10 Factors associated with mathematics and science achievement

England's results for TIMSS 2007 were analysed further, using a statistical technique called multi-level modelling. This enables relationships between different variables to be explored. It allows us to predict how an outcome might change for one variable if the size of a related variable changes. For example, it allows us to describe relationships such as, the higher pupils' attainment was at the end of key stage 1, the higher their attainment was likely to be in TIMSS at grade 4 (year 5).

The statistical model can separate out the effects of different variables, so that the identified variables can be described as significant over and above the effects of other variables. So, for example, both confidence in mathematics and the value pupils place on science and mathematics were significant positive predictors of enjoyment of mathematics at grade 8. We can therefore say that, for pupils with the same level of confidence, those who value science and mathematics more are likely to enjoy it more. It should be remembered that the models simply describe associations and not causal relationships: they cannot say whether, for example, confidence leads to enjoyment, enjoyment leads to confidence or whether a third factor causes both.

Most variables used in the model were derived from the questionnaires completed by pupils, teachers and headteachers. Their answers to some questions were entered into the model as separate variables; others were combined into 'factors' using a statistical technique called factor analysis. Other variables were derived from alternative sources (such as the IDACI index of deprivation, or pupils' prior attainment in the form of teacher assessment scores at key stage 1 and test scores at key stage 2). These approaches enabled the number of variables in the model to be sufficiently large to capture all areas of potential interest, but in a manageable way.

Six areas were investigated, identifying significant variables associated with:

- Attainment in grade 4 (year 5) science
- Attainment in grade 4 mathematics
- Attitudes to learning at grade 4
- Attainment in grade 8 (year 9) science
- Attainment in grade 8 mathematics
- Attitudes to learning at grade 8.

This chapter summarises the significant findings from the multi-level modelling in these six areas. Complementing the text is a series of bar charts, which show the variables significantly associated with attainment or with attitudes, in order of size. Variables with longer bars were more strongly associated with attainment or attitudes, measured as a

percentage of the standard deviation. The direction of the bar indicates the direction of the relationship. A positive relationship means that an increase in the variable was associated with higher attainment or a more positive attitude, and a negative relationship that it was associated with lower attainment or a more negative attitude. The variables identified were derived either from responses to the background questionnaires or from other sources. The source of each variable is listed in Appendix 3, the technical appendix. On the bar charts in this chapter, the following acronyms are used:

- SQ – student questionnaire
- HQ – school questionnaire (or headteacher questionnaire)
- TQ – teacher questionnaire (grade 4)
- TQM – mathematics teacher questionnaire (grade 8)
- TQS – science teacher questionnaire (grade 8).

More details on the variables used and the findings, as well as technical information about how the model was run, can be found in Appendix 3. That appendix also contains a series of charts, showing the 'quasi effect size' for each significant variable in each area of investigation, along with confidence intervals.

Although the statistical model can 'control for' variables (that is, separate out the effects of different variables), it can only do this when the variables act independently of each other. Because of the large number of factors in the model, there was the potential for some variables to be highlighted as significant when in fact they were not, simply because they were acting in a similar way to another variable. It is likely that such interference affects only a small number of results, including some of those where the effect was borderline.

This chapter summarises the key findings. Borderline results are presented in the bar charts but may not be discussed. The full list of findings can be found in Appendix 3.

10.1 Attainment in grade 4 science

Positive associations with grade 4 science attainment

The multi-level model (see Appendix 3 for more details) showed that the following variables were positively associated with attainment in science at grade 4 (that is, as each of these variables increased, so too did attainment in science).

- Key stage 1 mathematics and science attainment
- Being taught by a mathematics specialist
- Being born in the UK
- Having access to various resources in the home (books, a calculator, a computer, a study desk, a dictionary, an internet connection, own bedroom, a mobile phone and an encylopaedia in book or CD form) and to computers at home and elsewhere
- Enjoying science and being confident in it

- Being confident in mathematics
- Being encouraged to work independently during lessons
- Involvement in the second of two groups of out of school activities (reading a book for fun, helping with jobs at home, doing homework, doing art, playing a musical instrument).

Thus, it would appear that several factors relating to mathematics are important for attainment in science, in addition to more general factors and factors specifically related to science. This might be because, at grade 4, pupils will generally be taught mathematics and science by the same teacher, so that impact in one area of the curriculum might be carried over into other areas of the curriculum.

Negative associations with grade 4 science attainment

These variables were negatively associated with attainment in science at grade 4 (that is, as the incidence of each of these increased, so attainment decreased). The key findings are reported here. Those variables which were identified in the modelling but felt to be spurious as a result of potential interference or borderline significance are not included, but can be found in Appendix 3.

