very difficult to find interesting and manageable geographical data." Comments were also made about the way quantitative methods are taught. As another respondent stated: "Statistics are cumulative; they all build on each other so you can’t just pull out which bits fit to certain topics or parts of the curriculum." Concerns were also expressed about Geography at school level, comments here highlighted concerns that students are not covering the appropriate range of quantitative methods in the school curriculum and that there are problems with standardised assessment (i.e. quantitative skills are not necessarily explicitly linked with assessment). One instructor stated: "At A-level there is a lack of ambition to do interesting things with secondary data sets – part of the reason given is they are hard to get and hard to understand."

In the HEA STEM student survey, 37% (292 of 795) of students who responded to the question said that they agreed or strongly agreed with the statement: “I struggle with quantitative methods.” Students’ anxiety about quantitative methods was also raised in the HEA STEM staff survey, where 94% of respondents (44 of 47) stated that an inhibiting factor for students who struggle is Mathematics and/or Statistics anxiety. This is illustrated by the comments of one specific instructor, “Students have a fear of/mental block to Mathematics – at school pupils develop blinkers which convince them of their inability to do Mathematics, it’s difficult to unpick this at HE”. Of 47 responses from instructors, 43% (20) said an inhibiting factor for students who struggle is the failure to see the relevance for Geography. As one of these respondents stated: “Some students took Geography as they didn’t like the numerical content of other science subjects.”
Figure 2: Instructors’ response to the question “For students who struggle with quantitative methods, which factors typically inhibit their development in this area?” N = 47.

Other challenges identified included the issue of teaching mixed groups. Students in Geography programmes have a wide range of backgrounds and knowledge and skills in Mathematics and Statistics (see section 4.6), and instructors find it difficult to provide enough support and attention to those who are struggling, while at the same time engaging and challenging those who are more knowledgeable. Also, many instructors (79%, 37 of 47) stated that lack of confidence is an inhibiting factor for students who struggle (Figure 2).

The following comments were made by staff respondents concerning factors that inhibit students’ development.

“Those students who need to engage the most, i.e. with the lowest levels of quantitative methods skills, are the least likely to engage with the module and this can lead to a situation where those who have the potential to be most engaged, e.g. students with better quantitative methods skills become disengaged because the module is not challenging enough.”

“It’s very variable; some find quantitative methods in Geography patronisingly basic whereas others really struggle.”

“It is seen as socially acceptable to have poor statistical skills in a way that poor written skills are not.”

“Students don’t expect the degree to be quantitative…”
4.5 Entrance qualifications

The number of students entering A-level Mathematics has increased steadily since 2006, with a 33% increase in the last five years from 64,593 to 85,714 pupils (Department for Education, 2013a). Correspondingly, the proportion of students entering university to study Geography who have an A-level in Mathematics has also increased, from 15.8% to 19.4% from 2006 to 2009 (Onion and Follett, 2011). Data acquired by the RGS-IBG from UCAS\(^{12}\), includes data on possible combinations of the 20 most popular A2 level qualifications taken for those accepted onto a Geography degree programme (with the UCAS codes F and L). It does not provide data on A-level alternatives such as Scottish Highers or the International Baccalaureate. The data show that the proportion of students with Mathematics A-level has increased from 11% to 20% between 2003-2011 (688 students out of total 6,513 in 2003; 1,286 out of a total of 6,544 in 2011). The most popular combination of three A-levels taken by students on a Geography degree in 2011 was Geography, Biology and Mathematics. In 2003 the most popular combination was Geography, Biology and Chemistry. Students may have also encountered quantitative methods in subjects other than Mathematics at pre-university level, such as Physics, Economics and Psychology. In 2011, the most popular combination of only three Social Science subjects including Geography was Geography, Psychology and Sociology.

A report by the Advisory Committee on Mathematics Education (2011) suggested that many university programmes do not state clearly the level of mathematical skills required, leading students to be incorrectly advised in their choices for A-levels or equivalent and underprepared when entering university. A review of entry requirements on higher education institution Geography department websites found that of 121 Geography degree programmes (BA or BSc Geography), only 45% (54) explicitly state some Mathematics-related entry requirement. Six programmes (5%) recommend A-level Mathematics or equivalent qualification as a choice from a list of preferred subjects. However, only two programmes specifically encourage A-level Mathematics. Overall, Geography departments tend not to be prescriptive about any specific subject entry requirements.

