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Background

Widespread concern has been voiced across several industrialized countries about the low numbers of young people opting for a career related to Science, Technology, Engineering and Mathematics (STEM) (The Royal Society 2008). Policy makers in countries and regions such as Australia, Canada, Europe, and the USA have monitored, and continued to observe closely, student uptake of these STEM subjects during both compulsory and post-compulsory schooling (e.g., Ainley, Kos & Nicholas 2008, for Australia; Industry Canada 2007, for Canada; National Science Foundation 2010, for the USA; OECD 2009, for Europe; Sainsbury 2007). This concern is largely linked to shortages in projected workforce requirements (National Science Foundation 2010; Sainsbury 2007), the strategic global positioning of a national economy (Industry Canada 2007; OECD 2009), and concern over long-term consequences of decreasing trends in uptake (The Royal Society 2008).¹

Specifically in the UK, the government in 2004 set out an ambitious target to increase participation in science and mathematics among the nation's students. The Science and Innovation Framework 2004-2014 (H M Treasury, 2004) stated that by 2014 the number of students taking A-levels in chemistry, physics, and mathematics should increase. Furthermore, targets were set that would raise student performance at both Key Stage 3 (KS3) and General Certificate of Secondary Education (GCSE) levels². While it is widely claimed that an increase in participation and performance in science, technology, engineering, and mathematics (STEM) subjects is necessary to ensure a flow of skilled workers into these fields, the perceived problem of low participation in these subjects is not new. In the UK, the issue has been debated for at least forty years since the publishing of The Dainton Report in the late 60s (DfES, 1968). However, the perceived mismatch between supply and demand

¹ It should be noted that there is some evidence in the United States to suggest that the STEM shortage is overstated (e.g., Butz et al., 2003).

² KS 3 is years 7, 8, and 9 of pupils schooling in England and Wales. Pupils in these three years usually range in age between 11 and 14 years. GCSEs are an academic subject qualification in England and Wales. Pupils are usually aged between 14 and 16 years when they take the examination.

1
2 continues to be a pressing concern in the 21st century. There is a growing demand in the
3
4 economy for graduates who have studied STEM subjects at a time when participation in these
5
6 some of these subjects is declining (Roberts, 2002).
7

8 The Roberts report (2002) found that while there was an increase in the number of
9
10 students studying STEM subjects at secondary and degree levels, this growth was largely
11
12 because of an increase in students studying biological sciences and information technology
13
14 (Roberts, 2002). There was, instead, a downward trend in the number of students studying
15
16 physical sciences. It was reported that between 1991-2000, some 21 percent fewer students
17
18 were studying A-level³ physics and there was a decline of 3 percent of students studying A-
19
20 level chemistry. This compares with an increase in those studying biological sciences of 13
21
22 percent and an overall 6 percent increase in the number of students studying at A-level
23
24 (Roberts, 2002). Between 2001-2007, while biology remained in the top four choices of A-
25
26 level subjects for students, chemistry fell from 5th to 8th most popular and physics was outside
27
28 of the top ten during this time (Porter & Parvin, 2008). In 2005, approximately 375,000 A*-C
29
30 grades were awarded in double science or single subject science. However, in 2007, only
31
32 27,000 students completed A-level physics and 40,000 students completed chemistry (Porter
33
34 & Parvin, 2008). For qualifications taken at the end of compulsory education, there has been
35
36 in recent years a slight recovery in the number of students taking GCSE science subjects. In
37
38 2001-2002, the total number of science subject entries per head of population aged 15 in
39
40 England, for example, was 1.74. By 2005-2006 this had dipped to 1.66 entries per head of
41
42 population but then recovered to 1.79 in 2009-2010 (National Audit Office, 2010).
43

44 The Roberts report (2002) resulted in a flurry of activity by the government of the day
45
46 and a number of independent groups to address science participation. The most significant of
47

48
49 ³ The Advanced Level General Certificate of Education (more commonly referred to as the A-level). The A-
50 level is made up of AS level and A2 level. A-levels typically take two years and a student at the end of the first
51 year (AS level year) has essentially two options. They can take the AS level as their final qualification or they
52 can continue in to a second year of study (A2) and complete the full A-level qualification.
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1
2 these reports and policy documents was *Science and Innovation Investment Framework*
3
4 *2004-2014: Next Steps* (HM Treasury, 2004). The *Next Steps* report set out a number of
5
6 ambitious targets to be met by 2014. These included targets that would increase the number
7
8 of students taking A-level physics and chemistry. While the targets outlined in the *Next Steps*
9
10 report were clear, the key influence on participation in these subjects at the A-level and how
11
12 the targets would be attained were somewhat unclear (Royal Society, 2008).

13
14 In the last decade, a burgeoning number of reports from governing bodies,
15
16 examination boards, and funding bodies have raised the concern that young people are
17
18 disaffected towards STEM subjects, particularly science (HM Treasury, 2004; Smith, 2004).
19
20 Much of this work has focused on student engagement in science and differences in
21
22 engagement by various student and school factors.

