PISA: Engagement, Attainment and interest in Science (PEAS)

Executive summary

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Executive summary

The way in which science is taught can influence how interested, engaged and informed students are. Teachers are responsible for the delivery of curriculum content as well as shaping views towards, beliefs about and 'trust' in science. Different instructional approaches are used by science teachers as they work with their students. This report explores the association between the experiences of learning science and achievement in fifteen-year olds in England. Our analysis draws from two large data sets: the National Pupil Database (NPD) and the Programme for International Student Assessment (PISA) 2015 data. In PISA 2015, the student questionnaire explored different classroom teaching strategies including teacher-led instruction, adaptive teaching and inquiry-based teaching. Inquiry-based teaching is contested as an instructional strategy with compelling but often opposing arguments advanced by policy makers, educators and researchers.

Background

School science attainment, attitudes and engagement are shaped by student background, school experiences, and social structures and expectations. Despite the various small studies that explore these relationships, 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. Although research undertaken by Education Endowment Foundation (EEF) and The Royal Society (2017) show widening gaps in achievement associated with social disadvantage, no attempt has yet been made to explore or compare the effect of a range of school, system and student-level factors on achievement, interest and engagement. The release of Programme for International Student Assessment (PISA) 2015 data, and the capability to link these to the National Pupil Database (NPD), present a unique opportunity to explore the critical pre-General Certificate of Secondary Education (GCSE) period. We have identified important student (scientific literacy, attitude and engagement) and school-level variables (for example, such as instructional strategy, social advantage) on the pattern of science learning trajectories for the 2016 GCSE cohort.

We have taken a comparative perspective in exploring the science performance of 15-year-old students in the UK with students from other developed countries with a degree of shared cultural history, and more widely with OECD and partner nations to improve the external validity of findings. Specifically, we address the effect of different instructional strategies in science classrooms and increase our understanding of the student/school/system level interactions, particularly with respect to science subject interest, engagement and achievement. Given the enthusiasm amongst some leading science educators for 'inquiry-based' approaches, we wanted to explore associations between student-reported experiences of different instructional approaches and student achievement.

Methodology

Using data from PISA 2015 data, our analysis begins by presenting achievement data on the PISA assessment of scientific literacy (the 'PISA score') for each of the Anglophone countries (Australia, Canada, Ireland, New Zealand, United Kingdom, and the United States of America). The mean country data reflects different positions in the Organisation for Economic Co-operation and Development (OECD) rankings, which vary slightly from one round to another.

To determine the achievement score, or measure of scientific literacy, students answer a range of competency-based questions to determine 'students' capacity to apply knowledge and skills in key subjects, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations' (OECD, 2016, p. 25). Some examples of these questions are available (https://www.oecd.org/pisa/38709385.pdf) as released items from PISA. Coming towards the end of compulsory education, PISA assesses the extent to which different countries and systems of education have prepared their young people to be scientifically literate and informed citizens.

Students also respond to a short questionnaire about 'themselves, their homes, and their schools and learning' (OECD 2018, p. 3). Several items from the background questionnaire (e.g., parents' education, parents' occupations, home possessions, number of books, and other educational resources available in the home) are combined to form a student-level index representing socioeconomic status. In PISA, this variable is named the index of economic, social, and cultural status (ESCS) and is standardised to a mean of zero and a standard deviation of one (OECD 2016a).

PISA 2015 explored students' experiences of classrooms, of their teaching and learning experiences (see Appendix A). Students were asked about the frequency of certain activities ('never or almost never', 'some lessons', 'many lessons' or 'every lesson or almost every lesson') during their science lessons. Country comparisons are presented in PISA documents (OECD, 2016a, 2016b) detailing initial analysis and trends in performance, attitudes and equity, for example. The two-stage sampling process (first by school, then by student) used by PISA allows for national reporting priorities to be met and reflect the breadth of the student population in each country, even though some groups may be over-sampled. We draw from the publicly available primary analysis of the PISA data to retrieve their descriptive statistics (OECD 2016a, 2016b) in the first instance. Throughout this project, we used different statistical and modelling packages to address specific research questions. For example, we used the IDB Analyzer to produce descriptive benchmark analyses, and multivariate regression analysis, and to account for students' socioeconomic status (ESCS), as we examined the direction and relative size of the effect on scientific literacy for each instructional approach, while controlling for the other two approaches.