This is consistent with the responses from the HEA STEM staff survey, which revealed that of 76 respondents, 35 (46%) said there was a minimum Mathematics entrance requirement for their programme. (Note that because it is respondents being referred to here and not institutions, there may be some double counting of institutions.) However, from interviews with heads of departments, it is clear that there is a common expectation that students should have at least good GCSE level Mathematics skills. Therefore there is a disconnect between the explicitly stated requirements for students and what universities expect. There is a need to explicitly signal to the secondary sector and prospective students that GCSE level Mathematics is the minimum skill set required for undertaking a Geography degree and that quantitative methods will be part of their undergraduate degrees.

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\(^{12}\) This data shows selected qualifications held by UK domiciled accepted applicants from [http://www.ucas.ac.uk/about_us/stat_services/stats_online/selectedqualificationsheld](http://www.ucas.ac.uk/about_us/stat_services/stats_online/selectedqualificationsheld). These qualifications may not be required or accepted by an institution for entry. Institutions may require or accept qualifications that are not included in this data. For definitive information about entry requirements for individual courses see [www.ucas.com](http://www.ucas.com) or institutions’ own websites.
4.6 Diagnostic testing

Of 76 responses to the HEA STEM staff survey, only seven (9%) indicated diagnostic testing took place to determine the level of students' Mathematics/Statistics knowledge and skills. These positive responses come from six different institutions. The diagnostic testing takes the form of either a written or online test, or an introductory assignment. Respondents indicated that when diagnostic testing does take place its primary purpose is to assess the knowledge and skills of a student intake, rather than to group students into different module streams. It can also allow students with individual needs to be directed to the appropriate support.

In responding to the survey, one academic noted that their institution would be introducing diagnostic testing in the 2013/2014 academic year and another institution, despite not conducting specific quantitative methods testing, stated they do conduct computer skills diagnostic testing (for example in Microsoft Excel™).

4.7 Additional support

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<tr>
<td>None</td>
<td>5</td>
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<tr>
<td>Supplementary</td>
<td>16</td>
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<tr>
<td>Online resources</td>
<td>38</td>
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<td>In-class support</td>
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<td>Supplementary workshops or sessions</td>
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<tr>
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</tr>
<tr>
<td>Drop-in services provided by the University</td>
<td>44</td>
</tr>
<tr>
<td>Student Mentoring</td>
<td>13</td>
</tr>
<tr>
<td>Other (Extra tutorials; Open door policy for students to drop in and ask questions; Maths support centre; Supplementary training sessions; Mathematics/Statistics support staff member; Personal meetings with instructor)</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 2: Response to question “What forms of additional support are made available to students needing extra assistance with their mathematical and/or statistical knowledge and/or skills?” Each respondent (N=74) could give more than one response.

In the HEA STEM student survey, 57% (450 of 795) of students said that they agreed or strongly agreed with the statement “I can easily access quantitative methods support resources through my university”. A number of support methods are available to students who are struggling with their Mathematics and Statistics knowledge, although this support is not directly linked to entry qualifications in any Geography department. A total of 74 individuals responded to the question in the HEA STEM staff survey on the forms of student support available (Table 2). They each selected at least one form of support. The most
common method of support reported is drop-in services provided by the university (59%, 44 of 74). Only 7% (5) said there was no extra support available for students. 18% (13) said there was student mentoring at their institution for help with quantitative methods. Other forms of support mentioned were personal meetings with the instructor or an "open door" policy.

Of the 50 instructors who responded to the question about when support is provided, 46 stated that support was provided to students in all years; the remaining four highlighted support just in the first year:

Several examples of methods of delivering assistance for Geography students have been identified including:

- a Mathematics support centre focused on support for foundation, first and second year students whose programmes contain a mathematical element, but not those who are taking a dedicated Mathematics degree;
- student mentors. The student mentors (either third year or postgraduate students) organise training workshops for first and second years in Microsoft Excel™ and using quantitative data;
- a part-time (three days a week) Statistics and Mathematics support officer, who is available to advise Geography students on any aspect of Mathematics, Statistics and numeracy.

