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# Understanding the Impact of Teaching Strategies, Engagement and Interest in Science: An Analysis of the English PISA Cohort

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## Abstract

*There has been considerable interest in making use of Inquiry-based learning within science classrooms to promote deeper learning, building scientific skills and applying scientific knowledge to real-world inquiries. We address the effect of different teaching strategies in science classrooms and explore the student/school/system level interactions, particularly with respect to science subject interest, engagement and attainment using a unique dataset which combines the Programme for International Student Assessment (PISA) 2015 and the English National Pupil Database (NPD), linked for the first time to provide insight into the PISA and public examinations (GCSE) taken six months later by students in England.. PISA defines and uses a score as a measure of scientific literacy. A key finding from the linked PISA-NPD is that there is little evidence that more frequent use of inquiry-based approaches is associated with students making more progress in science at school. Data show that where students report high levels of inquiry in their classrooms, their levels of scientific literacy were lower. These analyses show a strong positive relationship between student reports of the frequency of teacher-directed and adaptive teaching instruction and scientific literacy.*

**Keywords**: *PISA, achievement, engagement, teaching approaches;*

## Introduction

The purpose of science education has been articulated as two-fold; to "educate students both about the major explanations of the material world that science offers and about the way science works" [18, p.8]. PISA aims to capture a definition of scientific literacy with a focus on students' ability to engage with science-related issues with "competencies to explain phenomena scientifically, to evaluate and design scientific enquiry, and to interpret data and evidence scientifically" [14, p.1] as a part of citizenship. High levels of scientific literacy are linked to economic growth and countries showing greatest gains in PISA seem to have weathered the recent financial storm well [12]. In 2015, scientific literacy was once more the focus of the PISA assessments in OECD countries. Criteria for determining a 'scientifically literate' young person have been articulated by PISA as being able to 'engage in reasoned discourse about science and technology' [12, p.7] thus requiring competencies to explain phenomena, evaluate and design scientific inquiry and interpret data and evidence scientifically.

School science attainment, attitudes and engagement are shaped by student background, school experiences and social structures and expectations but there is little understanding of how these influences combine. Improving our understanding of these processes is essential for underpinning policies and practices to improve science learning in schools. The PISA 2015 data, and the capability to link these to the National Pupil Database (NPD), provide an unprecedented opportunity to offers a unique opportunity to undertake a longitudinal study over a critical period in students schooling in England.

Year 11 in England is a particularly important time for pupils and their schools. At the end of this academic year, students sit important national exams, leading to the widely recognised General Certificate of Secondary Education (GCSE) qualification. The grades young people achieve have a significant impact upon whether they continue in full-time education beyond age 16, the type of higher education institution that they attend and, ultimately, their prospects when searching for a job. Moreover, as schools are publicly ranked and judged by their students' GCSE results, the academic progress young people make during this secondary school year is significant for teaching staff, too. Year 11 hence represents a 'crunch' point in the English education system, where students are expected to work particularly hard, with significant pressure to achieve well.

## 1. Literature Review

In England, aspects of scientific inquiry have been a feature of the National Curriculum since 1989, with a renewed focus on inquiry based learning, as part of '*Working Scientifically*'. In line with this, the recent *Maintaining Curiosity* [15] report from the schools inspection body for England suggests that in order to develop understanding and achieve well pupils must 'enjoy the experience of working scientifically, and sustain their interest in learning it' (p.4); the best teachers 'put scientific enquiry at the heart of their teaching' (p.5); and they allow 'students to see the purpose of science learning and its inquiry-based skills within a wider context applicable to future careers' (p.34). However, progress in developing or adopting inquiry-based approaches has been slow.

### 1.2 Teaching strategies in science education

A global movement for improving science education in schools using more inquiry-based approaches has been evident for several years [1,4,7,11]. The European Union (EU) has funded a number of IBL projects arguing that improvements in science education could be brought about with the introduction of inquiry-based approaches in schools, [19]. Key proponents claim that an inquiry-based teaching approach can help to: support and deepen learning of scientific concepts; overcome misconceptions as part of constructivist teaching and learning approaches; develop curiosity, engagement and interest in science; promote an understanding of the nature of science and what scientists do; develop future citizens who are able to make informed decisions about their lives, as 'current wisdom advocates that students best learn science through an inquiry -oriented teaching approach' [9,p.143]. Precisely what is understood by inquiry reamins elusive [2]. Is it about the nature of scientific practice [3,17], curriculum materials, or more concerned with teaching and learning [20]? The variety of uses and meanings range from and include 'an instructional approach, curriculum materials and a way for students to learn science' (p.162). A developing trend is to focus more on the teaching and learning of science as 'argument and explanation' and less on 'exploration and experiment' [8, p. 2005] and researching the conditions under which inquiry teaching can be effective. In a meta-analysis of inquiry-based teaching [4] a framework was developed to categorise the different aspects of inquiry, the types of instruction and student learning, distinguishing between the "cognitive features of the activity and degree of guidance given to students" (p. 300) concluding that epistemic activities had the highest mean effect sizes compared with other forms of inquiry, namely, procedural, and social.
A tension thus exists between advocates of 'more inquiry' and policy makers, and practitioners, responding to international comparisons.