23
24 Students' engagement in their learning experiences in science lessons have been
25
26 linked to uptake of 16-plus science. In a multi-nation study that included English, Australian,
27
28 and Swedish student's narratives about science learning, Lyons (2006) found that student's
29
30 engagement improved when the curriculum dealt with contemporary issues, when the
31
32 teaching style was less didactic and allowed for the student voice, and when a conscious
33
34 effort was made to make science less difficult. Stokking's (2000) research in the Netherlands
35
36 found that regardless of students' views about their school science experiences the main
37
38 reasons for uptake of post-compulsory physics studies are instrumental (i.e., as a strategic
39
40 positioning for desirable tertiary courses or desirable careers). A significant amount of
41
42 research has been conducted in the area of student engagement in science in the UK and in
43
44 other countries. However, while some recent studies have been relatively large-scale (e.g.,
45
46 Cerini, Murray & Reiss, 2003; Jenkins & Nelson, 2005), none has produced nationally
47
48 representative results. In addition, while some research has focused on the effectiveness of
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1
2 various teaching methods, few have examined the association between engagement in science
3
4 and multiple teaching and learning activities.
5

6 In this study we use the Programme for International Student Assessment (PISA)
7 2006 UK data, which is nationally representative, to explore the associations between (1)
8 student engagement and teaching and learning activities in the UK and (2) student
9 engagement and student and school factors in the UK. This study can be viewed as an
10 exemplary case study in which we not only explore factors associated with student
11 engagement in the UK but we also highlight the utility of the PISA data for researchers
12 worldwide and demonstrate what the international science community can learn from the
13 data.
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Deleted: Using the Programme for International Student Assessment (PISA) 2006 UK data, which is nationally representative data, the aim of this study was to explore the associations between (1) student engagement and teaching and learning activities in the UK and (2) student engagement and student and school factors in the UK.¶

22
23
24 *Engagement in Science*
25

26 Engagement is a multidimensional concept that broadly encompasses the three
27 components of *behavioural* engagement, *emotional* engagement, and *cognitive* engagement
28 (Finn, 1989; Fredricks, Blumenfeld & Paris, 2004). This research focuses on emotional
29 engagement as measured by reports of students' enjoyment of science and cognitive
30 engagement as measured by students' instrumental motivation and their future orientation
31 towards science.
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37 Emotional engagement is concerned with students' affective reactions (i.e., anxiety,
38 happiness, interest, enjoyment) to school and school activities (Connell, Spencer, & Aber,
39 1994; Connell & Wellborn, 1991). It should be noted that the literature on emotional
40 engagement has strong links with a large body of work that is concerned with student
41 attitudes (Fredricks, Blumenfeld & Paris, 2004). The research reported in this paper focuses
42 specifically on one indicator of emotional engagement, namely students' self-reported
43 enjoyment of science. For example, students in the PISA student questionnaire were asked
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2 about their level of agreement with statements such as “I generally have fun when I am
3 learning science topics” and “I like reading about science”. Research has suggested that
4 students who enjoy science are emotionally attached to learning the subject and consider
5 learning to be meaningful (Laukenmann et al., 2003).
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10 Cognitive engagement is concerned with a student’s “psychological investment in an
11 effort directed towards learning, understanding, or mastering the knowledge, skills, or crafts
12 that academic work is intended to promote” (Newman, Wehlage, & Lamborn, 1992, p. 12).
13 This research focuses on two aspects of cognitive engagement. These are (1) instrumental
14 motivation⁴ to learn science and (2) future-orientated motivation to learn science.
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20 To examine levels of instrumental motivation, students in the PISA survey were asked
21 about their level of agreement with such statements as “making an effort in my science
22 subject(s) is worth it because this will help me in the work I want to do later on” and “what I
23 learn in my science subject(s) is important for me because I need this for what I want to study
24 later on”. Prior research by Eccles (1994), Eccles and Wigfield (1995) and later by Wigfield,
25 Eccles, and Rodriguez (1998) has indicated that instrumental motivation is a salient predictor
26 of students’ careers choices and course selection.
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34 To determine students’ future-oriented motivation to learn science (i.e. their interest
35 in pursuing further studies in science and/or a career in science), students in the PISA survey
36 were asked about their level of agreement with such statements as “I would like to work in a
37 career involving science” and “I would like to spend my life doing advanced science”.
38
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42

43 *Science Teaching and Learning Activities and Engagement in Science*

44
45 Much of the research in this area has focused specifically on practical work and
46 students’ engagement in science. Osborne and Collins (2000) in their study of 144 English
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50 ⁴ Instrumental motivation in this context refers to a student being encouraged to learn science because of
51 external benefits such as achieving a good job in a science related area (i.e., becoming a medical doctor).
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1
2 students found that “without exception, pupils expressed a greater interest in work that
3
4 included opportunities for experimentation and investigation” (p. 36). In a large-scale survey
5
6 conducted by Cerini, Murray and Reiss (2004) of mainly 14 to 19 year olds in the UK, the
7
8 researchers found that when it came to doing a science experiment, 71 percent reported that
9
10 they found this teaching and learning method “enjoyable”.

