Handling a large data set post-16: Learning and assessment

Ben Redmond[1], Jennie Golding[2], Grace Grima[1]

[1]Pearson, [2] UCL Institute of Education

English 5-18 education until recently offered limited scope to develop increasingly important concepts related to authentic data set data handling, representation and interpretation skills. However, for examination from summer 2018, A-level Mathematics students are now required to engage with a 'large data set' using appropriate software. Their learning is then summatively assessed drawing on pre-release material. We report on a study which evaluates emerging opportunities to support and assess such learning within one such course. We focus on the challenges teachers and students faced, and their perceptions of the nature and extent of the support provided, during the first year of operation. We show that for both teachers and students there were tensions between education for appropriate use of software and an effective focus on the underpinning conceptual understanding. Teachers and students also experienced challenges in formative assessment of the related learning.

Keywords: pre-university mathematics, large data set, data handling software, formative assessment, summative assessment.

Introduction: the policy context

This paper reports on outcomes from the first year of a three-year study exploring teacher and student perceptions regarding the challenges and opportunities around the 'large data set' work: a newly-introduced mandatory component of the reformed Mathematics A-level in England, with first examination Summer 2018. A-level Mathematics is a high-stakes, calculus-rich pre-university course largely taken by students aged 16-18. Timelines for initial development and accreditation, and related teaching and assessment resources, were short, with little time for piloting or trialling new models. In this context, research which explores these qualifications becomes of particular importance for well-informed further development to better meet student and teacher needs.

A-level examinations in England are delivered by three Awarding Organisations, with Pearson a major provider. The content of the reformed A-level is not dissimilar to previous specifications, though there is much greater emphasis on genuine mathematical problem solving, on proof, and on mathematical modelling. These are consistent with the renewed emphases in the new General Certificate of Secondary Education (GCSE) examinations taken by almost all students at age 16. A new feature within the statistics strand of the A-level (one-sixth of the available credit) is that all students are expected to engage with a large data set, of sufficient size that it requires technology for its exploration, analysis and representation - and to be examined on their grasp of that in a written paper. The 'Requirements' for the new A-levels in mathematics (DfE, 2016, page 5) include:

> All students of A-level Mathematics must:
>
> - Become familiar with one or more specific Large Data sets (LDS(s)) in advance of the final assessment (these data must be real and sufficiently rich to enable the skills of data representation and interpretation in the specification to be explored); Use technology such as spreadsheets or specialist statistical packages to explore the data set(s);
>
> - Interpret real data in summary or graphical form;
>
> - Use data to investigate questions arising in real contexts.

In response, the Pearson specification (2017, p10) states that:

> Assessments will be designed in such a way that questions assume knowledge and understanding of the data set. The expectation is that these questions should be likely to give a material advantage to students who have studied and are familiar with the data set. They might include questions/tasks that:
>
> - assume familiarity with the terminology and contexts of the data, and do not explain them in a way that gives students who have not studied the data set the same opportunities to access marks as students who have studied them
>
> - use summary statistics or selected data from, or statistical diagrams based on, the data set – these might be provided in the question or task, or as stimulus materials are based on samples related to the contexts in the data set, where students' work with the data set will help them understand the background context and/or require students to interpret data in ways that would be too demanding in an unfamiliar context.
>
> Students will not be required to have copies of the data set in the examination, nor will they be required to have detailed knowledge of the actual data within the data set.

The Pearson specification offers a large data set focused on UK Meteorological Office weather data and covering five UK weather stations and three overseas weather stations in May-October 1987 and May-October 2015 (~184 records of each of 11 variables for each of eight locations in each year). Teachers are new to such curriculum demands, with many teachers of A-level Mathematics having limited knowledge themselves of data handling of this sort – or, often, of the appropriate associated software. Teacher support in this area is therefore critical. Pearson, like other Awarding Organisations, publishes support materials for teachers, assuming a subject content and pedagogical content knowledge to make use of those.

Changes to the A-level were developed largely top-down from Higher Education input, but were generally well-received by the subject community, seen as focusing on mathematically important processes rather than superficial facts and procedures, though many teachers were apprehensive about the demands of teaching for them (Golding & Smith, 2016).