Findings

PISA data are generated from 15-year olds in schools. The OECD recognises that not all young people are in schools, so any analysis of these data needs to be understood with this caveat in mind.

- In all six Anglophone countries, students who reported experiencing high frequencies of inquiry strategies in their classrooms consistently evidenced lower levels of scientific literacy. There is a strong and negative association between inquiry-based teaching and scientific literacy, amounting to between 40-80% of a school year's learning.

- Conversely, we found a strongly positive association between the frequency of teacher-directed and adaptive teaching strategies and students' scientific literacy.
- Doing practical work either *every lesson* or *very rarely* is negatively associated with students' scientific literacy.
- While enjoyment of science is a predictor for GCSE science, instrumental motivation or a 'pragmatic reason' seems to have a greater predictive and positive association with 'A' level choices.
- The role of self-efficacy as the largest predictor of achievement, is an important finding and reflective of the beliefs that students have about their own ability to learn, master and likely to determine effort and aspiration.
- There is a positive association between inquiry-based teaching and 'positive dispositions towards science' (Cairns & Areepattamannil, 2019), such as enjoyment and interest in science (McConney, Oliver, Woods-McConney, Schibeci & Maor, 2104).

These are important findings to share with teachers and science educators in developing proficiency in using inquiry-based teaching. PISA data analysis of student responses to questions about the *frequency* of classroom experiences provide no insight into the *quality* of students' pedagogical experiences, so our recommendations are crafted with this in mind. The analysis shows complex, often non-linear associations between aspects of inquiry and scientific literacy (Jerrim, Oliver & Sims, 2019; Teig, Scherer & Nilsen, 2018).

Recommendations

Based on these findings, we recommend:

- Some aspects of inquiry-based teaching warrant greater support in schools: the cognitive rather than procedural and behavioural, or the 'doing' of science.
- Consistent with the predictions of cognitive load theory (see Kirschner, Sweller & Clark, 2006) we find that *moderate* levels of *highly guided* inquiry-based teaching have a stronger (D≈0.2) relationship with student attainment on high-stakes GCSE.

- When science teachers use inquiry-based teaching, it should be carefully guided, well-planned and scaffolded (as this leads to positive cognitive and affective outcomes (Aditomo & Klieme, 2020).
- Teachers and schools use appropriate interventions to support self-efficacy especially in low socioeconomic status students. Importantly for policy makers, and those concerned to improve the quality of science education, attention needs to be given to how self-efficacy can be nurtured, developed and sustained in students.
- Environmental responsibility needs to be embedded into the curriculum from the early years.

Science is currently a 'poor relation' in the curriculum in many primary schools (Ofsted, 2021). Further research needs to explore the relative decline in performances in TIMSS, and of primary students in biennial tests and the extent of science experiences in primary schools in England. This will require exploring teachers' and students' experiences using observational classroom data.

Limitations

Although the survey organisers have reported the scale to have a high reliability, and our own robustness tests around this issue did not lead to a substantial change to our results, some attenuation of the estimated effects could nevertheless still be possible.

Rather than examining cause and effect, this is an observational study only, using student responses to the PISA ('low-stakes') assessment of scientific literacy and student questionnaire. Some science educators question the ability of students to 'judge teaching strategies'. Despite widespread support from science education and funding bodies (e.g. Association for Science Education, 2009; Holman, 2017), there is still a lively debate about whether the use of inquiry in science helps (Furtak, Seidel, Iverson & Briggs, 2012) or hinders (Alfieria, Brooks, Aldrich & Tenenbaum, 2011) pupil learning, including among policymakers (Gibb, 2017).

The focus of this study is on *frequency* of instructional approaches and not on the *quality* of classroom experiences. Although the measure of inquiry-based teaching within our dataset is based upon information reported by students, there may well be examples where inquiry-based teaching results in very high levels of student learning: we do not observe that using these PISA data. We cannot comment on the quality of the classroom experiences but the consistent patterning of responses across six (culturally similar) countries, suggests that the associations between achievement and instructional approaches are trustworthy.

We do not yet know whether the long-term and positive effects of inquiry-based teaching on students' dispositions to learning science may then encourage them to continue studying science beyond secondary school and on into a university degree.