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Learning through enquiries
in Key Stage 3 science

Context

Returning to the UK just four months before the science department would start teaching its first lessons, the big question on my mind was, 'what are we going to teach them?' What does our science curriculum at Ark Academy look like?

Obviously, I had my own (very different) experiences of teaching Key Stage 3 science in London and internationally, and the school had guidelines in place for curriculum planning. But the Ark Academy science department itself was a blank slate; no established schemes of work, no historic data about the students, nothing limiting our vision of what science lessons could be. It was exciting, stimulating and daunting, in equal measure.

To make things more difficult there was the uncertainty about how much science our students would know on entry. What students have studied in KS2 is always something of an unknown quantity, but in a start up school, with 57 feeder primaries, in a year when some Brent primaries boycotted reporting *any data at all* on the attainment of year 6 students in protest at the KS2 SATs, this was particularly tricky.

So we didn't know what they knew, but we knew what we knew, and what we wanted them to know. Our goal was simple – look at the end and plan backwards. The Science Department at Ark Academy is a stepping stone. A stepping stone for the future Watson and Cricks, the future alternative energy inventors, the future Jane Goodalls, the future cancer researchers, the future Nobel Science Award recipients. And why not? Our job is to help get them there, prepare them for university, prepare them for A level, prepare them for GCSE and, most importantly, prepare them to be a scientist.

A huge task – but what's the best way to eat an elephant? One bite at a time. So starting with the first bite, we began planning backwards from A level and GCSE, to design a Key Stage 3 curriculum that was essentially a 'junior version' of what they'd need to know in Key Stages 4 and 5. For us, that meant an emphasis on scientific enquiry; on being independent, confident scientists who could use deeply embedded knowledge, skills and concepts in science and apply these to new, unseen situations and investigations.

All of this planning was against the backdrop of major uncertainty about the review of the Key Stage 4 science syllabus. When we were planning Year 7 we had only the most slender indications about the direction GCSE science was heading in. The government was making noises about more rigour in assessments, a greater depth of scientific knowledge, and an end to blanket objective testing. And, most importantly for this case study, an increased emphasis on the scope of **scientific investigation** carried out as part of the GCSE award.

> *"Instead of concentrating on teaching and learning [in science] you had people who were being trained again and again to clear the hurdle of the examination along the way. That meant that unfortunately less time was being spent developing a deep and rounded knowledge of the subject."*[1]

This was the question at the forefront of my mind – how do I develop a deep and rounded knowledge of the subject in students, while at the same time training them in the skills of independent, scientific enquiry? Was there enough time to do both? Where does the emphasis fall? As is so often the case with a subject as broad as science, the challenge was striking the right balance, and ensuring the investigative nature of the subject wasn't underserved.

Scientific investigation has always been part of the KS4 requirements. The format of the investigation has varied – its most recent incarnations have been ISAs (Individual Skills Assessments) and 'Controlled Assessments'. But whatever the format, the fundamentals have been the same. Investigations challenge students to think like scientists, speak like scientists and apply their scientific knowledge to a range of authentic investigations.

Or put another way:

> *"[GCSE specifications in science must develop in students the ability to] plan practical ways to answer scientific questions and test hypotheses; devise appropriate methods for the collection of numerical and other data; assess and manage risks when carrying out practical work; collect, process, analyse and interpret primary and secondary data including the use of appropriate technology; draw evidence-based conclusions; evaluate methods of data collection and the quality of the resulting data"*[2]

The problem was that schools often waited until KS4 to expose students to scientific investigation. In Year 10 students were hit with a two week blitz of ISAs. Many departments took a strategic approach: have the students complete two or three ISAs in a set time period, with little preparation, and submit the best result to the exam board. This affords no opportunity to cover

1 Education Secretary Michael Gove MP in interview with Alan Marr 27 June 2011
2 Ofqual – GCSE Subject Criteria for Science (2011)

the principles behind scientific investigation in depth, and no time for students to reflect on what they've learnt and how it relates to their wider understanding of the subject. In my opinion it's completely the wrong way to tackle the problem.

At Ark Academy we asked ourselves: Why not prepare our students for GCSE investigations at as young an age as possible? Why not punctuate the KS3 curriculum with 'mini' investigations which introduce students to the language and processes of scientific research right from the first term? Why not build a student body who can approach the scientific enquiry in both the GCSE Controlled Assessment (or whatever it may be called when they reach it) and the GCSE papers with the confidence of a well versed practitioner?

The role of investigations in our curriculum

We decided that every half term students would encounter at least one investigation within their fertile question[3]. These would build throughout the year, and the language of scientific investigation would be drip fed through each one. Each investigation would consolidate and develop the knowledge and skills covered in the last. The investigations would link with the wider fertile question students were exploring and help them to construct their answers. We wouldn't attempt to cover every element of a full scientific investigation in each one, but would instead focus on one aspect; for example planning or data collection. However, across the six investigations all elements would be covered.