4.8 Teaching of mathematical and statistical topics

Of the 66 respondents to the question in the HEA STEM staff survey, 60 (91%) said that quantitative methods modules are taught by members of the Geography department. Of those that said it was not taught by members of the Geography department, three (5%) said quantitative methods content was taught by the Mathematics or Statistics departments in their institution and in one by the Biology department. One department had a part-time tutor to teach quantitative methods and one had a contracted member of staff. In terms of the responses of the Heads, 12 out of 16 indicated that decisions about instructors for quantitative methods modules were based on experience; three highlighted the currency of that experience; and five the preference of the instructors.

Heads of departments and directors of teaching were asked: “Do the members of staff teaching quantitative methods undertake any training which is specifically tailored to the teaching of quantitative methods?” Of the 13 responses to this question only one said yes, describing the training as “optional workshops held at the methods and data institute of the institution, which staff are encouraged to attend”. 59 of 66 respondents to the instructor’s survey indicated that they had not participated in specific training on the teaching of quantitative methods.

From 44 responses, 80% (35) of the lecturers said they were either confident or very confident in their subject knowledge of the quantitative methods they teach, with only 12% (5) unsure or very unsure (Figure 3).
Figure 3: Response from instructors to the question “How confident are you about your subject knowledge of the quantitative methods you teach?” N = 44.

Figure 4: Response from students to the question “How well did your experience of quantitative methods at school prepare you for university?” N = 795.
4.9 Students’ expectations

The HEA STEM student survey asked students how well their experience of quantitative methods at school prepared them for university (Figure 4). Of the 795 students who responded, 43% (342) said they were well or very well-prepared, 34% (270) said they were adequately prepared and 23% (183) said they were poorly or very poorly prepared. In the HEA STEM staff survey, a similar question was asked about how well-prepared students are in terms of Mathematics or Statistics skills to undertake a Geography degree programme. It is clear that there is a notable difference in the perspectives of these two groups. Of the 50 instructors that responded, 74% (37) said students are not very well or not at all prepared in terms of Mathematics/Statistics skills, 24% (12) said the students were adequately prepared and 2% (one) said the students were well or very well prepared. The instructors’ perception of student preparedness for the amount of mathematical and statistical requirements of Geography at degree level varies between institutions. The following quotations illustrate the point.

“Many human geographers think it is totally unnecessary/optional for them and resent having to do it. There is a sense of just having to pass rather than quantitative methods being essential skills of a geographer.”

“By and large the students cope well and get on with quantitative methods, they should be given more credit.”

A common response from students as to why they felt well-prepared for quantitative methods at university was because they had taken Mathematics and/or Statistics at A-level. However, comments from instructors indicate students who have Mathematics A-level are not necessarily better prepared at university for quantitative methods. Several instructors (particularly those from universities with high entrance requirements such as three As at A-level) indicated the problem was more to do with students engaging with quantitative methods.

An instructor made the following comment: “One challenge is getting the students to apply QM to a real world problem”.

Another challenge highlighted is the way quantitative methods content is currently taught which was described by one respondent as: “old fashioned and therefore dull, which affects student engagement”.

When asked how well they thought students’ expectations about the Mathematics and Statistics skills requirements of Geography higher education undergraduate programmes matched with reality, 62% of instructors (28 of 45) responded that the students do not know what to expect and that the students underestimate the skills requirements. What is curious about this difference between instructor and student perceptions is that 51% (402 of 795) of the students asked were in their second year of the degree programme and therefore had taken quantitative methods modules and had, presumably, been assessed. Their attitudes towards preparation can therefore not be described as wishful thinking. It may instead be a problem of recall, a testimony to the instructors’ capacity to teach the students, and/or a frustration from the instructors that the students are not as well prepared as they would like.

The instructors were asked which quantitative methods students find most difficult. 41 instructors responded; 29% (12) indicated inferential statistics, 17% (7) statistics more generally, and 15% (6) basic numeracy. Others highlighted difficulties with software and Mathematics.
4.10 The secondary sector’s understanding of higher education skills requirements

A discussion at the HEA STEM Tackling Transition event between secondary school teachers and higher education institution instructors revealed the lack of shared understanding across the sectors in terms of: (i) students’ preparedness in quantitative methods; (ii) where quantitative methods are taught in the school curriculum and in the degree programme; and (iii) the expectations of students. The event was held at the University of Reading in February 2013. In total there were 21 attendees, including 6 school teachers and 7 from higher education institutions. The remainder were representatives of examination boards, HEA and project staff, and postgraduate students (who acted as note takers). Although the number of attendees was low, the discussion did confirm findings from other sources.