## 2. Research questions

1. *Using the linked PISA 2015 and NPD, how do school and student-level variables predict the pattern of science learning trajectories for the 2016 GCSE cohort?*
2. *How are the affective variables associated with achievement?*
3. *How are students' attitudes towards and engagement with science associated with science achievement?*

## 3. Methodology

We use secondary analyses of PISA 2015 (OECD) and the linked PISA 2015-NPD to and GCSE data from the same population of students in England to address participation, progression, achievement in and attitudes towards science. As part of the PISA 2015 background questionnaire, young people were asked several questions about their knowledge and attitudes towards science. Of particular interest of this research are a series of questions asking about science self-efficacy and the practises of science teachers. Examples of self-efficacy and teacher teaching strategies questions can be found below, with responses provided on a four-point Likert scale:

- *How easy do you think it would be for you to perform the following tasks on your own?*
  - *Predict how changes to an environment will affect the survival of certain species*
- *The teacher provides individual help when a student has difficulties understanding a topic or task*
- *The teacher explains how a science idea can be applied to a number of difference science phenomenon*
- *Students spend time in the laboratory doing practical experiments*
- *Students are asked to do an investigation to test ideas*
- *Students are allowed to design their own experiments*
- *The teacher provides individual help when a student has difficulties*

- *A whole class discussion takes place with the teacher*
- *The teacher demonstrates an idea*

Responses to these questions grouped by PISA to form compound variables: adaptive (ADINST) inquiry-based (IBTEACH) and teacher-directed (TDTEACH) instructional strategies.

## 4. Results

Figure 1 provides a coefficient plot of our main varying intercept multilevel model of PISA scores. The estimated intercept was 490.9 [472.7, 508.9]. We found that despite controlling for demographic factors, prior attainment, interest and enjoyment in science (affective attitudes to science), hours of tuition and support, and school factors, a one-unit increase in pupil perceptions of the use of inquiry based teaching led to a 10.3 mark [-13.5, -7.2] drop in the overall science literacy score. On the other hand, one unit increase in pupil perceptions of the use of TDTEACH and ADINST led to small increases in the overall score – 3.0 [0.3, 5.9] and 3.2 [0.2, 6.1] respectively.

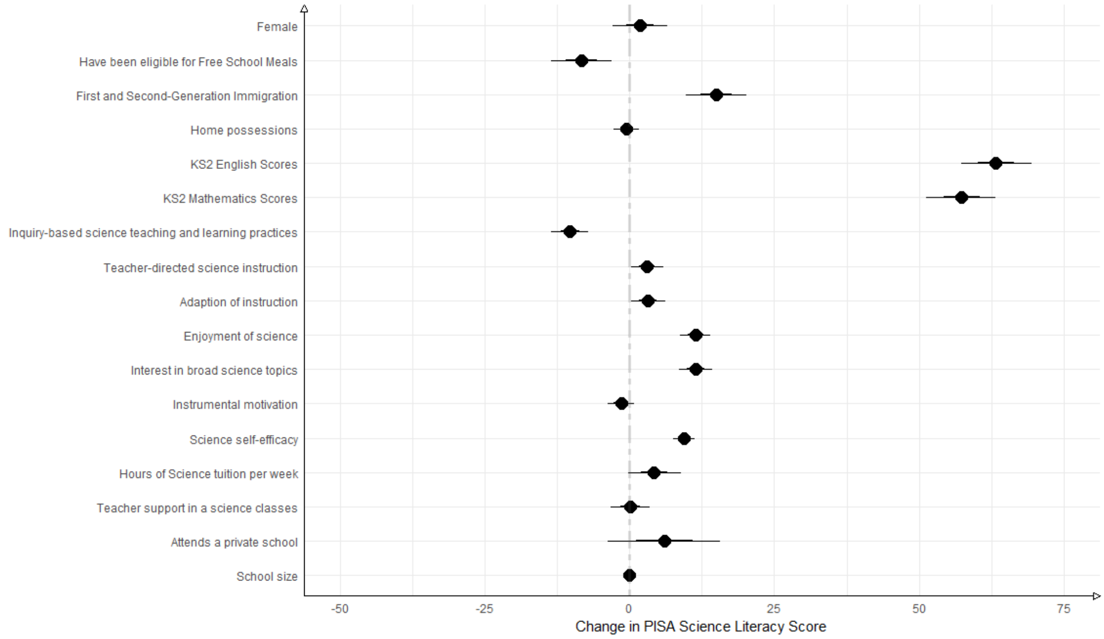


Figure 1: Estimated coefficients and 95% credible intervals from a varying intercept multilevel model exploring the 2015 PISA science literacy scores of pupils in England

