An independent review of quantitative methods in A Level geography

Royal Geographical Society with IBG

Advancing geography and geographical learning

- Report for Royal Geographical Society (with IBG)

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The Royal Geographical Society (with IBG) welcomes this independent review of the quantitative methods in A Level geography undertaken by Richard Harris, Professor of Quantitative Geography, University of Bristol.

This is a timely review undertaken nearly two years after the first assessment of the new A Level geography specifications in 2018. It also provides an update on comparable work previously undertaken across a range of subjects by the Nuffield Foundation in 2012.

The Society welcomed the new A Levels and had advocated for a strengthening of the quantitative/data skills elements of these courses. This was achieved through the integration of such methods within the required content of the specifications, rather than as a separate element, and also through the reintroduction of assessed coursework (known as the Independent Investigation or non-examined Assessment (NEA)). The coursework provides significant opportunities for students to apply quantitative (and qualitative) approaches to their own geographical investigations, including the collection, analysis and review of primary geographical data and the comparison of their data to secondary data sources.

At A level (and GCSE) geography is one of the best gender balanced of all subjects, recruiting equally between female and male students (51% F, 49% M, JCQ 2019). This report is a welcome reminder of how geography provides significant opportunities for both young women and young men to develop their mathematical, statistical and data skills abilities through a subject which relates these methods to real and relevant investigations into the world's people, places and environments.

This report will be of interest to A level geography teachers, Higher Education geographers, Awarding Organisations, Ofqual and other A level subjects across the social and physical sciences, which also carry significant elements of data skills.

The Society thanks Professor Richard Harris for producing the report and the Nuffield Foundation, who funded the Data Skills in Geography programme.

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Introduction

In 2012, the Nuffield Foundation published a report entitled *Mathematics in A Level assessments* that looked at six of the larger subjects associated with the social sciences, one of which is geography.[1] The report's motivation was the relatively low participation in post-16 mathematics (as a free-standing subject) in England, Wales and Northern Ireland when compared to other countries. It recognised that exposure to maths – in a broad sense that includes numeracy, data handling and statistical skills, as well as the interpretation and communication of quantitative information – is not confined to mathematics classes but can be present in the teaching, learning and disciplinary skills taught to and required of pupils in other subjects. With that in mind, the report was interested in the amount (extent), difficulty and types of mathematics assessed by examination in each subject, using the summer of 2010 exam papers as the benchmark to evaluate those criteria. It found little by way of a typical student experience because of "significant variation" (p. 6) arising not just from the differences between Awarding Organisations (AOs) – in regard to their subject content and how it was examined – but also *within* them, arising from the differences between the units available and, within units, between the choice of questions answered. However, where it was encountered, much of the mathematical content involved statistics (which need mean 'only' the interpretation of 'statistical', i.e. quantitative, data) and the combination of subject-specific reasoning with simple mathematics.

At the time of the review, A Level geography, common with other subjects, was 100 per cent assessed through unseen examination (with no coursework element). For geography, the most common type of mathematics skill required in examination was statistical interpretation – translating information and drawing conclusions from summary data, graphs and maps. Across five AOs, and with one exception, the report "found few, if any, questions which were mathematically complex" (p. 13). In most cases, "the assessments required subject-specific reasoning combined with a fair understanding of graphical and statistical methods." Some questions, "referred to students using their own work, data or fieldwork" (p. 14),

[1] Nuffield Foundation (2012). *Mathematics in A level assessments.* London: Nuffield Foundation. Available at: https://www.nuffieldfoundation.org/sites/default/files/files/Maths_in_A_level_Assessments_Nuffield_Foundation_WEB.pdf

introducing a further source of variability between students.

Overall, the percentage of marks that *required* mathematics (of any level or type) for geographical examination was estimated to range from 10 to 20 per cent across the AOs. The extent of that range is exaggerated by an outlier at the lower end: only one AO had less than 16 per cent. The percentage of marks that could be gained using mathematics was estimated to range from 19 to 35 per cent, amongst which three AOs were estimated to be at approximately 25 per cent. The AO that had the highest potential offering (the 35 per cent) also required the most mathematics; however, the AO offering least marks overall was not the one requiring least. The report does not identify the names of the AOs.

Since 2012, the nature of the examination in geography has changed: 20 per cent of a student's final marks are now allocated to a non-examined assessment (NEA) – an individual and independent study incorporating fieldwork. This was not considered in (since it did not apply to) the previous report but now adds to the difference between geography and other subjects. In any case, there is a further source of variation making comparisons across subjects difficult both in 2012 and today. This is the nature of the maths itself. For geography, the report identified geography-specific mathematics that include the use of geographical co-ordinate systems, choropleth mapping, and the interpretation of spatial data – what may be regarded as spatial as well as statistical literacy. These mathematical skills were not found in the other disciplines. This suggests that the types of mathematics found in geography curricula are linked to the types of knowledge and practices that are valued within the discipline. For geography, that is thinking spatially, and includes identifying and exploring the causes of spatial variation and of spatial clustering, at a variety of geographical scales.

Since 2012, considerable changes have been made to A Level (and to GCSE) geography, with the introduction of new content and changes to the subject specifications for geography across all AOs. These changes provided opportunity to place greater emphasis on mathematical and data skills within geography and, as outlined below, a concerted effort was made to do so. To judge the success of that effort, a review has been made of the 2018 A Level papers, mimicking (but not exactly replicating) the approach of the 2012 report. It is that review that is reported on here. The conclusion from that review could be interpreted as saying very little has changed, which, in terms of the amount and difficulty of the maths now found in unseen examination, may well be true. However, this new report also recognises, (a) the re-introduction of the independent study with the opportunity for data skills that it provides (this study is also known as the non-examined assessment or NEA where 'non-examined' does not mean that it isn't assessed; it is, contributing 20% of the overall marks in A Level geography), and, (b) that what is assessed in examinations does not necessarily capture what is practised in terms of the day-to-day 'doing' of geography where there is (by design) considerable scope for the use of data to be embedded into the teaching of the four compulsory and key geographical themes – water and carbon cycles, landscape systems, global systems and global governance, and changing place, changing places – alongside the other areas of content within a geography A Level's specification.[2] To that end, in-depth interviews were undertaken with representatives of each of the four AOs from which a more nuanced picture of change emerges – generally one of greater exposure to data and data skills but with some particular 'blockages' and hence recommendations for the future.

Key findings

- The mathematical demands on geography A Level students are not especially high and have not been made harder (though it is quite likely greater than most other social science/humanities subjects but that comparison is outside the scope of this report).
- However, the cognitive/intellectual demands made of students in relation to maths and data skills is greater than the level of maths alone suggests.
- This relates back to the importance of statistical and spatial literacy in geography, which involves the analysis, interpretation and synthesis of sometimes conflicting (or, at least, not perfectly related) data, as well as

[2] A useful review of the geographical curriculum is found on the Geographical Association's website: https://www.geography.org.uk/A-level-curriculum

their application to the discussion of geographical processes in contexts that may be unfamiliar to students, under exam conditions or as part of the independent study.

- There is evidence that what the changes to A Level have induced is a shift from rote learning of statistical tests and methods that were held at arms-length from the rest of geography to something more challenging yet also recognisably geographical.

- A Level students are learning with data that is more firmly embedded within a geographical context and this requires deeper reasoning and understanding than a superficial understanding of a statistical test, for example.

- Such a shift places a demand on teachers to be able to identify and support the use of such data in their classroom teaching.

Executive summary

1. Data skills are not an adjunct to geography but are central to what it means 'to do geography' and to acquire geographic knowledge.

2. The reforms of the AS and A Levels provided opportunity to strengthen the skills content of geography, both quantitative and qualitative. Changes at GCSE have also strengthened the quantitative component (but raising issues of progression from this, at the higher levels).

3. In 2012, the Nuffield Foundation report found that few if any of the questions contained in Geography A Level assessment were mathematically complex. That conclusion remains valid today. The focus on maths alone may, however, undervalue other skills such as spatial literacy.