11
12 Research by Abrahams (2009) examined whether practical work in science resulted in
13
14 affective outcomes. The results indicated that the majority of students had high levels of
15
16 short-term situational engagement in science. However, practical work was found to produce
17
18 no long-term gains in generating engagement in science. This finding is largely consistent
19
20 with recent work by Toplis (in print) in which some of the 13 to 16 year olds students he
21
22 interviewed viewed practical work as nothing more than a welcome break from other
23
24 teaching and learning approaches.

25
26 Some of this lack of long-term engagement may be the result of the nature of practical
27
28 work in schools. For example, Abrahams and Millar (2008) suggest that much practical work
29
30 in science classrooms seems to be preoccupied with pupils being able to “produce the
31
32 intended phenomenon” (p. 1955). Students might therefore be able to recall the experiment
33
34 and what happened, but be unable to explain why they got the results they did and what
35
36 scientific ideas were behind the exercise. Practical exercises and scientific theory were not
37
38 always linked together effectively.

39
40 In terms of investigations, Cerini, Murray and Reiss (2004) found that 50 percent of
41
42 students in their study reported that they found doing a science investigation enjoyable and
43
44 similarly Nott and Wellington (1998) found that year 12 students also viewed investigations
45
46 positively. However, Nott and Wellington found differences by sex with boys more likely to
47
48 find investigations interesting than girls. Interestingly, they reported that while there was a
49
50

1
2 general positivity towards doing investigations in science lessons, both the students and
3
4 teachers they interviewed were sceptical about their value.
5

6 DeWitt and Osborne (2008) found that certain classroom activities were more
7
8 likely to encourage and motivate students to pursue science at higher levels of study – what
9
10 they termed ‘points of engagement’ (p. 110). The activities that engaged and motivated the
11
12 most were those requiring a greater amount of autonomous, self-directed learning,
13
14 collaboration with classmates and also continuous collaboration with students overseas,
15
16 activities that were active, hands-on and that are extended beyond the scope of one lesson
17

18 19 **Methods**

20
21 As previously stated, the data used for this study was taken from the Program for
22
23 International Student Assessment (PISA), which is one of several international assessments in
24
25 which the UK has participated over 40 years. PISA was first implemented in 2000 and is
26
27 carried out by contractors for the Organization for Economic Cooperation and Development
28
29 (OECD). PISA measures 15-year-olds’ capabilities in reading literacy, mathematics literacy,
30
31 and science literacy every 3 years. Each PISA data-collection effort assesses one area in
32
33 depth, although all three are assessed in each cycle so that participating countries have an
34
35 ongoing source of achievement data in every subject. In 2006, science literacy was the
36
37 subject area assessed in depth across the 57 participating countries. The average UK score in
38
39 science literacy was 515 score points (on a scale of 0-1,000 with an average of 500 scale
40
41 points and a standard deviation of 100). Of the OECD countries, Finnish students (563 score
42
43 points) recorded the highest average literacy score and Mexican students (410 score points)
44
45 recorded the lowest (see OECD, 2007 for complete results).
46

47 Measuring student’s engagement and attitudes in science was a major component of
48
49 PISA 2006. Data were gathered from students in four areas that included (1) support for
50
51 scientific enquiry (2) self-belief as science learners (3) interest in science and (4)
52

1
2 responsibility towards resources and environments. These areas were selected according to
3
4 OECD (2007) because “they provide a summary of students’ general appreciation of science,
5
6 personal beliefs as science learners, specific scientific attitudes and values, and responsibility
7
8 towards selected science-related issues that have national and international ramifications” (p.
9
10 122).

11
12 The survey collected data on these four areas through a combination of the student
13
14 questionnaire and through items embedded in the actual assessment (for a fuller explanation
15
16 of this embedded approach please see Drechsel, Cartensen, & Prenzel, 2011; OECD, 2007).
17
18 All four areas were measured using the non-contextualised instrument (i.e., the student
19
20 questionnaire). The analysis in this paper focuses on the area of *interest in science* as
21
22 measured by the items contained in the student questionnaire.
23
24
25

26 **Objective, Analytic Strategy, and Measures**

27
28 The objective of this analysis was to describe the variation in students’ reports of
29
30 engagement in science across science teaching and learning activities. In addition, this study
31
32 examined student and school characteristics that may be associated with students’ levels of
33
34 engagement in science⁵.

35
36 For the purposes of this analysis, student engagement consists of measures of
37
38 students’ motivation in science, students’ enjoyment of science, and students’ future
39
40 orientation towards science. These measures of student engagement are described below
41
42 along with the student, school, and science teaching and learning activity variables used in
43
44 this analysis.

45
46 The analytical sample for this study was 15-year-old students in the UK who attended
47
48 school in 2006 which results in an overall sample size of 11,775. All estimates are weighted

49
50
51 ⁵ It should be noted that all analyses were conducted by the authors using the PISA 2006 student and school
52
53 databases.