There was strong agreement by the workshop participants that including numeracy, familiarity with data handling and analysis, and units/measurement needs to be encouraged more at school level. Some delegates expressed the view that less focus was needed on specific statistical techniques. Arguments were made for students being able to look at data to see patterns and trends. Moreover, it was felt that students should be able to use databases and to extract and interpret the results. Essentially it was agreed that there is a need to encourage familiarity and comfort with data – to be hands-on and confident in working with data rather than memorising the particularities of any given statistical test.

Those in the secondary sector stressed that there is no clear message from the higher education sector about what quantitative skills are necessary to be taught at secondary level, rather the only message they hear is that students need high grades. The university instructors highlighted the confidence issue/anxiety of many students: “For those students without an A-level (or equivalent) in Maths, they shy away from even the most basic of Mathematics, even to the point of simply disregarding [the equation of a straight line] for no other reason than... ‘I can’t do Maths.’”

The key barriers to teaching in secondary schools highlighted by teachers included lack of time, the absence of opportunities in the curriculum to teach quantitative methods and the challenges in teaching and assessing GIS content to get students prepared for university. These problems have been exacerbated by the removal of coursework in assessments at school-level and opportunities to demonstrate a range of these skills in independent work having diminished.

In line with many previous discussions, a key theme that emerged from the discussion at the event was that more communication between the higher education and the secondary sector is needed to better understand the demands and expectations of each. Some specific suggestions came forward from individuals at the event. One was that higher education institutions could invite teachers to follow a Geography degree programme to better understand current content. The teachers could sit in on a first year quantitative methods module, for example, to see what is being taught and feedback to students. This may be different to their experience at university.

A second suggestion was that university lecturers should be more engaged in keeping up with developments in qualifications such as A-level. It was suggested that many instructors do not know what is currently in pre-university Geography curricula. Recent changes in educational policy to encourage greater involvement of the higher education sector in the secondary sector may serve to address this area (Department for Education, 2013b).
4.11 What needs to change?

A number of suggestions from instructors, heads of teaching and heads of department were made through the HEA STEM staff survey highlighting interventions that they believed would be most beneficial for the teaching of quantitative methods. Five main areas were identified.

**Teaching resources and workshops**

Open learning resources for university teachers that show how to teach core techniques would be valuable. University instructors are keen to make teaching more lively, engaging and interesting and identify the need for workshops for teachers on how to motivate students and transmit that enthusiasm to an audience “that sees a number and reacts with blind panic”. Requests were also made for extra resources to employ more teaching assistants per practical class, to gain access to datasets for student use, and to create a greater variety of tasks that are individual for students, rather than all the students working on the same dataset or task. Extra resources are already being made available, particularly online; for example there are an increasing number of tutorials available for open source software such as R. A number of teaching datasets are available through the UK Data Service (UK Data Service, 2013) but these do need to be better publicised.

**Teaching with relevant/real-world examples**

University instructors highlighted the benefits of teaching with relevant examples and datasets, either using their own research or using examples from students’ dissertations. Other opportunities using open tools such as Google Earth (Thorndycraft *et al.*, 2009), or other widely available visualisation technologies, to “tell stories” with data in more imaginative and engaging ways were suggested. Other suggestions were to utilise opportunities to work with the Office of National Statistics census data, or use real-world policy or risk and hazard examples.

**Changes to school secondary level curricula**

Some respondents felt that students are not exposed to enough quantitative methods teaching in Geography at secondary level. Suggestions to counter this are for students to work more with data and that more statistical analysis should be incorporated into the syllabus at Geography A-level or equivalent. There is also a strong recommendation for the need to change students’ views on Human Geography at school level; i.e. that it incorporates the study of small and large datasets, primary and secondary data and a variety of quantitative methods.

**Linking quantitative methods to student dissertations and to employment**

To improve student motivation to study quantitative methods and to demonstrate their importance and value, it has been suggested that degree programmes need to be designed to emphasise to students the value of using data in their dissertations. Good examples of this approach do exist. It is also seen as important to stress the role of quantitative methods in enhancing employability and the need to build confidence in using quantitative methods.