4. In the 2010 exams, the percentage of marks that required maths was estimated to be in the range from about 10 to 20 per cent for the Awarding Organisations (AO). In 2018 it is estimated to be about 10 to 30 per cent although the estimates are inexact, limiting the comparison. There is no evidence that geography examination now has less mathematical content but, instead, has more embedded / contextualised content.

5. All geography students encounter at least some quantitative content in examination. The expectation is that they will in the classroom, too.

6. The most frequent mathematical element requires being able to interpret graphically presented information – sometimes to describe it in its own right, sometimes to draw out the relationships (or lack of) between various geographical features or phenomena, and sometimes to combine it with other disciplinary knowledge to reason to a conclusion. The inclusion of real-world and 'messy' data (without a necessarily simple interpretations) is present.

7. Although the mathematical demands on geography A Level students in 2018 is not especially high and has not been made harder since 2012, the cognitive / intellectual demands made of students in relation to maths and data skills is greater than the level of maths suggests. In addition, the mathematical elements have become more explicit and are not see as an 'add on'.

8. All Awarding Organisations are examining maths and data skills within a geographical context. Many of the examinations are extremely visual with often quite imaginative and well-developed uses of data and graphics in order to communicate quantitative information. Whilst the way maths and skills are examined does vary across the AOs with different AOs having different foci, all the examinations suggest the sort of embedding of data skills within geographically relevant contexts that the changes to the A Level specification sought. In this regard, the differences between AOs appear to have narrowed.

9. There is evidence that what the changes to A Level have induced is a shift from rote learning of statistical tests and methods held at arms-length from the rest of geography to something more challenging yet also recognisably geographical – data that are more firmly embedded within a geographical context and which require deeper reasoning and understanding.

10. The introduction of the Independent Investigation (NEA) provides for very significant use of data skills within this assessed piece of course work (20% of final marks) and to also explore the validity of data within a

live geographical investigation.

11. Examples of good practice include, for example, more conversations and collaboration between maths and geography teachers, the use of sharing on social media to bolster teachers' confidence, the focus on questioning data and understanding the limitations of it, workshops on how to bring data skills into lessons (such as the RGS-IBG's Data Skills in Geography CPD programme), and providing clear guidance between the skills taught and how they link to topics.

12. Teaching quantitative skills remains a challenge to some teachers who may not have the confidence or expertise required to do so. Progress has been made but it would not yet be true to say that the use of data skills in geographical teaching is as routine as, say, interpreting a map.

Recommendations:

1. That Ofqual and the Department for Education keep the mathematics components provided by the Awarding Organisations for A Level (and GCSE geography) under review.

2. To explore with the Awarding Organisations whether there is a desire for greater guidance on what aspects of quantitative skills should be assessed – on the balance between calculation and interpretation, for example.

3. Organisations such as the RGS-IBG, Geographical Association, Higher Education Institutions and others continue to support geography teachers with the use of data skills within their courses through CPD, resources and highlighting the availability of relevant open access data sets.

4. To consider establishing an online repository for suitable data resources and/or an online catalogue with links to where such data are available, tagged with relevant information such as location, scale, year, type of data, variables contained and recommendations for use.

5. To consider publishing further guides to classroom statistics for geographers suitable for teachers and students undertaking an independent study.

6. There is a greater need for the coverage of data skills within geography Initial Teacher Training programmes.

7. That more opportunities are created for geography teachers to share good practice with each other and to engage with the expertise of other subject teachers.

8. That more work is undertaken to highlight how a geographical approach and analysis is a distinctive contribution to the better use of data skills, within geography and also the mathematics and data skills communities.

9. That the lessons learnt in geography continue to be shared with other subject bodies and communities.

10. That care be taken to protect the methodological diversity within geography. Although support for quantitative skills remains an important area to invest in, there is evidence that support for the qualitative aspects of geography require attention too.

Quantitative skills in the geography subject content

The geography-specific nature of some of the maths found in geography's A Level subject content (its curricula) – mapping data with GIS, for example – relate to the spatial nature of geography and the importance of geographic context. Because of its longstanding tendency to teach statistics in context, especially through fieldwork, geography is viewed favourably in a report entitled *The future of Statistics in our Schools and Colleges* that was commissioned by the Royal Statistical Society and by The Actuarial Profession.[3] In addition, in 2010 the Higher Education Funding Council recognised geography in Higher Education as a 'part-STEM' subject.

Teaching data skills in context means that the various parts of what is described as the 'statistics cycle' are better kept together, rather than separate. The different stages of the cycle include posing a question (of relevance to the discipline), data collection, and then undertaking the analysis and drawing conclusions from it. Although a 2013 report for The Royal Geographical Society (with IBG) revealed that quantitative skills in school curricula might sometimes be taught at arms-length from the rest of the disciplinary content, the potential for data skills to be taught in an applied and disciplinary-appealing way was clear (Harris *et al*., 2013).[4] Elsewhere, I have argued that data skills are not an adjunct to geography but are central to what it means 'to do geography' and to acquire geographic knowledge (Harris, 2018).[5] It is a pedagogic approach that is central to and exemplified by The Royal Geographical Society (with IBG)'s Data Skills in Geography project, also funded by the Nuffield Foundation, and one that has the support of the Awarding Organisations. [6]

[3] Porkess R (2011) *The Future of Statistics in our Schools and Colleges*. London: Royal Statistical Society / The Acturial Profession. Available from: https://www.rss.org.uk/Images/PDF/publications/rss-reports-future-statistics-schools-colleges-roger-porkess-2012.pdf

[4] Harris R, Fitzpatrick K, Souch C, Brunsdon C, Jarvis C, Keylock C, Orford S, Singleton A & Tate N (2013). *Quantitative Methods in Geography: making the connections between schools, universities and employers*. London: Royal Geographical Society (with IBG). Available from: https://www.rgs.org/getattachment/Geography/Key-information-about-geography/Geography-in-higher-education/Quantitative-methods-in-geography-making-the-connections-between-schools,-universities-and-the-workplace-Harris-et-al-2013.pdf/?lang=en-GB

[5] Harris R (2018) From data to knowledge: teaching data skills in geography. *Geography*, 103 (1),

[6] https://www.rgs.org/about/the-society/what-we-do/teachers/data-skills-in-geography/

Data Skills in Geography From 2016 to 2019 The RGS-IBG's Data Skills in Geography programme

- Worked across schools and Higher Education to inform both sectors of the changes and opportunities, and shared good practice and expertise
- Produced a series of teaching materials for the GCSE and A Level specifications, including the award winning Student Guide to the Independent Investigation, and curated 10 open data sets for use in the geography classroom Provided a national programme of continuous Professional Development (CPD) for around 2,000 teachers which raised teachers' confidence in their use of data skills, on a five-point scale, from 2.2 to 4.0*
- Developed a national network of teacher Data Skills Champions to support teachers locally and worked with providers of Initial Teacher Training (ITT) to support the coverage of Data Skills within geography ITT programmes
- Collaborated with Awarding Organisations, ITT, other Learned Societies, Higher Education including Q-Step centres to secure greater impact and underpin sustainable activity for the future within geography and in other subject disciplines
- Advocated for the importance of data skills in geography in a wide range of fora, networks and publications including:
  - A Level mathematics round table (Department for Education)
  - Academy of Social Sciences
  - British Academy
  - Core Mathematics
  - Data Skills for the Future (Data Skills Task Force)
  - Dynamics of Data Science (Royal Society)
  - Geographers need to be mathematicians too (Financial Times)
  - Geographical Magazine
  - Post 16 maths pathways (Advisory Committee on Math Education)
  - Quantitative skills aren't just about maths (Times Higher Education)
  - Smith Review of Post 16 Maths (Department for Education)

* Phase 2 data

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Data skills have been present within school curricula for many years – much longer than the decade or so that has passed since Redfern and Skinner (2008) were able to identify the skills listed in the left-hand side of Table 1, below, as present in the AS/A Level geography of that time.[7] Taken as whole, these skills are impressive and wide-ranging. However, as the Nuffield report confirmed, the actual exposure to quantitative methods depended on the AO content followed. The table overlaps with the quantitative skills contained in the GCE AS and A Level subject content for Geography, published by the Department for Education (DfE) in 2014 against which the new specifications for A Level geography were developed (see also the right-side of Table 1).[8] Those quantitative skills are described in sections of the publication outlining the geographical skill, as well as the content of fieldwork and independent study for the revised AS and A Levels. In the most part, the skills are mandatory and required to be embedded in the wider disciplinary teaching (the same is true of qualitative skills):

> Competence in using geographical skills should be developed during study of core content and non-core content, not as a separate theme or topic. While the relative balance of quantitative and qualitative methods and skills will differ between each of the core and non-core themes, students must be introduced to a roughly equal balance of quantitative and qualitative across the specification as a whole (*ibid*, paragraph 19, p. 12, emphasis added).