1
2 to be nationally representative and adjustments have been made for the sampling design in
3
4 the statistical tests using Fay's Balanced Repeated Replication method. Comparisons made in
5
6 the text have been tested for statistical significance to ensure that the differences are larger
7
8 than might be expected due to sampling variation. The statistical significance of the
9
10 differences between estimates is at the 0.05 level as measured by two-tailed Student's *t* tests.
11
12 All differences reported are statistically significant at the 0.05 level unless stated otherwise.
13
14 Ordinary Least Squares (OLS) regression was used to estimate the association between
15
16 science teaching and learning activity measures and student engagement.
17
18
19

20 *Measures*

21
22 In PISA 2006, information concerning students' engagement in science, student
23
24 background characteristics, and science classroom activities were all reported by the student
25
26 using a questionnaire. The school characteristics were also collected using a questionnaire,
27
28 which was completed by a school administrator. The analysis comprised of three dependent
29
30 variables, five student characteristics variables, six school characteristic variables, and four
31
32 science classroom activity variables. The student engagement and the science teaching and
33
34 learning activity variables are indices. The indices were constructed for these analyses and
35
36 tested for reliability using Cronbach's alpha.
37
38
39

40 *Dependent Variables*

41
42 The index for students' *motivation in science* was derived from students' responses
43
44 about their level of agreement with the following statements (1) making an effort in my
45
46 science subject(s) is worth it because this will help me in the work I want to do later on (2)
47
48 what I learn in my science subject(s) is important for me because I need this for what I want
49
50 to study later on (3) I study science because I know it is useful for me (4) studying my
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1
2 science subject(s) is worthwhile for me because what I learn will improve my career
3 prospects and (5) I will learn many things in my science subject(s) that will help me get a job.
4
5 This index has a Cronbach alpha of 0.92. The index for students' *enjoyment of science* was
6
7 derived from students' responses about their level of agreement with the following statements
8
9 (1) I generally have fun when I am learning science topics (2) I like reading about science (3)
10
11 I am happy doing science problems (4) I enjoy acquiring new knowledge in science and (5) I
12
13 am interested in learning about science. This index has a Cronbach alpha of 0.92. The index
14
15 for students' *orientation towards a future in science* was derived from students' responses
16
17 about their level of agreement with the following statements (1) I would like to work in a
18
19 career involving science (2) I would like to study science after secondary school (3) I would
20
21 like to spend my life doing advanced science (4) I would like to work on science projects as
22
23 an adult. This index has a Cronbach alpha of 0.89. These indices were constructed
24
25 specifically for these analyses and the reliability statistics are based on the UK data only.
26
27

28 A four-point scale with the response categories “strongly agree”, “agree”, “disagree”
29
30 and “strongly disagree” was used in PISA. The indices for student motivation, student
31
32 enjoyment, and student orientation were created by inverting the response scores so that
33
34 “strongly agree” had a point value of 4, “agree” had a point value of 3, “disagree” had a point
35
36 value of 2 and “strongly disagree” had a point value of 1. The values for each student were
37
38 summed to create the indices for each of the three measures of student engagement. The
39
40 index for student motivation, therefore, has a range of 5-20; the indices for student enjoyment
41
42 and student orientation have ranges of 4-16.
43
44

45 *Independent Variables of Interest*

46 The PISA 2006 science teaching and learning variables consisted of four indices.
47
48 These include the index of interaction, the index of hands on activities, the index of student
49
50

1
2 investigations, and the index of applications in science. The *index of interaction* was derived
3
4 from students' responses about the frequency with which the following four activities occur
5
6 when learning science topics at school (1) students are given opportunities to explain their
7
8 ideas (2) the lessons involve students' opinions about the topics (3) there is class debate or
9
10 discussion (4) the students have discussions about the topics. This index has a Cronbach
11
12 alpha of 0.77. The *index of hands on activities* was derived from students' responses about the
13
14 frequency with which the following four activities occur when learning science topics at
15
16 school (1) students spend time in the laboratory doing practical experiments (2) students are
17
18 required to design how a science question could be investigated in the laboratory (3) students
19
20 are asked to draw conclusions from an experiment they have conducted (4) students do
21
22 experiments by following the instructions of the teachers. This index has a Cronbach alpha of
23
24 0.68. The *index of student investigations* was derived from students' responses about the
25
26 frequency with which the following three activities occur when learning science topics at
27
28 school (1) students are allowed to design their own experiments (2) students are given the
29
30 chance to choose their own investigations (3) students are asked to do an investigation to test
31
32 out their own ideas. This index has a Cronbach alpha of 0.73. The *index of applications* was
33
34 derived from students' responses about the frequency with which the following four activities
35
36 occur when learning science topics at school (1) the teacher explains how a school science
37
38 idea can be applied to a number of different phenomena (e.g. the movement of objects,
39
40 substances with similar properties) (2) the teacher uses science to help students understand
41
42 the world outside school (3) the teacher clearly explains the relevance of science concepts to
43
44 our lives (4) the teacher uses examples of technological application to show how school
45
46 science is relevant to society. This index has a Cronbach alpha of 0.77.