Research questions and theoretical frameworks

This paper draws on findings from the first year of a three-year study carried out by Pearson in collaboration with UCL, that set out to understand the implementation and efficacy of the reformed Mathematics/Further Mathematics A-levels and Pearson's associated free/paid-for resources. Research questions were informed by Pearson's stated intended learning aims and objectives for the A-level specification (Pearson, 2017, p7) and derived from Pearson's intended learner outcomes. They included:

- How do teachers and students use Pearson's free and paid-for resources to support learning around the large data set, including in preparation for summative assessment?
- What are teacher and student perceptions of resource effectiveness in meeting cognitive and affective needs in relation to the large data set?

While this study focuses on the perceptions of teachers and students, the influential GAISE reports on K-12 and college statistics were used as a framework when exploring the teaching, learning and assessment of the large data set. These guidelines recommend that 21st century curricula fit for purpose will;

- Teach statistical thinking;

- Focus on conceptual understanding;

- Integrate real data with a context and a purpose;

- Foster active learning;

- Use technology to explore concepts, analyse data;

- Use assessments to improve and evaluate student learning.

(ASA Revision Committee, 2016)

The intentions of the new A-level curricula in mathematics are to meet those recommendations, yet there are considerable challenges involved in attempting to do so, as addressed in Nicholson and Darton (2003) and Nicholson, Ridgway and McCusker (2006). Further there are already emerging some principled critiques not of the *intentions* of this part of the specification, but of its enactments across Awarding Organisations (Nicholson & Ridgeway, 2018).

Methodology

This paper references findings from the first year of a study that will be carried out over three academic years (2017/18 to 2019/20). Table 1 shows data collected in year one, with each yearly cycle comprising three phases that collect largely primary data from ten centres that have adopted Pearson Mathematics A-levels.

Table 1: Data collection in first academic year

Phase 1 (Start of year)	Telephone semi-structured interviews (24 teachers including Heads of Maths) Collected baseline (GCSE Mathematics) data for participating classes
Phase 2 (Spring 2018)	20+ Semi-structured lesson observation notes 20+ Post lesson observation teacher semi-structured interviews 20+ Student semi-structured focus groups
Phase 3 (Summer 2018)	Teacher Survey (approaches and related learning outcomes) 19 respondents Student Survey (approaches and related learning outcomes) 168 respondents End of year assessment data collected

The first year's sample was drawn from convenient Pearson centres willing to participate; it showed reasonable variation but was not completely representative, being slightly skewed towards historically high-achieving centres. Within each centre we focused on collecting data from the Head of Mathematics or equivalent person responsible for A-level Mathematics, and in the first year, on two year 12 classes and their teachers; in year 2 we expanded this to follow through those students into year 13, and to included two year 12 classes from the new cohort and their teachers. We recruited two further centres to address the skew somewhat, and intend to further address representativeness of sample in year 3. However, despite limitations the study gives insights into how the large data set resources are being used in the early years of this specification and their study experience. All interviews were recorded and transcribed; all qualitative data was then iteratively analysed by research question and then using an open grounded approach (Charmaz, 2006) to expose grounded sub-themes.

Findings: teacher and student experience

At the time of the first year visits, most students had not gained significant experience regarding the large data set. Consequently, this paper focuses on the perceptions of teachers with more substantial analysis of student perspective to be carried out in the second and third year of the study. In principle, teachers were largely supportive of the inclusion of the large data set in the reformed Mathematics A-level.

> I think it's really good that we should be teaching stats via a real-life data set and using ICT. (Centre 9, Teacher 1, Initial Telephone Interview)

> I love the concept of large data set. (Centre 1, HOM, Post Observation Interview)

However, significant concerns were expressed around enactment and assessment. These were strongly represented in interviews with teachers. Six out of 19 teachers also explicitly referenced the challenges surrounding the large data set in survey responses. Teachers' in-class experiences were varied, particularly early on in their engagement with the reformed A-level. One centre with confident, knowledgeable teachers was thriving on tech-intensive engagement.