Term	Investigation title	Original focus
Autumn 1	Does the amount of water that cress seeds receive affect how quickly they germinate?	Plan
Autumn 2	Does the type of food being burnt affect the maximum temperature reached in the water?	Analysis
Spring 1	How different am I from my friends?	Data Presentation Conclusion
Spring 2	Does the temperature of the water affect how much sugar dissolves?	Plan and analysis
Summer 1	Does the height that the ball is dropped from affect the size of the crater formed?	Full investigation
Summer 2	No new investigation planned as a shorter half term focused on revision.	

3 See case study 1 – A year in the life – for definition of a 'fertile question'

Sequencing the investigations

In the first investigation students focused solely on the planning stage (where better to start than at the beginning). As a route into 'planning' we asked overarching questions of students to guide their thinking and help them understand the fundamentals of investigations. The wording and delivery of these questions was key; they had to be open and accessible enough to generate a meaningful dialogue between students and teachers, and be rich enough to have all the key knowledge lying behind them. Some examples were:

- **How do scientists find things out?**
- **How do scientists carry out an investigation?**
- **What makes a good scientific investigation?**
- **What is a prediction and how do I make one in science?**
- **What are the factors that must be taken into account in an investigation?**

Slowly we began to circulate the key vocabulary into their discussions; terms like 'independent', 'dependent' and 'control' variables. We'd provide concrete examples to help students remember what the different types of variables meant. Just as you would do with GCSE students, we provided Year 7 with exemplar investigations to illustrate the key features of a good scientific investigation.

With these broad questions answered students now understood the basics of a good plan, and were able to begin their investigation. It was titled, 'Does the amount of water that cress seeds receive affect how long it takes them to germinate?', and they were able to apply what they had just learnt to this authentic situation. Our view as a department was that the success or failure of the actual experiment wasn't the main thing here – instead it was the ability of the students to **plan** correctly.

Sample Investigation

Research question:

Does the type of chocolate affect the time it takes for Miss Keane to eat the entire bar?

Background information:

Miss Keane is a known chocaholic. Even as a little girl, she was described as a slave to the power of cocoa. Her natural desire to finish a bar of chocolate before it should get a chance to be exposed to the air is legendary.

Prediction:

Based on my knowledge of Miss Keane I predict that the type of chocolate will have no effect on the time it takes Miss Keane to eat the entire bar.

Variables:

Independent Variable: this will be the type of bar of chocolate that Miss Keane will have to eat.

Dependent Variable: the time it will take for Miss Keane to eat the bar of chocolate.

Control Variables: it is important to realise that there are other factors that may influence how quickly or slowly Miss Keane eats the bar of chocolate. These other factors must be controlled or kept the same for each experiment or the test result would be unfair.

The next fertile question focused on energy resources. This time the students were provided with a ready-made plan for the investigation – one that exemplified the good features they'd worked on last time. This reinforced their understanding of planning and also saved time, allowing us to focus in sufficient depth on the key element of this investigation: analysing data. Titled, 'Does the type of food being burnt affect the maximum temperature reached in the water?' this investigation provided the students with the opportunity to collect and analyse numerical data.

Initially students were given free rein on how to record their data and present it in their books. The only guidance they were given was the deliberately open reminder: 'don't forget to write down your results.' We wanted to see what they had been taught before and what they could intuitively understand. This helped us to formatively assess students, and allow them to discover for themselves the benefits of recording data neatly in tables etc. They puzzled out the best strategies for recording their data through trial and error, and then for presenting the data in a form that allows easy analysis.

This was one of the most valuable lessons over the course of the year. Never overestimate how much the students know and retain – their recall of the science they'd learned at primary school was, at best, mixed. The value of getting the students to just show us how they thought they should draw a graph and how to collect results was immense. Slightly scary, but immense.

Participation

The first lesson of the investigation revealed major weakness across the board with the students' ability to present results, so the focus of the next few lessons shifted. We went back to basics with tables of results and graphs. What must a good table do? What should it include? How much information should we capture? With graphs we started further back. How do we read off different scales? What is the importance of dividing a scale equally? We literally started from first principles and built the students up to how to draw points onto a line graph, or how to draw bars onto a bar graph.

This process of co-evaluating the success of each lesson in order to refine and improve the next one has become standard practice in our department. In the end, the weakness in students' data collection led us to change not just the next few lessons, but the whole of the next term's investigation.

The Spring 1 investigation had the original focus of data presentation and conclusion – we adapted it to look exclusively at recording and presenting data. The investigation was titled 'How different am I from my friends?' and the data collected was on the heights, arm lengths etc of the different students in the class. We repeated and then developed the skills of the last investigation, introducing students to more complex ideas about different types of variables in a science investigation (for example **continuous** vs **categoric)**, and how different graphs are used to represent these types of data.