47
48 A four-point scale with the response categories “in all lessons”, “in most lessons”, “in
49
50 some lessons” and “never or hardly ever” was used in PISA for all the science teaching and
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1
2 learning activity measures. The indices were created by inverting the response scores so that
3
4 “in all lessons” had a point value of 4, “in most lessons” had a point value of 3, “in some
5
6 lessons” had a point value of 2 and “never or hardly ever” had a point value of 1. The values
7
8 for each student were summed and the average was calculated for each student across each of
9
10 the science teaching and learning activity measures.

11 12 13 14 *Additional Independent Variables*

15
16 The analysis used five student characteristic variables that include sex, parental
17
18 education, parental occupational status, whether the parent is in a science-related career, and
19
20 whether the student expects to be in a science-related career. These variables capture the
21
22 students’ socioeconomic context and the student and parent’s expectations for a career in
23
24 science. All the student characteristic variables are reported by the student. The school
25
26 characteristic variables include school control (i.e., public and private), class size, school
27
28 selectivity, teacher-student ratio, whether the school has a shortage of science teachers, and
29
30 the number of science activities such as science fairs and clubs that take place at the school.
31
32 These school variables capture the context of the school environment for each of the students
33
34 in the analyses. All the school characteristic variables were reported by the school
35
36 administrator.

37 38 39 **Results**

40 41 *Descriptive analysis*

42
43 *Teaching and learning activities.* Table 1 contains the percentage distributions for the
44
45 four the science teaching and learning activity indices. Eighty-nine percent of students
46
47 reported that student investigations (designing own experiments, choose own investigations,
48
49 and investigations to test out their own ideas) occurred in most or all lessons. In comparison,
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51

1
2 less than 50 percent reported that interactions (i.e., class debates and discussions), hands on
3 activities (i.e., draw conclusions from experiment), and applications in science (i.e., teacher
4 explains how a school science idea can be applied to a number of different phenomena)
5
6 occurred in most or all lessons.
7
8

9
10 (insert table 1 about here)
11

12 Table 2 shows that across all three measures of student engagement, higher mean
13 levels of engagement were reported by those students who also reported that interaction,
14 hands on activities, and applications in science occurred in *all lessons* compared to students
15 who reported that these teaching and learning activities *never or hardly happened, happened*
16 *in some lessons, or happened in most lessons*. For the indices of interaction, hands on
17 activities, and applications in science the pattern of the association is uniform. Higher
18 reported frequencies of these teaching and learning activities resulted in higher reported
19 levels of enjoyment, future orientation, and motivation towards science. For example,
20 students reported higher levels of enjoyment of science where interactions were reported to
21 occur in *all lessons* than in *most lessons, some lessons, none or hardly any lessons* (14.22 vs.
22 13.22, 12.19, and 10.84, respectively). The results for student investigations are less uniform.
23 For the engagement measures of enjoyment and future orientation, there are statistically
24 significant differences between *never or hardly ever* and the three other frequency measures
25 (*some lessons, most lessons, and all lessons*). For example, for enjoyment of science index
26 scores for in *all lessons* (13.70), in *most lessons* (13.26), and in *some lessons* (13.17) were
27 significantly greater than for *never or hardly ever* (12.42). However, there were no significant
28 differences between the index scores for in *all lessons* (13.70), in *most lessons* (13.26), and in
29 *some lessons* (13.17). This same pattern was found for students' future orientation towards
30 science. Differences were found in students' levels of motivation by frequency of student
31 investigations. Higher levels of motivation towards science were found where students report
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1
2 that student investigations occurred in *all lessons* and in *most lessons* compared to in *some*
3
4 *lessons* or *never or hardly ever* (15.96 and 15.26 versus 14.47 and 13.52, respectively).

5
6 (insert table 2 about here)
7

8 9 *Student and School Characteristics*

10
11 Consistent with prior research (e.g., Nott & Wellington, 1998), males reported higher
12 levels of student engagement (enjoyment, orientation, and motivation) than females (table 3).
13
14 There also seems to be a clear association between the three measures of student engagement
15
16 and measures of parents' educational and occupational status. For example, students whose
17
18 parents have had more years of education and have higher occupational status are more likely
19
20 to say they enjoy science, have a future orientation towards science, and be motivated in
21
22 studying science. Students who have either one or both parents working in a science-related
23
24 career report higher levels of enjoyment, future orientation, and motivation than students who
25
26 do not. Interestingly, students who expressed an expectation to be working in the future in a
27
28 science-related career did not report significantly higher levels of enjoyment, future
29
30 orientation, and motivation towards science.
31
32

33
34 (insert table 3 about here)
35
36

37
38 In terms of school characteristics and their association with measures of student
39 engagement, differences were found by school control (i.e., public or private), shortage of
40 science teachers, class size, and the number of science activities at the school (e.g., science
41 fairs and science clubs). There were no discernable differences found for school size (see
42
43 table 3).
44
45

46
47 For enjoyment and future orientation, students who attended private schools reported
48
49 higher levels on these two indices of engagement than students in state schools (see table 4).
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1
2 Students in schools that report no shortage of science teachers reported higher levels of
3 enjoyment, future orientation, and motivation than students in schools that reported high
4 levels of shortage. Interestingly for these same two measures of student engagement,
5 students in larger classes (31-35 and 36 or more students) reported higher levels of enjoyment
6 and future orientation than those in class sizes of 15 students or fewer. While there were
7 statistically significant differences for all three measures of student engagement with the
8 number of school science activities, there was no consistent pattern. In other words, having
9 more science activities in the school did not result in higher levels of student engagement in
10 science.