Table 1. Examples of quantitative skills in geography at A Level

(1)	(2)
Types of survey and sources of secondary data	• understand the nature and use of different types of geographical information, including qualitative and quantitative, primary and secondary, images, factual text and discursive/creative material, digital data, numerical and spatial data and innovative forms of data, including crowd-sourced and 'big data' • demonstrate knowledge and understanding of implementing chosen methodologies to collect data/information of good quality that is relevant to the topic under investigation
Types of sampling	• measurement, measurement errors, and sampling • understand how to observe and record phenomena in the field and be able to devise and justify practical approaches taken in the field, (including frequency/timing of observation, sampling, and data collection approaches)
Types of mapping, including flow mapping	

(1) Quantitative skills present in the geography AS/A Level curricula according to Redfern & Skinner (2008)
(2) Extracts from the new AS and A Level subject content for geography (Department for Education, 2014).

[7] Redfern D & Skinner M (2008) *AS/A-Level Geography: Investigative and Research Skills and Techniques*. London: Phillip Allan.

[8] Department for Education (2014) *Geography: GCE AS and A Level subject content*. London: DfE. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/388857/GCE_AS_and_A_level_subject_content_for_geography.pdf

Geographical Information Systems (GIS)	• understand what makes data geographical and the geospatial technologies (e.g. GIS) that are used to collect, analyse and present geographical data • demonstrate an ability to collect and to use digital, geolocated data, and to understand a range of approaches to the use and analysis of such data;
Pie charts,[9] bar graphs, proportional symbols, histograms, scatter plots and other graphs	• involve the individual drawing of conclusions and their communication by means of extended writing and the presentation of relevant data
Measures of central tendency and of dispersion	• descriptive statistics of central tendency and dispersion
Spearman's rank correlation, the chi-squared test, and the Mann Whitney U test	• descriptive measures of difference and association, inferential statistics and the foundations of relational statistics, including (but not limited to) measures of correlation and lines of best fit on a scatter plot
Location quotients	
Nearest neighbour statistics	
Questionnaires and scales to measure attitudes	
Arithmetic and logarithmic graphs, and Lorenz curves	

[9] Although widely criticised as an ineffective method of data visualisations with better alternatives such as a bar plot, the pie chart seems firmly entrenched in not just geography but maths as well.

Changes to the A Level Specifications

Reforms to the AS and A Levels (as well as to GCSE) provided opportunity to strengthen the skills content of geography, both quantitative and qualitative. The Royal Geographical Society (with IBG) advocated strongly for a strengthening of the quantitative elements of the new specifications. For example, as part of its response to an initial consultation (made in 2013), the RGS-IBG wrote:

> The Society supports the principle of identification of specific quantitative skills in A Level geography. We also welcome the proposal from Ofqual that quantitative skills in geography should comprise 10% of the overall assessment [a proposal that was later dropped]. However, the current proposals do not, in many instances, present the necessary level of challenge or progression within the discipline for this stage of education. The exception is the inclusion of some statistical methods beyond the basic descriptive ones, which is genuinely a progression from GCSE methods. Most of the remaining proposals either replicate work required for GCSE (and even as specified for primary pupils!), or as written do not present sufficient challenge for A Level. The Society previously has made specific suggestions for the strengthening of coverage of quantitative skills at GCSE and the comparison of these to the A Level proposals highlight the significant level of overlap and lack of progression.

The spirit of the changes are outlined in a 2018 article written for the Geographical Association (GA), entitled *From data to knowledge: teaching data skills in geography.*[10] There I argue that quantitative (and qualitative) skills are an inherent part of what it means to be taught, to learn and to practise geography. It should not be a case of separation with methods in one hand and 'more substantive' disciplinary content in the other. Rather, disciplinary knowledge is explored, communicated and advanced through appropriate geographic training, which includes the importance of data skills. The members of the *A Level Content Advisory Board* (ALCAB) for geography – tasked with creating criteria for the revised A Level geography specifications – took a similar position.[11] The GA's website

[10] *Op. Cit.*

[11] The ALCAB Geography Panel was chaired by Professor Martin Evans, University of Manchester and included representatives from Higher Education (one of whom was myself), schools, the RGS-IBG and Geographical Association, GA.

contains an overview of the A Level reform process since 2012,[12] with also a link to ALCAB's final report (July, 2014).[13] Within that report, in a section about geographical skills, is the following paragraph:

> Geographical skills must be understood in the context of geographical knowledge covered in both the core and non-core content. The consensus among the panel and in the teacher consultations was strongly that skills teaching should be embedded and not a standalone component of specifications (p.29).

To that end, the Board recommended that A and AS Level content be balanced equally between human and physical geography, with human geography's two core themes written with the expectation that both quantitative and qualitative approaches would be required (so quantitative skills could not be restricted to physical geography only). It also made specific recommendations about the use of geographical fieldwork, that there should be a minimum of four days fieldwork during A Level, and the introduction of a non-examination assessed independent investigation (the NEA).

Following on from ALCAB's report, and various periods of consultation, the new *GCE AS and A Level subject content for Geography* was published by DfE in 2014 (see above), and the *GCE Subject Level Conditions and Requirements for Geography by Ofqual*, in March 2015.[14] As previously mentioned, the former required that there must be a roughly equal balance of quantitative and qualitative skills embedded within the teaching across any AO's specification as a whole. The latter required that between 20–30 per cent of the weighting assigned to assessment must be for using "a variety of relevant quantitative, qualitative and fieldwork skills to: investigate geographical questions and issues; interpret, analyse and evaluate data and evidence; [and] construct arguments and draw conclusions" (p. 10). The assessment objectives for geography AS and A Level are shown in Table 2.

[12] https://www.geography.org.uk/The-A-level-reform-process

[13] A Level Content Advisory Board, The (2014) *Report of the ALCAB Panel on Geography.* Available from: https://alevelcontent.files.wordpress.com/2014/07/alcab-report-of-panel-on-geography-july-2014.pdf

[14] Ofqual (2015) *GCE Subject Level Conditions and Requirements for Geography.* Coventry: Ofqual. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/418412/gce-subject-level-conditions-and-requirements-for-geography.pdf

Table 2. The assessment objectives for geography AS and A (source: Ofqual 2017, Table 2.19)[15]

Objective	Requirements	AS	A Level
AO1	Demonstrate knowledge and understanding of places, environments, concepts, processes, interactions and change, at a variety of scales	30 to 40%	30 to 40%
AO2	Apply knowledge and understanding in different contexts to interpret, analyse, and evaluate geographical information and issues	30 to 40%	30 to 40%
AO3	Use a variety of relevant quantitative, qualitative and fieldwork skills to: investigate geographical questions and issues; interpret, analyse and evaluate data and evidence; construct arguments and draw conclusions	20 to 30%	20 to 30%

Together, the subject content and requirements should ensure that every student is exposed to qualitative and quantitative approaches in the course of their A Level studies, and will be assessed, in examination, on some aspects of them. In addition, whilst most marks arise from such examination (80 per cent), geography benefits from the remaining 20 per cent being apportioned to the NEA that "involves, but need not be restricted to, fieldwork" (*ibid.*, p. 12). The nature of the independent study means it will vary from student to student with no explicit requirement that it has to be quantitative. Nevertheless, it provides opportunity to bolster quantitative (and other) skills – a feature of it that is recognised by the AOs (see the summary of the in-depth interviews, below).