Figure 2 provides a similar coefficient plot investigating the impact of the same factors (with the exception of school-level variables at present). The GCSE Science point score has been rescaled for a mean of 0 and standard deviation of 1, with the main varying intercept model having a mean score of 0.11 [0.05, 0.16]. Again, as with the PISA scores above, after controlling for demographics, prior ability, affective variables, and hours of tuition and support, inquiry based learning still has a small negative effect of -0.04 [-0.07,-0.01].

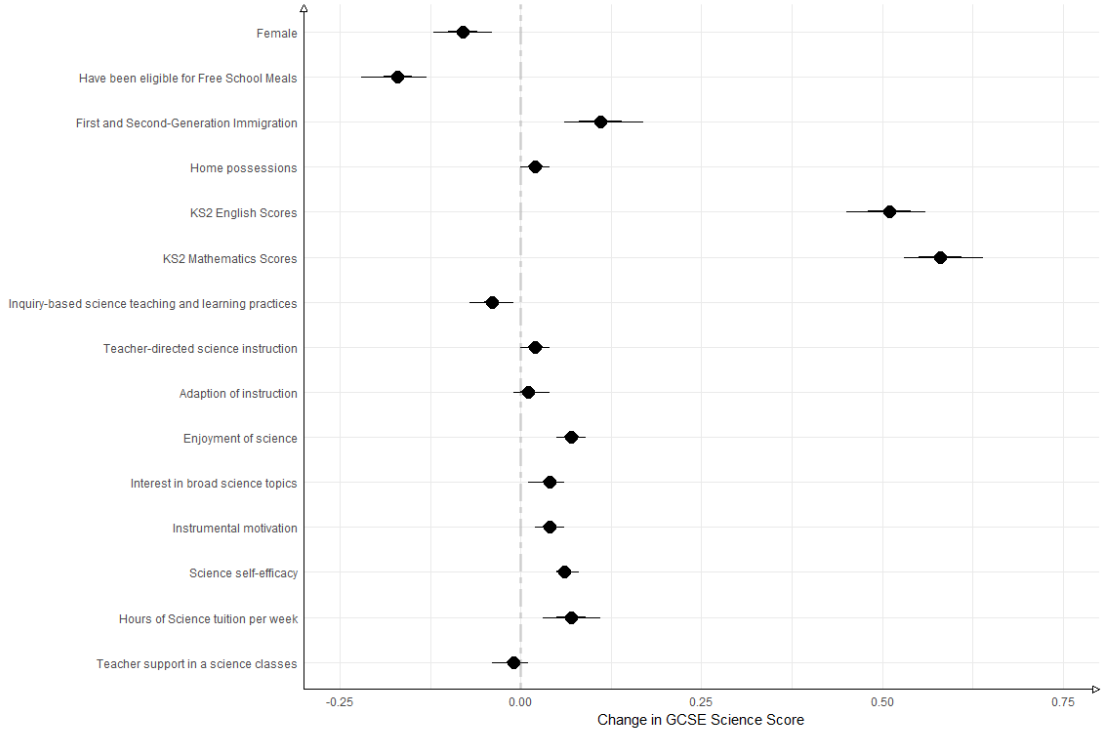


Figure 2: Estimated coefficients and 95% credible intervals from a varying intercept multilevel model exploring the 2015 English PISA cohort's GCSE science scores

## 5. Discussion, Conclusion and Implications

A key finding is that there is little evidence that more frequent use of inquiry-based approaches is associated with students making more progress in science at school. This holds true not only on average, but also across several different sub-groups, and even when considering specific inquiry-based practises

## 6. Limitations

There are of course some limitations to our analytic approach, which we duly acknowledge. First is the issue of causality. Although a key advantage of the PISA-administrative linked data is that it contains a number of background achievement measures and controls, a 'selection-on-observables assumption', in our estimation strategy nevertheless remains, where what we see and measure as common variables generate the dependence. Consequently, our outputs will be careful to make clear all results refer to conditional associations only, not necessarily reveal cause and effect and warrant exploring further; Second, although PISA scores and GCSE grades are highly correlated (e.g. around 0.7 to 0.8 for science) there are some subtle differences in the specific types of skill that they measure. This could then confound our attempts to isolate the factors associated with academic progress children make during Year 11. In other words, do we observe a given factor to be associated with GCSE grades because our measure of baseline achievement (PISA scores) is measuring a subtly different skill? As we include other prior achievement measures in our models which are likely to pick up such residuals, we do not believe this to be a major obstacle to our analysis plan.

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