By Spring 2 students were ready to dive deeper into scientific investigations, and begin to look at more the conceptually challenging areas of analysing their findings, evaluating their methods and drawing robust conclusions. The title this time was, 'Does the temperature of the water affect how much sugar dissolves?' The idea here was for students to begin the investigation by conducting an experiment in which they would quickly see obvious areas for improvement. For example, the investigation asked the students to measure how much sugar dissolves by simply counting the number of spatulas used. We would prompt the student to take their scientific thinking further by asking: Do you think a real scientist would do this? If they were to measure sugar, what might they use? Do you think Einstein counted sugar by the spatula full? How would he do it? If you were to do this again how would you do it? These ideas for improvement would then form the basis of their evaluations and conclusions. The investigation was effectively a model for how good scientists include a frank commentary on the errors in their research methods, and a detailed plan for future improvements. In the sugar water experiment, because of these planned weakness in the method, students were able to spot quickly the obvious inaccuracies in the data collection, and had plenty of ideas for their evaluations. However, some difficulties came when the students were asked to marshal these ideas into extended written evaluations, particularly with the lower band classes.

Of course, all of the above investigations are just a start, and part of the long term trajectory students are following through KS3 and into GCSE. The Year 8 investigations – for example **'What are the factors that affect the strength of concrete?'** – are designed to contain more complicated problems for students to investigate, and include more sophisticated terminology in the write ups. In Year 9 students will be introduced to formal ISA investigations, having to complete them in the manner of a GCSE examination. Because of the experience in Years 7 & 8 it is hoped they will be more confident with the ISAs, and the learning curve will be more gentle. All these investigations though are just preparation for the all important GCSE Controlled Assessments they will begin in Year 10.

Investigating the investigations

What evidence is there of positive impact?

The real measure of impact will come with this cohort's GCSE results, and particularly their performance in the Controlled Assessment (or equivalent). But what can we say at this early stage?

- **Increased engagement. Students were more engaged in their investigation lessons and in science lessons generally than they would have been otherwise. This didn't happen immediately. Presented with their first investigation, students were excited by the research and experiments, but reluctant about the extended writing that was involved (they could see this from the exemplars). However, careful scaffolding of this writing and introducing the key language gradually, meant that their attitudes changed. Once they had this confidence their excitement grew about collecting results, competing with their peers and discovering if their results matched their predictions (always fun).**
- **Increased independence. The activities undertaken by students in their investigation lessons engendered an independence in their thinking and behaviour; they were no longer relying on their teachers for all the answers, but instead could rely on their own observations and those of their peers.**
- **Increased curiosity. There were a number of occasions during investigation lessons last year when we were genuinely delighted by the quality of the questions students were asking. High level stuff that cut right to the heart of the issue, and linked with some of the really big ideas in the subject. Hearing them say, 'I wonder what would happen if…' was really heartening.**
- **Increased progress. This is a tricky one. Each of the six formal assessments sat during the year had a 20% weighting towards investigative style questions (in line with GCSE requirements). But while we know the overall progress of students from their Year 7 baseline was, on average, 2.64 sub-levels, we can't disaggregate the data to show how their performance in the investigations contributed to this. Whether or not the progress was accelerated by investigations or other aspects of the schemes of work is hard to say – the answer is that it was probably the interrelation of both.**

Reflection – what would we change?

Inevitably there are things we would change about the investigations in the Year 7 science curriculum, based on our experience of this year. Here goes:

- **A major weakness in our Year 7 intake is their basic graph drawing skills. Too much time was spent on honing this skill in Year 7 last year. This time round, in a bid to save time during the course of the year, we have introduced a new, 'introductory' unit, which we teach to Year 7 for the first four weeks of the academic year. During this unit we explicitly teach and re-teach our expectations for graph drawing. Classroom displays have also been created in each room that highlight the elements of an 'A*' graph. We refer to these displays throughout the year.**
- **While we're on the theme of explicit teaching, based on our experience of the first year we realised we needed to be more explicit and more consistent with Year 7 about stating the key scientific terms (and their definitions) that they will need at GCSE. This key language needs to be made student-friendly and consistently displayed in all science classrooms.**
- **The extended writing piece still needs more thought. We need to be more rigorous in how we expect students to complete longer pieces of scientific writing. Careful scaffolding which avoids giving students the answer, but provides them with the handhold they need, is useful here.**
- **Linked to this, the weakest areas of Year 7's investigations were the concluding and analysing sections. These areas require higher order thinking skills which are unfamiliar to many students. Many failed to demonstrate a clear understanding of how to spot and explain patterns seen in graphs, suggest improvements to an investigation, or give intelligent reasons for anomalous results. We have thought carefully about how to prepare students for the analysis and conclusion sections this time round. We aim to break down the sections into more manageable chunks, and provide better scaffolds.**
- **As well as looking back over Year 7 we need to look forward to Year 8 and 9. We now know what can be achieved in the first year of KS3 – now we need to think how do we consolidate and extend that as they move into Year 8 and 9, and flesh out the plans we made before the school opened. We have to keep an eye on the new GCSE requirements, understand the specific skills controlled assessments will require of our students, and build in suitable preparation to KS3.**

So overall, that initial challenge of building a curriculum from scratch that will help mould the future scientists of the world has begun. We have a clear vision, we have the plan behind it, and we now have experience of implementing it. And most importantly, we have been able to teach proper scientific investigation in a curriculum phase where it is often missing. By starting with the end product, we've made Year 7 a firm stepping stone; one that will build the skills and understanding students will need in order to become the scientists of tomorrow.


SINGLE SEX CLASSES