As an indication of what might be done quantitatively, we can turn to the Royal Geographical Society (with IBG)'s *A Student Guide to the A Level Independent Investigation.*[16] It includes a guide on: how to form

[15] https://www.gov.uk/government/publications/assessment-objectives-ancient-languages-geography-and-mfl/gcse-as-and-a-level-assessment-objectives#geography-1

[16] https://www.rgs.org/CMSPages/GetFile.aspx?nodeguid=882a6e79-5e28-4667-a753-17d26cec8c19&lang=en-GB

statistical hypotheses (null and alternative); on data collection methods and techniques, sampling techniques and avoiding data biases; data presentation for univariate and bivariate continuous data, and for multivariate and categorical data; mapping; on descriptive statistics – measures of central tendency and dispersion, calculating proportions/percentages and other ratios –, inferential statistics (Spearman's Rank, Chi-Squared, Simpson's Diversity Index, Mann Whitney) and correlation (Pearson's correlation coefficient); and about a spatial statistical method, which is nearest neighbour analysis. In fact, it covers almost the same quantitative skills as those listed by Redfern & Skinner (2008) (see Table 1, above), providing circumstantial evidence that, at minimum, the range of quantitative skills that could be employed by an A Level geographers has not narrowed.

The new examination specifications were provided to schools for first teaching in September 2016 and their first examinations were in the summer of 2018.

Mathematics in the 2018 geography A Level examinations

As indicated earlier, some of the changes to the geography A Level arise from what can be understood as a direct and deliberate intervention intended to strengthen the level of quantitative (and qualitative) skills training given to geographers by embedding those skills within the wider subject content and its teaching. In principle, somewhere in the range from about 10 to 30 per cent of all marks in examination should now be testing quantitative skills (the proportion depends upon the split between quantitative and qualitative approaches), a range greater than the 10 to 20 per cent estimated by the Nuffield Foundation in their report about the summer 2010 examinations. This, and the spirit of the interventions, suggests the amount of mathematical content will have risen (or, at least, stayed the same) since 2010, with less variation between AOs.

Are those expectations realised? To assess it, a review of the 2018 summer examination papers for A Level geography follows, using the same framework for analysis previously employed by the Nuffield Foundation.[17] The framework allows the extent, type, mathematical difficulty and the subject-related nature of the mathematical content to be evaluated for each exam paper, and provides some basis for comparison with the past.

There are limits to that comparison, however, because even an apparently standardised framework is open to different judgements – on the "complexity of the task", for example. Past-to-present comparisons are further limited by the Nuffield Foundation's decision to review but not to name each Awarding Organisation (AO); a decision taken, perhaps because of the variation between the AOs and to avoid suggesting that some were 'easier' or 'better' than others. *All such value-judgements should be avoided here also:* the purpose of the review is only to explore the mathematical content of the examinations, not to make judgements of their quality. However, it seems easier to be open about which AO is which because if there no attempt to conceal their identity then there is no risk of accidental disclosure arising from going beyond the framework to providing a richer descriptive vignette of the sorts of questions with maths content in each exam paper. That description is useful because it helps

[17] Who, in turn, based it on a parallel exercise looking at Mathematics within A Level Science 2010 Examinations: http://www.score-education.org/media/10036/full%20maths.pdf

address a built-in weakness of the framework – *that otherwise it is looking at maths not geography skills per se*. The importance of the distinction arises when, for example, the framework implies that the level of maths is easy but actually the cognitive demands are much higher; when, for example, the question requires visual and numeric information to be interpreted, synthesised and related to each other to form knowledge of broader geographical processes and contexts. Understanding the maths content of the examinations and how it relates to geographical study benefits from a less opaque assessment than the framework can offer alone.

It is acknowledged that examination papers evolve and that common lessons and experiences are shared between the Awarding Organisations. Those that are reviewed are the first under the new specifications. Not all of these will have 'worked' as intended; nor are the question styles set in stone. AOs receive and respond to feedback from teachers. Therefore, it is possible that the extent, type and level of difficulty of the maths will change in future years. Nevertheless, the 2018 papers (and the accompanying assessed independent investigations) do represent a 'first response' to the changed A Level specifications and the AOs' interpretation of what they required in examination.

Each AO is considered in turn, in declining order of their market share (school year, 2017–18)

AQA A Level Geography (market share: 41%)

The AQA examination consists of two papers; Paper 1 – Physical Geography and Paper 2 – Human Geography. They are equally weighted at a total of 120 marks each.

Physical Geography

Section A is answered by all students. Question A1.2 is worth 6 marks and requires students to "analyse the data shown in Figure 1", which is a stacked bar plot showing sources of greenhouse gas emission, with the bars grouped by the relative wealth of the countries and, within those groups, ordered by time. The complexity of the maths is low and single-step, requiring numbers to be read from a graph although potentially also calculating differences or ratios. However, the task itself is harder since it requires summarising what is a multivariate set of data. It invites subject-specific comprehension (since the context for the maths is geographical) although the question could be answered without it. The type of maths is Number, Measure, Statistics and Graphs.[18]

Question A1.3 is also worth 6 marks, instructing "Using Figure 2 and your own knowledge, assess the challenges associated with reducing greenhouse gas emissions." Figure 2 has a proportional area plot showing the top 10 greenhouse gas emitters and whether they had ratified the Paris Accord as of May 2017, and also a map of which of 197 countries had or had not. In this example, the complexity of the maths is low and single-step and is of the Statistics and Graph types. The maths can contribute to the answer but is not required for it.

Section B has a choice of three questions. Each of these includes an "analyse the data" sub-question (6 marks), of which one is a somewhat complex time-series plot of population, overlaid with a bar plot of relative rainfall, as well as other symbol-based annotation indicating periods of locust outbreaks, civil unrest, drought and famine. The level of maths is low but the interpretation of the data more complex, with maths of type Number, Statistics, Measure and Graph required. The sub-question is followed by (amongst other parts) a further sub-question (6 marks) containing an image or photograph, for the other a map of a digital elevation model, to be used in conjunction with the students' own knowledge to assess the validity of a stated view or about the potential impact of a physical process.

Finally, Section C has a choice of two questions. Both have an "analyse the data shown in Figure X and Figure Y" question (6 marks), where the figures have to be used in conjunction with each other, interpreting and relating graphed data to mapped data. Again, the level of maths is low, with maths of type Number, Measure, Statistics and Graph but it does require multi-step thinking and the synthesis of multiple data sources and types.

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
18 of 120 (15%)
Number of marks that could be gained with maths:
up to 30 of 120 (up to 25%)

[18] See pages 53–54 of the previous Nuffield Report (op. Cit.) for the definitions of these.

General complexity of mathematical task:
1 (on a scale from 1 to 4, 4 being most complex)
Types of maths most commonly used: Number, Measure, Statistics and Graph

Human Geography

This paper has two sections with questions answered by all students, which are Sections A and B. Question A1.2 (6 marks) requires students to have knowledge of what an inter-quartile range is (but not to memorise its formula; there is an element of 'fill in the blanks' within the question), using it and a time-series graph to discuss variation around a rising trend of July temperatures in Antarctica. It is followed by Question A1.3 (6 marks) which uses a flow map with proportional symbols to illustrate the global trade in oil in 2017. Students are asked to use this map and their own knowledge to "assess the extent to which this pattern is similar to the global trade in a food commodity or manufactured product you have studied". As previously, the level of maths is not high, with a focus on the interpretation of statistical data especially in its visual form but it is made more demanding by the need to relate the information across geographical settings.