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21 (insert table 4 about here)

22 23 *OLS Regression Analysis*

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26 Table 5 contains the OLS regression coefficients for the enjoyment of science
27 (dependent variable). Four models are estimated in total. Model 1 is a reduced model in
28 which only the science teaching and learning activities are included. Model 2 includes the
29 student background characteristic variables. Model 3 contains the science teaching and
30 learning activities and the school characteristics and Model 4 is the full model in which the
31 science teaching and learning activities and the student and school characteristics are
32 included. The same models are fitted for the other two engagement measures of future
33 orientation to science (see table 5) and instrumental motivation towards science (see table 6).

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43 (insert table 5 about here)

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46 Model 1 indicates that there is a positive association between increased frequency of
47 science and teaching and learning activities that involve: interactions (e.g., students are given
48 opportunities to explain their ideas); hands on activities by students (e.g., students are

1
2 required to design how a science question could be investigated in the laboratory); and
3
4 applications of science (e.g., the teacher uses science to help students understand the world
5
6 outside school). For teaching and learning activities that involve student investigations (e.g.,
7
8 students are asked to do an investigation to test out their own ideas), the relationship is
9
10 negative (-0.28). In other words, an increase in the frequency in which student investigations
11
12 occur results in lower student enjoyment. The same pattern of results was found for students'
13
14 future orientation towards science (see table 6) and motivations towards science with one
15
16 exception. For students' motivation towards science, the coefficient for student investigations
17
18 is not significant (0.09) (see model 1, table 7).

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21 (insert table 6 and table 7 about here)
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23
24 The student background characteristics are entered into model 2 for each of the three
25
26 engagement measures (see tables 5, 6, and 7). The socio-economic measures (parent's
27
28 occupational status and parent's education in years) are positively associated with all three
29
30 engagement measures with one exception (parent occupational status and motivation towards
31
32 science). In other words, students with parents who have more prestigious occupations and
33
34 are educated to a higher level report greater levels of enjoyment in science, future orientation
35
36 and motivation towards science. Being a male is also positively associated with all three
37
38 engagement measures. There is a positive association between students who reported that
39
40 they had either parent in a science-related career and student's enjoyment (0.25) and future-
41
42 orientation towards science (0.22). As expected, there is a positive association between
43
44 students' expectations to be in a science-related career and their engagement in science. For
45
46 example, it is predicted that students' who expect to be in a science related career in the
47
48 future would score nearly three points higher (2.90) on the motivation towards science index.
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2 Model 3 includes the teaching and learning variables along with school
3
4 characteristics. There is a positive association between being in a private school and students'
5
6 enjoyment of science and future orientation towards science. In addition, there was negative
7
8 association between schools that reported shortages of science teachers and students'
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10 enjoyment of science and future orientation towards science. No significant associations were
11
12 found for the engagement measure of motivation towards science.
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15 Model 4 is the fully specified model for each of the student engagement measures. In
16
17 this model the science teaching and learning activities are included along with the student and
18
19 school characteristics variables. As can be seen in tables 5, 6, and 7, once all variables are
20
21 included in the model, the effect of the school characteristic variables are no longer
22
23 significant. The pattern for the science teaching and learning measures are similar to the
24
25 reduced model (model 1). For example, there are positive associations between teaching and
26
27 learning activities that involve interactions, hands on activities, and application in science for
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29 all three engagement measures. In other words, the greater the frequency of these three
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31 teaching and learning activities, the greater the student's enjoyment of science, and future-
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33 orientation and motivation towards science (tables 5, 6, and 7). There is also a positive
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35 association between student investigations and students' motivation towards science (table 7).
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37 However, there is a negative association for students' enjoyment of science and their future-
38
39 orientation towards science (table 5 and 6). For these two student engagement measures, the
40
41 greater the frequency of student investigations occurring in class, the lower the levels of
42
43 enjoyment of science and future orientation towards science.
44

45 **Summary of Findings and Discussion**

46
47 There were two aims to this research. These were to explore the associations between
48
49 (1) student engagement and teaching and learning activities and (2) student engagement and
50
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1
2 student and school factors. The results of this research indicate that teaching and learning
3 activities are associated with students' engagement in science. Greater levels of student
4 motivation, enjoyment, and future-orientation towards science were found in classrooms
5 where students reported that various measures of interaction, hands on activities, and
6 applications in science took place frequently. The regression analysis indicated that there was
7 a positive association between the frequency of measures of student investigations in class
8 and student's motivation in science. However, conversely, increased reports of student
9 investigations resulted in lower levels of enjoyment of science and future orientation towards
10 science. As previously reported (see table 1), 47 percent of students indicated that
11 investigations occurred in all their lessons. This is in contrast to the other three science
12 teaching and learning activities in which 5 percent or less reported that measures of
13 application in science (5 percent), interaction (5 percent), and hands on activities (2 percent)
14 occurred in all lessons. This may suggest that it is not necessarily the case that student
15 investigations are associated with lower levels of enjoyment and future orientation to science,
16 instead it may be the situation that this mono-approach to teaching and learning in science
17 has contributed to this finding.