**Change the way quantitative methods content is taught in higher education**

Several suggestions were made for how the teaching of quantitative methods could be changed in higher education – these related to university instructors being more aware of the quantitative skills students are likely to have on starting a Geography degree programme in their institution; to better integrate standalone and embedded modules through the degree programme; and in an era of “big data” to focus on using large datasets to “infuse a sense of the modern”.


5 Conclusions

The degree programme, entry requirements and diagnostic testing

The findings of this work do not discount what some regard as the diminished importance given to quantitative methods in Geography (especially in Human Geography), nor the frustration and sometimes lack of support given to those who teach quantitative methods. Yet no evidence was found that the teaching and learning of quantitative methods have been abandoned. Based on the reviews of online information about programmes and the responses from the HEA STEM staff survey, there is no evidence to suggest that any Geography degree programme is purely qualitative in nature; each programme appears to incorporate some element of using or interpreting numeric data.

It may be that what is taught is insufficiently demanding (mathematically or statistically) to meet more advanced research needs, and to compete with levels of training found in other countries (as has been documented by the Economic and Social Research Council and others). Moreover, some of the training may lack currency and is not necessarily the most appropriate for effective analysis, visualisation and handling of “big data”.

The amount of quantitative methods taught in degree programmes does vary considerably between institutions, as does the manner of its teaching, in terms of whether it is taught in standalone modules or embedded in other modules. Most programmes provide training in descriptive and inferential statistics, GIS content and some data handling. Excel, SPSS and ArcGIS are the most commonly used software applications, but some institutions use a wider range of software. The growth of R as a teaching and research tool is evident, facilitated by a large user community, free availability, interoperability across operating systems and a growing number of Geography-focused tutorials on its use.

An online review of entry requirements listed on university Geography department websites found that less than half (45%, 54 of 121) explicitly state some form of Mathematics-related entry requirement. Only two programmes explicitly encourage A-level Mathematics.

Diagnostic testing to determine the level of students’ Mathematics/Statistics knowledge and skills is very limited in Geography programmes. In the HEA STEM staff survey only 7 of 76 respondents said that such testing was used.

QAA subject benchmark statement

Although the QAA subject benchmark statement for Geography clearly identifies quantitative methods and familiarity with the associated technologies as key skills in a Geography degree, the statement lacks specificity in its definition of quantitative methods and the skills and methods of particular importance.
Instructors’ concerns about teaching quantitative methods in universities

Instructors and heads of department in their responses to the surveys administered as part of this study highlighted a lack of resources to support teaching quantitative methods: this includes lack of time, difficulty in finding teaching resources, problems with access to or use of software, or adequate data storage capacity. Respondents were also concerned that school students were not covering the appropriate range of quantitative methods in the GCSE and A-level Geography curricula.

High levels of anxiety were expressed by students about quantitative methods. 94% of the 47 instructors who responded on the issue stated that an inhibiting factor for students who struggle with quantitative methods is anxiety about Mathematics and Statistics. This is most evident in those students who have not taken some form of post-16 qualification in Mathematics.

Students’ expectations of the degree programme

The results from the surveys indicate a notable difference of opinions between students and academic staff on how well prepared students are in terms of quantitative methods. Of the 50 instructors who responded on this issue, 74% (37) said students are not very well or not at all prepared in terms of Mathematics/Statistics skills; in comparison only 23% (183 of 795) of students said they were poorly or very poorly prepared.

Most instructors responded that the students do not know what to expect and their perception is that students underestimate the skills in quantitative methods that will be required in their degree programme.

Secondary teachers and higher education instructors

The HEA STEM Tackling Transition discussion highlighted the lack of shared understanding across the sectors in terms of students’ preparedness in quantitative methods, where these are taught in the school curriculum and in degree programmes, and the expectations of Geography students in terms of mathematical and statistical skills at university. Secondary school teachers and higher education instructors agreed that there is a need for particular attention to handling data, especially large datasets.

Overall, it must be emphasised that although the focus of this study was on quantitative methods, there is no intention to suggest that there should be a dominance of quantitative methods at the expense of a qualitative, or any other, approach. Geography as a discipline benefits from a diversity of perspectives and methodologies. Although there is not such a large under-capacity surrounding the teaching of quantitative methods in Geography as there is in some social sciences (Parker et al., 2008), there are still some concerns that need to be addressed.
6 References


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Project support for discipline work

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