The same is true of Question B2.2 (6 marks), which is of the "analyse the data shown in Figure X and Figure Y" sort, where Figure X is a pictograph indicating levels of life satisfaction in selected London Borough's and Figure Y is a choropleth map of average income. Whilst the level of maths is no greater than reading values off the graphics, relating the two is more demanding because the correlation is not exact (there is no simple relationship). The types of maths required in Sections A and B are Number, Measure, Statistics and Graph, with a small amount of Algebra.

Section C offers a choice of three questions. Within the first question, sub-question C3.5 (6 marks) requires that a map of Portland, USA be analysed with respect to the urban island effect for the same city; sub-question C3.6 (9 marks) provides ethnicity data as a pie chart and employment data as a table, as part of a requirement to use those and the student's own knowledge to assess the extent to which Vancouver is a post-modern western city. Within the second, sub-question 4.5 (6 marks) requires a choropleth map of predicted changes in crop yield worldwide to be analysed with respect to a choropleth map of the percentage of each country that is undernourished; in this case it is followed by a longer question (9 marks) that does not require any maths. Within the third, sub-question C5.5 (6 marks) requires a choropleth map of greenhouse gases per capita in selected European countries and a choropleth map of the percentage of electricity generated from renewable sources to be analysed; it is followed by a longer sub-question, C5.6 (9 marks) which includes a table of data amongst other information to assess, with also the student's own knowledge, the extent to which renewable energy can be used to achieve energy security.

Indicative scoring based on the Nuffield framework:
Number of marks that require maths: from 18 to 24 of 120 (15 to 20%)
Number of marks that could be gained with maths:
up to 33 of 120 (up to 27.5%)

General complexity of mathematical task: 1
Types of maths most commonly used: Number, Measure, Statistics and Graph

In summary, the AQA exam papers are near equally balanced in the level and types of mathematics found in the human and physical examination papers, with maths being required for at least 15% of the total marks. The emphasis is on interpreting statistical data that often are multivariate in form and presented graphically with respect to a relevant geographical context. The level of maths required is not high and does not go above simple numeric skills. However, the cognitive demands are higher upon the student: the challenge is in being able to understand the data and to relate them to each other, to the context and/or to her/his prior learning.

Pearson Edexcel (market share: 39%)

The Pearson Edexcel A Level examination has three papers – Paper 1, which covers physical geography, Paper 2, which covers human geography, and Paper 3, which is the most focused on data skills.

Paper 1

Paper 1 begins with Question 1A, which has a table showing the annual frequency and mean focal depth of earthquakes in New Zealand at two plate boundaries in 2016. The students are asked to calculate the average monthly frequency of the earthquakes (2 marks). This is a one-step mathematical calculation of a low level and of type Number. It does, however, require the student to apply information that is not explicitly contained in the table (to appreciate that the monthly average is obtained by dividing the yearly total by 12). The question continues with a t-test of the difference between the mean focal depth of the earthquakes at the plate boundaries, including a formal specification of the null and alternative hypotheses and the formula to complete a t-test. However, that formula is already completed, with the student told that t = 22.1 / 4.43. What is left is for the student to calculate the answer (most likely with rounding, 1 mark) and then, using a table showing the critical value of Student's t-test at the 90, 95 and 99% confidence levels, "state whether there is a significant difference between the mean focal depth of the earthquakes" (1 mark). There is, at the 99% level, although the question does not require the level to be stated. Again, the level of maths is low and of type Number, with some Statistical knowledge also required. The maths is embedded in the disciplinary context (tectonic processes and hazards). The majority of the marks (a further 12 marks) are to "assess why some communities are more vulnerable than others to tectonic hazards" for which reference to a map showing the tectonic setting of New Zealand may be helpful. This map does not contain any numeric information and does not require any mathematical skills to interpret.

Section B has a choice of two questions. The first (1B2a) requires the student to interpret a time series chart of the retreat/advance of the snout of a glacier to explain how changes in its position "may provide evidence for changing climate" (6 marks). Alternatively, the second (1B3a) requires a bar plot of historic rates of coastal recession be interpreted to explain how variation in the rates "may provide evidence for the different approaches to coastal management" in North Norfolk (6 marks). In both cases, there is an element of critical evaluation of the data as evidence, as well as maths skills of type Number, Measure, Statistics and Graph.

Finally, in Section C, question 1C4a (3 marks) requires a time series plot showing amounts of precipitation and evapotranspiration over a 12-month period in Cloverdale, CA to be interpreted to "explain the relationship between precipitation and soil moisture."

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
13 of 105 (12.4%)
Number of marks that could be gained with maths:
13 of 105 (12.4%)
General complexity of mathematical task: 1
Types of maths most commonly used: Number, Measure, Statistics and Graph

Paper 2

Section A contains a table that ranks five countries by five separate variables, weights the rankings and sums them together to obtain an overall score. Students are asked to complete the table, requiring some simple multiplication and summation (4 marks) and then "to assess the view that Figure 1 [the table] gives an accurate summary of the relative strength of these emerging powers" (12 marks). It is a question that requires students to show understanding of the limitations and subjective nature of the scoring process; that is, to show critical understanding of how the data have been employed (the choice of variables and weighting), as well as disciplinary understanding of what other characteristics of the countries could be included. It is not mathematically demanding but the cognitive demands are greater. No other questions in this paper employ maths skills (they do, however, draw on the interpretation of other sources of data, including a blog and images of postage stamps, reflecting the need to also assess qualitative skills).

Indicative scoring based on the Nuffield framework:
Number of marks that require maths: 4 to 16 of 105 (between 3.8% and 15.2%)
Number of marks that could be gained with maths:

16 of 105 (15.2%)
General complexity of mathematical task: 1
Types of maths most commonly used: Number, Statistics

Paper 3

Paper 3 has no question choice in it and is almost wholly given over to using various sources of geographic information that are presented in a resource booklet to develop answers in relation to particular geographic contexts. For example, Section A has a table of data about ASEAN countries, as well as a series of radar plots, which are to be used to analyse the differences in the ASEAN countries' social, economic and political development. It has a map of the interconnections between the ASEAN countries in terms of transport, energy supplies and so forth, of South China sea disputes, a pie chart and table of their most important trading partners, a pie chart of the sources of foreign direction investment, and a bar plot of average expenditure on Research and Development. There is information on their vulnerability to natural disasters and a map of their vulnerability to climate change. Other than a question that requires some simple algebraic manipulation and also the summing of data, as well as understanding of how regional averages can conceal sub-regional variability (and be distorted by outliers – neither an unimportant understanding given how geographical patterns are scale dependent), the main mathematical skill being tested is that of interpreting and synthesising information from a variety of sources to reach conclusions within a disciplinary setting that may not be familiar to the student. The level of maths required is not high; the challenge is in being able to understand the data and to relate them to each other, to the context and/or to her/his prior learning.

Indicative scoring based on the Nuffield framework:
Number of marks that require maths: up to 66 of 70 (94%)
Number of marks that could be gained with maths:
66 of 70 (94%)
General complexity of mathematical task: 1
Types of maths most commonly used: Number, Measure, Statistics and Graph

In summary, as much of 30 per cent – perhaps more – of the Pearson Edexcel papers require maths skills. The difficulty in placing a more exact value on it is related to the type of maths skills that are most required: the papers, especially Paper 3, have a strong emphasis on interpreting statistical data that often are multivariate in form and presented graphically with respect to a relevant geographical context. The amount of maths required depends upon how much the students use the quantitative information in their answers; in any case, there is plenty of scope for them to do so. The level of maths required is not high and rarely goes above simple numeric skills. However, the cognitive demands are higher, requiring require students to draw meaning from across a range of data, and data types, combining it with prior learning to obtain what is a fair share of the total marks available.