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34 In terms of differences by student background characteristics, socio-economic status
35 is positively associated with student engagement. In addition, males reported higher levels of
36 engagement than females. There was a clear association between student engagement and
37 whether the student had one or more parents in a science-related career. Not surprisingly,
38 students who reported that they expected to go in to a science-related career also reported
39 greater engagement in science.

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46 For the school measures, there was a positive association between students who
47 attended private schools and students' enjoyment of science and future-orientation towards
48 science. In contrast, there was a negative association between these two student engagement

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2 measures and science teacher shortage. In other words, students in schools where there is a
3
4 shortage of science teachers reported lower levels of enjoyment of science and future-
5
6 orientation towards.

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8 Clearly, more research in this area is needed, particularly studies that examine science
9
10 teaching and learning activities other than practical work and their ability to engage students
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12 in science.

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14 As in much research, there are limitations to this study. Using self-administered
15
16 questionnaires restricts the depth of responses or clarification of responses from the students
17
18 that a face-to-face interaction can achieve. In addition, cross sectional data, as used in this
19
20 research, is very much a snap shot of 15-year-olds in 2006. The PISA data do not allow for
21
22 longitudinal or causal analysis. However, this study contributes to our understanding of the
23
24 role of teaching and learning activities on student engagement in several ways. First, this
25
26 study uses large-scale nationally representative data. All estimates are weighted to population
27
28 levels and are representative of 15-year-old students in 2006. Second, the teaching and
29
30 learning activities are student reported. This is important because this gives us a student
31
32 perspective on the teaching and learning activities they perceive to be taking place during
33
34 science lessons. Of course, if the teachers were also asked to report on the teaching and
35
36 learning activities that took place in their classrooms, there might be a mismatch in responses.
37
38 Given that this study is examining students' engagement in science, it is important to rely on
39
40 students' reports and perceptions of what activities take place during their lessons. Third, this
41
42 study looks at three types of student engagement and four types of science teaching and
43
44 learning activities rather than single constructs. This research also provides a national picture
45
46 in the UK of students' engagement in science and the factors that influence their motivation
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48 in science, enjoyment of science, and future-orientation towards science. More research
49
50 needs to be completed, not only in the UK but in other countries, which focuses on the

Deleted: that

1
2 association between student engagement and the various teaching and learning activities that
3
4 take place in the classroom. [A starting point could be for other researchers to explore their](#)
5
6 [own country's PISA 2006 data.](#) Understanding student engagement in science, and the factors
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8 that influence it, is essential in addressing the issue of uptake of science in post compulsory
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10 schooling.
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Table 1. Percentage distribution of student's reports of science teaching and learning activities: 2006

Frequency of science teaching and learning activities	In all lessons	In most lessons	In some lessons	Never or hardly ever
Index of interaction	5	36	49	10
Index of hands on activities by students	2	39	54	5
Index of student investigations	47	42	10	1
Index of applications in science	5	44	43	7

Note: Weighted percentages adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.

Table 2. Mean index scores for UK student's engagement in science by frequency of science teaching and learning activity: 2006

Indices of frequency of science teaching and learning activities	Enjoyment	Orientation	Motivation
Total	12.80	10.07	14.12
Index of interaction			
In all lessons	14.22	11.20	15.55
In most lessons	13.22	10.40	14.58
In some lessons	12.19	9.59	13.45
Never or hardly ever	10.84	8.51	11.72
Index of hands on activities by students			
In all lessons	13.99	11.05	15.94
In most lessons	13.30	10.48	14.59
In some lessons	12.25	9.63	13.47
Never or hardly ever	9.83	7.74	11.04
Index of student investigations			
In all lessons	13.70	10.77	15.96
In most lessons	13.26	10.45	15.26
In some lessons	13.17	10.37	14.47
Never or hardly ever	12.42	9.76	13.52
Index of applications in science			
In all lessons	14.75	11.61	16.34
In most lessons	13.47	10.61	14.88
In some lessons	12.20	9.59	13.42
Never or hardly ever	10.31	8.08	11.24

Note: Weighted means adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.

Table 3. Mean index scores for UK student's engagement in science by student characteristics: 2006

Student characteristics	Enjoyment	Orientation	Motivation
Total	12.80	10.07	14.12
Sex			
Female	12.40	9.75	13.88
Male	13.20	10.40	14.36
Parents education in years			
Less than 11 years	12.08	9.45	13.30
11–13 years	12.66	9.95	13.94
14–16 years	13.13	10.34	14.44
Parent occupational status			
Lowest quarter	12.22	9.61	13.82
Middle quarters	12.77	10.05	14.08
Highest quarter	13.38	10.53	14.51
Either parent in science-related career			
No	12.67	9.97	14.00
Yes	13.38	10.55	14.68
Students' expectation to be in science-related career			
No	12.03	9.41	10.84
Yes	12.31	9.69	13.37

Note: Weighted means adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.