> A bit of uncertainty in the build-up…but actually, once we started teaching it, it fell very, very quickly into place…some really good discussions [among students and staff]. (Centre 2, Head of Maths, Initial Telephone Interview)

The following teacher suggested that with greater opportunity to engage with the large data set they were becoming more comfortable with it as the academic year had progressed.

> The large data set is always at the top of our thinking. I'm feeling a lot happier about it now than I was before. (Centre 5, Teacher 2, Post Observation Interview)

Conversely, teachers in at least five of the 10 centres said that they lacked experience of the necessary data handling and technological knowledge required to engage successfully with the large data set. Individual teachers commented on increased pace of teaching demanded by the aspirational nature of the reformed qualification as well as the challenges of teaching an unfamiliar specification.

> Teaching resources, homeworks, large data set - all take more time than I can put in to prepare. (Centre 10, Summer Teacher Survey)

In this context some teachers were struggling to adapt their subject and pedagogical knowledge for the delivery of the large data set.

> I think I'm very much at a loss to know really what I should be doing with the LDS. (Centre 10, Teacher 2, Initial Telephone Interview)

Developing the technological skills required to engage with the large data set was also a barrier that some teachers were working to overcome.

> My knowledge of Excel is simply what I have taught myself. Nobody's ever given me a training course on it. (Centre 10, Teacher 2, Post Observation Interview)

Where teachers lacked subject and pedagogical knowledge as well as technological skills, some commented that they felt 'upskilled' by Pearson (paid-for) resources. CPD was seen as particularly valuable in supporting teachers to adapt their teaching to allow the effective delivery of the large data set. Some teachers (at least six of 20) had accessed support from FMSP but there was a sense that more long term support would have been advantageous.

> A great course – it just needs to extend over a year or 18 months rather than a day (Centre 2, Summer Teacher Survey)

A number of teachers perceived students as lacking some of the skills and conceptual understanding to engage with the large data set. This was, in some cases, due to the complexities of understanding and manipulating real life data.

> [Students are] not enjoying the big data set though, and it's quite a struggle to get them to just play around with...I understand the whole point of it because it's real life data; however, they're not really seeing it. (Centre 3, Teacher 2, Initial Telephone Interview)

Students struggled with technological skills required to begin engaging with the large data set.

> In order to engage with this large data set, I'm going to have to spend lesson after lesson teaching them how to use Excel. (Centre 10, Teacher 2, Post Observation Interview)

> [The students] have very little experience of using Excel now it is not part of the curriculum for any GCSE. (School 5, Summer Teacher Survey)

Access to technology was also a significant barrier for some centres:

> You have the issue of actually having access to laptops or an IT suite…which is not the easiest thing always to be able to arrange. (Centre 10, Teacher 1, Initial Telephone Interview)

At least five teachers expressed concern regarding the clarity of guidelines for assessment, and the inevitable limited supply of past assessment materials for this new specification. A recurring theme around uncertainty was linked to the late accreditation of some specifications (less than six months before first teaching) and as a consequence, late provision of supporting resources and specimen assessment materials (SAMs)

> We're still a little bit mystified as to what the assessment for the large data set is going to end up looking like…There's so few sample papers…that you're sort of grasping at one or two papers and within that there's maybe two questions that refer to the large data set, and maybe each one is a two marker. The extent to which it can be examined, I still find quite baffling. (School 4, Teacher 1, Initial Telephone Interview)

The available SAMs were seen by at least six teachers as requiring memorisation of arbitrary aspects of the large data set, contrary to Pearson's stated intentions. At least three teachers highlighted what they felt were statistically inappropriate expectations in some assessment materials. As the following comments suggest, there was concern that the assessment would not adequately assess or reward genuine engagement with the large data set.

> It's a nightmare to assess…how do you assess that? And again from the sample assessment material it looks like it's been quite contrived and rewarding exposure to the set rather than necessarily teaching through it. (Centre 9, Teacher 1, Initial Telephone Interview)

> Large data set questions - it is almost just luck if they are familiar enough to know the answers and it really does not test their maths (Centre 10, Summer Teacher Survey)

> My fear is that [assessment of the large data set] won't end up being what it was intended to be. (Centre 5, Teacher 1, Post Observation Interview)

These comments reflect the fact that valid and reliable assessment of curriculum intentions is complex and challenging (Nicholson & Darnton, 2003). They are also an indication of the pressures of teaching for high stakes assessment where, given the newness of the qualification, there are still significant unknowns.