OCR A Level Geography (market share: 15%)

The OCR A Level examination consists of three papers – Physical Systems, Human Interactions and Geographical Debates. The Physical and Human geography papers count 66 marks each (27.5% × 2), and the Debates paper, 108 (45%).

Physical Systems

Section A has three options. Each includes a table of data from which the median and inter-quartile range (IQR) must be calculated (6 marks). Mathematically, this is a multi-step question as the data needs to be re-ordered (from highest to lowest) and then, because, there are nine observations, an averaging of the second and third, and also the seventh and eighth observations is required to obtain the first and third quartiles, the difference between them then giving the IQR. The types of maths tested are Number and Statistics. The level of maths is one that requires knowledge of what the IQR is, how to calculate it, and the mathematical ability to do so. The task is broadly linked but not tightly to a wider geographic context.

Section B, without choice and answered by all students, includes a

choropleth map of precipitation totals across mainland USA. Students are asked to reference the map to "suggest how variations in precipitation totals influence runoff processes in the water cycle" (4 marks) – knowledge of water cycles must therefore by applied to information that is presented in the map about a specific study region. It is followed by a question asking students to "explain three limitations of presenting rainfall data using choropleth maps" (3 marks). To answer this, students will need to know not just how to interpret the choropleth map but also to understand its strengths and weaknesses as a method of visual presentation too. The level of maths is low and of types Measure, Statistics and Graph but developed into critical thinking skills, set within a geographical context.

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
13 of 66 (20%)
Number of marks that could be gained with maths:
up to 13 of 66 (20%)
General complexity of mathematical task: 1 or 2
Types of maths most commonly used: Number, Measure, Statistics and Graph

Human Interactions

Section A is answered by all students, without choice. It contains two map extracts for the rural-urban fringe of Ipswich in 1955 and 2010. The students are asked to interpret these to understand causes of economic change in the area (8 marks). The question is not specifically mathematical as it does not contain nor pertain to any numeric information. It is, however, a test of spatial literacy and of understanding how geographical processes create spatial formations.

Section B does allow for choice. However, in all cases the student is asked to consider the advantages of a (very well designed) bar-plot for showing variations between the countries within the EU in regard to a particular measured quantity (4 marks). The thought-out design of the bar-plot is deliberate: it allows the students to comment on the cognitive benefit of ordering the data from highest to lowest, adding careful annotation, and so forth. The students are then asked to draw on their geographic knowledge to account for the variation between countries (6 marks). The level of maths is less demanding than on the Physical Systems paper but, as with that other paper, it requires that students be knowledgeable of good and bad ways of presenting data, to be cognisant of good practice. It is of type Number, Measure, Statistics and Graph.

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
Up to 9 of 66 (14%)
Number of marks that could be gained with maths:
up to 9 of 66 (14%)
General complexity of mathematical task: 1
Types of maths most commonly used: Number, Measure, Statistics and Graph

Geographical debates

This paper consists of three sections, of which only the first (Section A) contains maths skills (for 3 marks), although these can be avoided depending upon the choice of question. Whichever question students choose, they are presented with information presented in a particular form (one is a scatter plot, one a cartogram, one a table of data, another a photograph, and the other a textual extract) and asked to discuss its limitations. The focus is not on maths per se nor on interpreting the data but on understanding the limitations of different sources of data and/or their presentation (which implies knowledge of research design and data collection / communication).

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
Up to 3 of 108 (2.8%)
Number of marks that could be gained with maths:
up to 3 of 108 (2.8%)
General complexity of mathematical task: 1
Types of maths most commonly used: Statistics and Graph

In summary, approximately 10% of the total marks available across the OCR A Level Geography papers have a mathematical component, with the amount and level being slightly greater

on the physical than on the human side. The focus is less on interpreting the data to generate geographical knowledge (under exam conditions) and instead on demonstrating understanding of the strengths and limitations of their graphical presentation as a valid source of geographic knowledge. However, the Physical Systems paper contains a question that requires numeracy skills (ordering, averaging and differencing) to complete.

Eduqas A Level Geography (market share: 5%)

The Eduqas examination has three papers – Changing Landscapes and Changing Places, Global Systems and Governance, and Contemporary Themes in Geography. These attract 26%, 34% and 40%, respectively, of the total 320 marks available.

Changing Landscapes and Changing Places

This paper consists of two Sections, A and B, each of which has some core questions and also some choice. Whichever is chosen in Section A, the student is required to fill in the blanks of a table containing the steps needed to complete a chi-square test (i.e. a formal statistical test). To do so requires that one value be squared, one value be divided by another, the summation of (five) column values, and the rounding of the final answer to 2 decimal places (the question explicitly requires this). The formula for calculating chi-square is provided; to be useful, the student would need to understand it (knowing, for example, that the use of sigma means to sum together). In practice, rote learning would likely suffice. The calculation attracts 3 marks, with a further 2 marks available for determining at what level of statistical confidence (95%, 99% or none) the observations differ from expectation. The tests are set in the context of a geographic landscape, are of maths type Number, Algebra and Statistics, and at A Level that is a little beyond the easiest because calculations are required.

Mandatory question B9a contains two map extracts, one for 2003/4 and the other for 2008. Students are asked to use these "to describe changes in the distribution of vacant buildings" (5 marks). As with the similar style of question found in the OCR Human Interactions paper, the question is not specifically mathematical as it does not contain nor pertain to any numeric information but it does require the interpretation of spatial and visual information, and a geographical vocabulary in order to undertake the description.

Question B10a (5 marks) is also mandatory, asking students to "describe changes in the employment structure of the country shown in Figure 8", which is a time series chart showing the percentage of employment in each of the primary, secondary and tertiary/quarternary sectors in a selected European country (not named) over the period from 1950 to 2013. The level of maths required is low and of type Number, Algebra, Statistics and Graph, set within the disciplinary context of changing places and a follow-up question (8 marks) asking "how the changing employment structure shown in Figure 8 is influenced by changing technology and globalisation."

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
10 of 82 (12%)
Number of marks that could be gained with maths:
up to 18 of 82 (22%)
General complexity of mathematical task: 2
Types of maths most commonly used: Number, Measure, Statistics and Graph, with some Algebra

Global Systems and Global Governance

This paper has three Sections, each offering an element of choice. However, Section A requires all students to answer two questions that pertain to quantitative data. The first is to use Figure 1 (a bar plot) "to analyse long-term changes in December precipitation in England and Wales (5 marks), and also to "suggest reasons why the amount of precipitation […] varies from year to year in Figure 1" (a further 5 marks). The second is to "Use Figure 2a" – a land use map with a scale bar – "to estimate the size of the area of mature forest in square kilometres" (i.e. to estimate the area of a sub-space of the map) (2 marks), and then, "Describe the pattern of carbon storage shown in Figure 2b", which is a choropleth map of the same study region (therefore allowing the pattern to be related to land use) (3 marks).

Section B requires that a form of bar

plot showing survey responses on a 'left' and 'right' scale be used to compare attitudes towards immigration in seven selected countries (5 marks) and to then suggest "how attitudes such as those shown […] could affect government migration policies" (5 marks). It also requires that a pictograph be used to contrast the maritime power of 4 countries (5 marks).

Finally, Section C provides a range of maps, two of which are choropleth maps (of net migration within Europe in 2014, and of projected temperature changes in Europe by 2100). It instructs students that they "should use the maps […] and apply your knowledge and understanding across the whole specification" to answer a broader question about rural change (worth 30 marks).

Overall, this paper presents the student with a fair amount of quantitative information in visual form that needs to be interpreted in its own right and also applied in conjunction with wider disciplinary learning about the geographical context for the question. Section C, in particular, requires the student to reason to a conclusion with the data available, drawing information from across the data sources and integrating that with her/his prior knowledge. The mathematical demand is generally low (a little higher for the area calculation in Section B) but the intellectual demand is greater. The maths is of type Number, Measure, Statistics and Graph.