Table 4. Mean index scores for UK student's engagement in science by school characteristics: 2006

School characteristics	Enjoyment	Orientation	Motivation
Total	12.80	10.07	14.12
School control			
Public	12.75	10.03	14.17
Private	13.48	10.63	13.94
School size			
0-759 students	12.80	10.08	14.08
750-999 students	12.84	10.09	14.24
1000-1249 students	12.82	10.10	14.21
1250 or more students	12.76	10.04	14.13
Shortage of science teachers			
Not at all	12.82	10.09	14.20
Very little	12.93	10.18	14.07
To some extent	12.79	10.05	14.28
A lot	12.11	9.54	13.43
Class size			
15 students or fewer	12.69	9.99	14.37
16-20 students	13.18	10.38	14.11
21-25 students	12.76	10.04	14.10
26-30 students	12.76	10.03	14.20
31-35 students	13.84	10.98	14.80
36 or more students	14.23	11.38	14.81
School science activities			
0 activities	13.05	10.22	14.27
1 activity	12.60	9.92	14.20
2 activities	12.77	10.03	14.08
3 activities	12.82	10.09	14.18
4 activities	12.67	9.97	14.05
5 activities	13.13	10.35	14.39

Note: Weighted means adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.

Table 5. OLS regression coefficients for Enjoyment of Science: 2006

	Models							
	I		II		III		IV	
Intercept	8.09	**	6.40	**	7.59	**	6.35	**
Science teaching and learning activities								
Index of interaction	0.48	**	0.51	**	0.54	**	0.53	**
Index of hands on activities by students	0.50	**	0.45	**	0.39	**	0.38	**
Index of student investigations	-0.28	**	-0.21		-0.25	**	-0.22	**
Index of applications in science	1.05	**	0.86	**	1.00	**	0.82	**
Student characteristics								
Parent occupational status			0.30	**			0.28	**
Parents education in years			0.16	*			0.12	
Sex (male)			0.76	**			0.79	**
Either parent in science-related career			0.25	**			0.24	*
Students' expectation to be in science-related career			1.72	**			1.78	**
School characteristics								
School control (private)					0.50	*	0.16	
School size					-0.02		-0.05	
Shortage of science teachers					-0.14	*	-0.10	
Class size					0.08		0.07	
Number of school science activities					0.05		0.03	
Sample size	11,758		10,697		9,754		8,934	
Adjusted r square	0.10		0.18		0.10		0.18	

* $p=0.05$, ** $p=0.01$

Note: Weighted estimates adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.

Table 6. OLS regression coefficients for Orientation to Science: 2006

	Models							
	I		II		III		IV	
Intercept	6.31	**	4.93	**	5.92	**	4.90	**
Science teaching and learning activities								
Index of interaction	0.37	**	0.39	**	0.42	**	0.41	**
Index of hands on activities by students	0.41	**	0.37	**	0.33	**	0.32	**
Index of student investigations	-0.22	**	-0.15	**	-0.20	**	-0.16	**
Index of applications in science	0.84	**	0.68	**	0.79	**	0.65	**
Student characteristics								
Parent occupational status			0.23	**			0.22	**
Parents education in years			0.15	*			0.11	
Sex (male)			0.61	**			0.64	**
Either parent in science-related career			0.22	**			0.20	*
Students' expectation to be in science-related career			1.32	**			1.37	**
School characteristics								
School control (private)					0.40	*	0.13	
School size					-0.02		-0.04	
Shortage of science teachers					-0.11	*	-0.08	
Class size					0.06		0.05	
Number of school science activities					0.05		0.03	
Adjusted r square	0.10		0.18		0.10		0.18	
Number of observations	11,775		10,712		9,768		8,947	

* $p=0.05$, ** $p=0.01$

Note: Weighted estimates adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.

Table 7. OLS regression coefficients for Motivation towards to Science: 2006

	Models							
	I		II		III		IV	
Intercept	8.77	**	7.74	**	8.94	**	8.04	**
Science teaching and learning activities								
Index of interaction	0.42	**	0.39	**	0.53	**	0.48	**
Index of hands on activities by students	0.48	**	0.36	**	0.37	**	0.29	**
Index of student investigations	0.09		0.20	**	0.08		0.16	*
Index of applications in science	1.13	**	0.97	**	1.13	**	0.96	**
Student characteristics								
Parent occupational status			0.01				0.03	
Parents education in years			0.18	*			0.22	**
Sex (male)			0.41	**			0.44	**
Either parent in science-related career			0.23				0.19	
Students' expectation to be in science-related career			2.90	**			2.84	**
School characteristics								
School control (private)					-0.13		-0.41	
School size					0.01		0.01	
Shortage of science teachers					-0.07		-0.03	
Class size					0.04		0.04	
Number of school science activities					0.01		0.01	
Adjusted r square	0.11		0.23		0.11		0.24	
Number of observations	11,732		10,672		9,732		8,912	

* $p=0.05$, ** $p=0.01$

Note: Weighted estimates adjusted for design effects.

Data Source: Programme for International Student Assessment (2006). OECD.