Discussion

Despite widespread support for the large data set in principle, findings from this study showed mixed enactment, mixed confidence in the subject matter and technology, and low confidence in validity of the emerging assessments. As a consequence, teaching and assessment in the first year of enactment did not fully support the GAISE recommendations.

The extent to which teachers were able meet the first four GAISE recommendations, (*teach statistical thinking, focus on conceptual understanding, integrate real data with a context and a purpose and foster active learning*) was restricted by their capacity to adapt their subject and pedagogical skills to fit the delivery of the large data set. This was especially challenging where teachers were delivering a new, more aspirational curriculum at the same time as familiarising themselves with its content, creating additional time pressures. This was intensified for those teachers used to teaching for the former A-level Mathematics (Nicholson & Darnton, 2003). Given that centres in this study were skewed towards high attainment, participating teachers were likely at least as knowledgeable as those in more typical centres. It is therefore a reasonable assumption that these findings underestimate the wider challenges being experienced in initial enactment. Focused and substantial CPD, as well as targeted resources that support teaching, will be key to equipping teachers to deliver the reformed A-level Mathematics specification and in particular the large data set.

Enactment of the fifth GAISE recommendation *(use technology to improve and evaluate student learning)* was restricted in some centres where teachers lacked relevant

technological skills to engage with the data set. In some centres limited access to appropriate hardware added additional barriers. Teachers also perceived students as lacking experience of data handling and related software which, given the time pressures of the aspirational curriculum, was difficult to overcome.

The sixth GAISE recommendation (*use assessments to improve and evaluate student learning*) was impeded by a deficit in available SAMs as well as a perceived lack of clarity in assessment guidelines. The policy system of high stakes, relatively short written examinations was also seen by some teachers as having limited capacity to assess meaningful engagement with a large data set. In this context, delivering the large data set was viewed by some teachers as prohibitively time consuming given the relatively small credit associated with it.

It is important to note that in the first year of this study, enactment of the new qualification was in what one teacher called a "fledgling state" (Centre 9, Head of Maths, Initial Telephone Interview) and perceptions of the large data set were evolving as teachers and students moved forward in their engagement with it. In its first year this study engaged with students and teachers at three points across the academic year. It was evident that teachers' survey responses at the end of the year showed greater confidence having had more opportunity to engage with the large data set and related assessments. However, for some teachers, feelings of uncertainty around the teaching and assessment of the large data set persisted. As this study continues into its second and third years these evolving perceptions will be an important focus, offering a longitudinal dimension to the analysis.

References

ASA Revision Committee. (2016). Guidelines for assessment and instruction in statistics education college report. Retrieved from http://www.amstat.org/education/gaise.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis.* Thousand Oaks, California: Sage.

Department for Education. (2016). Mathematics AS and A level content. Retrieved from https://www.gov.uk/government/publications/gce-as-and-a-level-mathematics

Golding, J. & Smith, C. A. (2016). *Beginner mathematics teachers learning to teach and assess advanced problem solving*. London: FMSP.

Nicholson, J. & Darnton, C. (2003). Mathematics teachers teaching statistics: What are the challenges for the classroom teacher? In *Proceedings of the 54th Session of the International Statistical Institute*, Berlin, Germany. Retrieved from https://iase-web.org/documents/papers/isi54/3463.pdf

Nicholson, J., Ridgway, J., & McCusker, S. (2006). Reasoning with data – Time for a rethink? *Teaching Statistics 28*(1), 2-9

Nicholson, J. & Ridgway, J. (2018). Real-world contexts in statistics components of UK Mathematics examinations: Aiming forwards, walking backwards. In M. A. Sorto, A. White, & L. Guyot (Eds.), *Proceedings of the Tenth International Conference on Teaching Statistics* (ICOTS10, July, 2018), Kyoto, Japan.

Pearson. (2017). A level mathematics specification: Issue 3. Retrieved from https://qualifications.pearson.com/en/qualifications/edexcel-a-levels/mathematics-2017.html