Indicative scoring based on the Nuffield framework:
Number of marks that require maths:
greater than 17 of 110 (15%)
Number of marks that could be gained with maths:
up to 60 of 110 (55%)
General complexity of mathematical task: 1 or 2
Types of maths most commonly used: Number, Measure, Statistics and Graph

Contemporary Themes in Geography

This paper contains questions of a more essay-based, discuss a statement style. It encourages students to "make the fullest possible use of examples in support of your answers" but does not explicitly require any maths.

Indicative scoring based on the Nuffield framework: NA

In summary, it is hard to provide an exact figure for the amount of maths content in the Eduqas exams because of the more open-ended / essay style nature of some of the questions. At a rough estimate, it is about 18 per cent. Its Changing Landscapes and Changing Places examination is unusual in requiring students to complete a statistical test under exam conditions. Its Global Systems and Global Governance paper is very visual, requiring students to interpret and to apply information that has been presented as a graphic or map. There is a focus on using the data in support of answering a broader question within a particular theme of geographic learning.

Discussion

Recall that the 2012 Nuffield Foundation report found that few if any of the questions contained in geography A Level assessments were mathematically complex. That conclusion remains valid today. The level of maths is generally low and most frequently requires being able to interpret graphically presented information – sometimes to describe it in its own right, sometimes to draw out the relationships (or lack of) between various geographical features or phenomena, and sometimes to combine it with other disciplinary knowledge to reason to a conclusion.

Direct comparison with the previous report is difficult but there is little evidence that the amount of mathematical content of the assessment has changed in the assessment of geography through the unseen examinations. In the 2010 exams, the percentage of marks that required maths was estimated to be 10, 16, 16, 19 and 20 per cent for the Awarding Organisations (of which there were then five). Here it is estimated to be about 10, 15, 18 and 30. An average is not especially warranted given the uncertainty of the estimates but, in passing, it is 16 per cent for 2010 and 18 per cent for 2017. It would be hasty to read this as an increase (because of the uncertainty) but, equally, there is little evidence of a decline. Recall also that the examinations are now weighted at 80 per cent of the final grade where previously they were 100 per cent.

The remaining 20 per cent is for the independent study (the NEA) where quantitative methods play a significant role. All geography students will undertake an NEA and it is likely almost all will be undertaking quantitative methods as part of that study. Hence, the mathematical component of geography assessment is under-estimated by looking at the examinations alone.

Differences between the AOs remain. Those differences are not only in extent but also in style, with different approaches being adopted. In the examinations looked at here, some AOs placed emphasis on supplying a range of data resources (in tabular and graphical form) that need to be interpreted 'in the round' to draw knowledge from them and to use them to support geographical reasoning; another AO had an emphasis on understanding the strengths and weaknesses of various data presentation techniques. Some include reference to a formal statistical test but not all.

Have the intended interventions (to strengthen the quantitative content of geography) failed? Not necessarily. Firstly, it may be observed that all AOs are examining maths and data skills within a geographical context. Quite how tightly coupled the quantitative component is to other (related) questions does vary but all the examinations suggest the embedding of data skills within geographically relevant contexts. In this regard, the differences between AOs may have narrowed.

Second, all geography students encounter at least some quantitative content in examination. The expectation is that they will in the classroom too.

Third, many of the examinations are extremely visual with often quite imaginative use of data and graphics. As past examinations become classroom resources for following cohorts of students, it is likely that those students will be exposed to a range of data communication techniques and how to interpret them.

Fourth, an intention to strengthen the quantitative content of geography is not the same as an intention to strengthen the quantitative content in unseen geographical examination. The former speaks to the use of data as a classroom resource to teach geographical topics; the latter may be a test of statistical knowledge under exam conditions. If the topics are selected in such a way that knowledge about them is evidenced by relevant data sets then data skills such as how to summarise data, map and visualise them, look for geographical variations and differences, measure change, and so forth become embedded in the teaching. This was the goal that members of ALCAB sought when outlining changes to the A Level curricula and, looking at the examination papers, it appears to have worked.

Fifth, to this point maths has been used as an umbrella term for quantitative methods, numeracy and data skills. They do, of course, intersect with maths but whether they are subsumed by it is a moot point. For example, data skills are not only about maths: they also involve computational skills, cartographic skills, visualisation skills, and other elements that are not mathematical, per se. Further, the focus

on maths might not be the correct one if what actually is needed is a focus on those data skills:

> The ability to understand and interpret data is an essential feature of life in the 21st century: vital for the economy, for our society and for us as individuals. The ubiquity of statistics makes it vital that citizens, scientists and policy makers are fluent with numbers. Data analysis is revolutionising both how we see the world and how we interact with it (British Academy, 2015).[19]

The problem with looking at the maths content of formal A Level assessment is that it may not reflect the extent to which data and data skills are used to inform disciplinary knowledge within the geography classroom. It also discounts the role of the independent investigation (NEA). A question which should be asked is whether assessing maths as an endpoint is more or less important than using data skills throughout the journey? Further, there is a risk that too narrow a focus on maths overlooks other important skills such as spatial reasoning that also are an essential feature of the 21st century.

Interviews with the AOs

To explore some of the wider issues around the teaching of quantitative skills in geography, the assessment thereof, and the extent to which changes in the curricula had led to changes (or not) in the teaching of mathematical and data skills in geography, in-depth interviews were undertaken with representatives from each of the four AOs during September 2019. Separate meetings were undertaken with each of the AOs with interviews typically lasting an hour. No common set of questions was asked of each AO; instead, the conversation was open, broadly exploring the theme of maths skills within geography and the representatives' perceptions of what, if anything, had changed with the A Level reforms. The interviews were recorded and listened back to by me, highlighting key points of interest in the transcripts. In order to preserve anonymity, only a summary of those key points is provided below. The summary aims to capture the essence of what was raised in at least some of the meetings. It does not mean that every AO would necessarily agree with every point.

(1) With regard to the amount, level and embedding of maths within geography

It was generally agreed that there is now more emphasis in the exam papers on assessing quantitative (and qualitative) skills – on not just demonstrating the skill but on understanding and interpretation too, and on setting the questions within a geographical context. Nobody argued that the maths had got harder, and it was suggested that there was no new quantitative methods. However, there was general agreement that there is greater exposure to maths and data skills (in their broad sense). Some of the new content lends itself better to having a quantitative component.

It was commented that old style examinations may not have prepared candidates well for ways of presenting and interpreting data, and in having the vocabulary to do so. New GCSEs and A Levels prepare candidates better in this respect.

With regard to maths, there is not necessarily more or less, it is just what students are expected to do is different – students are engaging more with data in the context of what they are taught.

[19] British Academy (2015) *Count Us In.* London: British Academy. The quote and the report appear on this webpage: https://www.thebritishacademy.ac.uk/sites/default/files/Count-Us-In-Full-Report.pdf

It was suggested that the quantitative component is now more explicit: there are (for that particular AO's papers) more marks available and it is more explicit what is required and where it will be assessed. This increases accountability. Quantitative skills are no longer an 'add on'. Skills are linked to topics.

Students might understand the mechanics of a statistical test but wouldn't necessarily have the confidence to match that to how to analyse a particular data set, which would be difficult to test anyway. The independent study, if quantitative in method, provides greater opportunity to match the statistical test to the data (and research question) but this 'openness' places a demand on teachers' statistical knowledge to be able to support pupils in doing this.

(2) On teachers' confidence to teach quantitative skills

Quantitative skills are not an area of confidence for lots of teachers. One interviewee suggested that the confidence of teachers is not necessarily increasing; others were more sanguine. It was widely recognised that the increased emphasis on maths and statistics has been a concern for teachers (perhaps particularly at GCSE level where that emphasis features more prominently in assessment requirements).

The move away from rote learning of statistical tests to the embedding of data skills within a geographical context may make things harder – whereas teachers might easily follow formulae and work out an answer in a prescribed way understanding what it actually means (or when the test is or is not valid) can cause anxiety.

A consequence of the A Level changes and the focus on quantitative skills is that some geography teachers need to 'upskill' but might not have the confidence (nor necessarily the time) to do so. Acquiring quantitative skills if you don't already have them is a challenge, which links to the prior training of teachers including in undergraduate geography courses.

The supply of new teachers was discussed – with a greater number having human geography degrees and without always the necessary quantitative training, and also geography sometimes being taught by non-specialists in the subject.

It can be hard to run data skills training courses for teachers because of the diversity of experience – different people are looking for different things from the training.

(3) On the relationship to changes at GCSE

The changes at A Level did not take place in isolation from those at GCSE – how, then, to build upon what was taught at GCSE given that a particular level of maths was expected (and required) at GCSE?

One step-up from GCSE to A Level is in the use of data that don't have simple or easy interpretations. However, it takes greater confidence from the teacher and student to use data in less obvious ways and to appreciate there is no definitive answer.

The 'overload' of all the changes occurring at once was mentioned (together with a lot of new content), which may have forced some teachers to focus more on the changed content and less on the quantitative skills component. Maths numeracy content isn't always placed up front and centre: some teachers may still view quantitative skills as an 'add-on' to geography rather than being central to it. Numeracy / data skills might have got lost in the midst of all the other changes especially where they attract relatively few marks; initial resourcing may have focused more on assessment rather than on providing resources to embed data skills in the day-to-day teaching and learning. The extent of all the changes may mean that time is needed for teachers to 'catch up'.

(4) On the links to maths

In principle, what is taught quantitatively in geography A Level should complement that taught in maths (and a geography teacher might get support from maths colleagues to do so). However, the teaching of data skills / maths is not consistent across subjects. The way that a geographer might teach maths skills (e.g. Spearman's Rank) can be different from how a maths teacher might – partly because the latter has greater understanding of the importance of different data types (and the underpinning mathematical and statistical foundations) but also because geographers tend to teach in context (as users, not specialists, in quantitative methods). Consequently, teaching in the same way across disciplines doesn't particularly work and maths skills are not necessarily

quite as transferable as we might like to think.

Indeed, the maths required in geography is not necessarily in GCSE (nor A Level) maths – notably, statistical testing, Consequently, there isn't always a transfer of the requisite mathematical knowledge into geography from outside of it.

Some students find it really hard to transfer their maths skills into geography perhaps because real life data is messy. It is the need to understand, interpret and make linkages between data in a geographical context that takes the quantitative component (e.g. the doing of a statistical test) beyond rote learning and adds to the challenge of it.

Core Mathematics (a post 16 qualification) may be drawn upon as a classroom resource because of the complementary of some of its questions (e.g. river discharge and climate data).

(5) On access to suitable data and resources

Data that could be used in teaching are more freely available but sometimes those used are not complex enough to develop more critical skills (e.g. comparison, synthesis, to evaluate the differences between groups / places).

Some teachers by not using detailed data can create a problem by giving students resources without sufficient complexity.

It is not just the analysis of data; there are challenges for students in selecting (or collecting) enough and relevant data with which to analyse.

There is a difficulty of being able to find data usable in the classroom. It would be helpful if teachers had places they could go to access e.g. sample material – if an examination board creates it, they then can't use it in an exam.

There is need to provide support (and resources) for the embedding of data skills for earlier years (pre A Level and pre GCSE too). Also to create resources so teachers can demonstrate what might be regarded as more sophisticated (difficult) skills in different contexts.

(6) On the role of the Non-Exam Assessment (independent study)

The role of the NEA is important as it allows for students to demonstrate methodological skills. It was observed that the opportunities to use statistics in the NEA were not always taken. In addition, the NEA component creates variation – some will use it to engage with data, others will not. [This is an observation rather than a concern necessarily as it allows students to specialise in topics and methods of especial interest to them].

The NEA throws up the challenge of working out how best to analyse data (interpret, analyse and evaluate in quite an independent way). A teacher cannot teach every possible analytical scenario for all different types of data; there is also the issue of how independent the work should be (so how much guidance should a teacher give to a specific pupil and her/his data?).

Some of the variation between AOs will relate to how many of the skills marks have been allocated to the NEA (as opposed to the unseen examination).

(7) On the lack of guidance given to AOs

There is little guidance to Awarding Organisations on how the marks should be distributed between working out, interpretation and coming to a geographical conclusion. They are different in terms of examination (this is the balance between mechanics and interpretation).

Unlike GCSE, there is little stipulation about how much maths content there should be in assessment. Greater guidance in this might have strengthened subsequent use of numeracy skills (and it is useful to AOs to know their approach is appropriate).

Is there a suggested level of maths that people think is appropriate for A Level geography?

(8) On GIS

GIS is still an issue – many teachers lack confidence with it. It needs to be more embedded in the curriculum. It is maybe something associated with fieldwork rather than a more general resource for teaching the subject content.

Consequently, it is still a mixed bag – despite the availability (and usability) of GIS changing massively. [20]

Nevertheless, geographers are exposed to the language of geographic data science – for example, 'Big Data' and crowdsourcing.

[20] For example, over 2500 schools have taken up a free subscription provide by Esri UK to ArcGIS

(9) On other issues

Various examples of good practice were cited – for example, more conversations between maths and geography, the use of sharing on social media to bolster teachers' confidence, the focus on questioning data and understanding the limitations of it, workshops on how to bring data skills into lessons, and providing clear guidance between the skills taught and how they link to topics.

Does geography serve maths or maths geography? We don't want calculations to be so complicated that geography is lost.

If the purpose of the A Level changes was to get away from rote learning of particular techniques then we have not yet provided the mechanism to reassure teachers they can do so because the learned method might well appear in an exam.

It might be the qualitative skills that teachers find scarier!

Lessons for the future

Teacher support and supply

A consequence of the A Level changes and the focus on quantitative skills is that some geography teachers need to 'upskill' in this area but might not have the confidence (nor necessarily the time) to do so.

Teacher supply is an issue, with a greater number of newer teachers having human geography degrees and without always the necessary quantitative training. The fact that geography is sometimes being taught by non-specialists was felt to add to the issue.

A renewed priority for data skills

The changes to AS and A Level geography occurred at the same time as changes to GCSE, putting substantial pressure on teachers as well as on Awarding Organisations to prepare and deliver new content. Numeracy and data skills may have 'got lost' somewhat in the midst of all the other changes; the extent of all the changes may mean that more focused time is needed for teachers to 'catch up' in regards to data skills.

Is the maths needed in geography reinforced through other areas of the curriculum?

The maths required in geography is not necessarily in GCSE (nor A Level) maths – notably, statistical testing – so there isn't always a transfer of the requisite mathematical knowledge into geography. Even where the maths overlaps, the way of approaching it may differ. It was suggested that the Core Maths qualification may be drawn upon as a classroom resource because of the complementary nature of some of its questions (e.g. about river discharge and climate data).

Language and terminology

Maths has been used as an umbrella term for quantitative methods, numeracy and data skills. They do intersect with maths but whether they are subsumed by it is a moot point. For example, data skills are not only about maths: they can also involve computational skills, cartographic skills, visualisation skills, and other elements that are not simply mathematical, per se. Further, the focus on maths might not be the correct one if what actually is needed is a focus on those wider data skills.

The use of GIS is still not as widespread as is required and it needs to be more embedded in the curriculum. Nevertheless, through the use of GIS, geography pupils are exposed to the language of geographic data science, for example, 'Big Data', crowdsourcing, and so forth.

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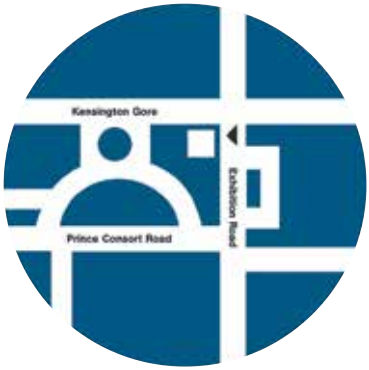

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