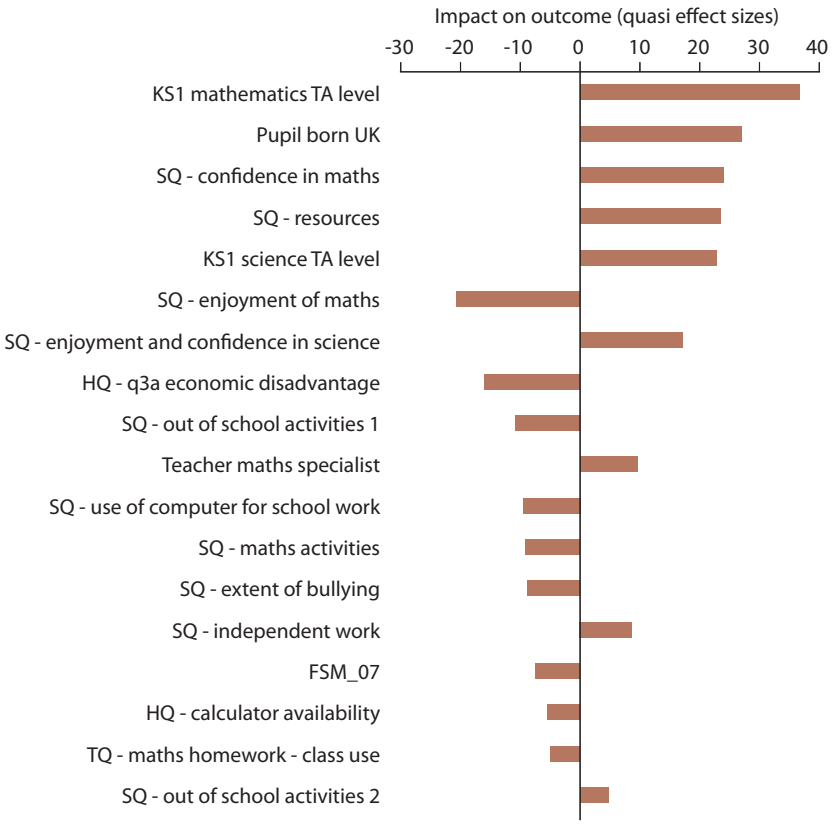
- Percentage of economically disadvantaged pupils in the school
- Eligibility for free school meals
- Extent of bullying (verbal, physical or social exclusion) in the school as perceived by pupils
- Mathematics activities (frequency of doing the following: calculations, fractions, decimals, measurement, data handling, shape activities, memorising solutions, working with other children)
- Computer use for school work
- Having calculators available for school work
- Using homework in class as the basis for discussion
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, playing sports, using the internet, listening to music).

It should be remembered that the model simply describes associations; it cannot say what caused the findings. So, for example, the link between increased computer use and lower attainment does not necessarily imply that lower attainment is a result of using computers at school. It could simply indicate that lower attaining pupils are given more opportunities to use a computer. The same could be true for the findings about mathematics activities, calculator availability and discussion of homework.

Equally, a third variable might influence both variables in the relationship. For example, involvement in the first group of out of school activities might depress attainment, might arise from the lower attainment, or both might be caused by a third, related, factor such as low motivation for learning.

As described earlier, Exhibit 10.1 summarises the associations, in order of effect size (measured as quasi effect sizes; see Appendix 3 for more information).

Exhibit 10.1 Variables significantly associated with grade 4 science attainment



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with higher attainment and a negative relationship that it was associated with lower attainment. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with higher attainment and a negative relationship that it was associated with lower attainment. (i.e., in this case, being born in the UK was associated with higher attainment). Details of the variables and more information on how to interpret them can be found in Appendix 3.

10.2 Attainment in grade 4 mathematics

Positive associations with grade 4 mathematics attainment

The multi-level model (see Appendix 3 for more details) showed that the following variables were positively associated with attainment in mathematics at grade 4, that is, as each of these variables increased, so too did attainment in mathematics:

- Key stage 1 mathematics and science attainment
- Being taught by a mathematics specialist
- Being confident in mathematics
- Being born in the UK

- Having access to various resources in the home (books, a calculator, a computer, a study desk, a dictionary, an internet connection, own bedroom, a mobile phone and an encyclopaedia in book or CD form) and access to computers at home and elsewhere.
- Teachers' perception of their contribution to school climate (that is, the extent to which they felt that teachers in their school had job satisfaction, understood the school's curricular goals, successfully implemented the curriculum, and had high expectations for children's achievement)
- Being encouraged to work independently during lessons.

Many of the same variables, but not all, that were associated with higher science attainment are also associated with higher mathematics attainment at grade 4. As before, it should be borne in mind that causality cannot be demonstrated. For example, working independently in lessons might result in higher attainment, might arise from higher attainment, or might be caused by a third, related, variable.

Negative associations with grade 4 mathematics attainment

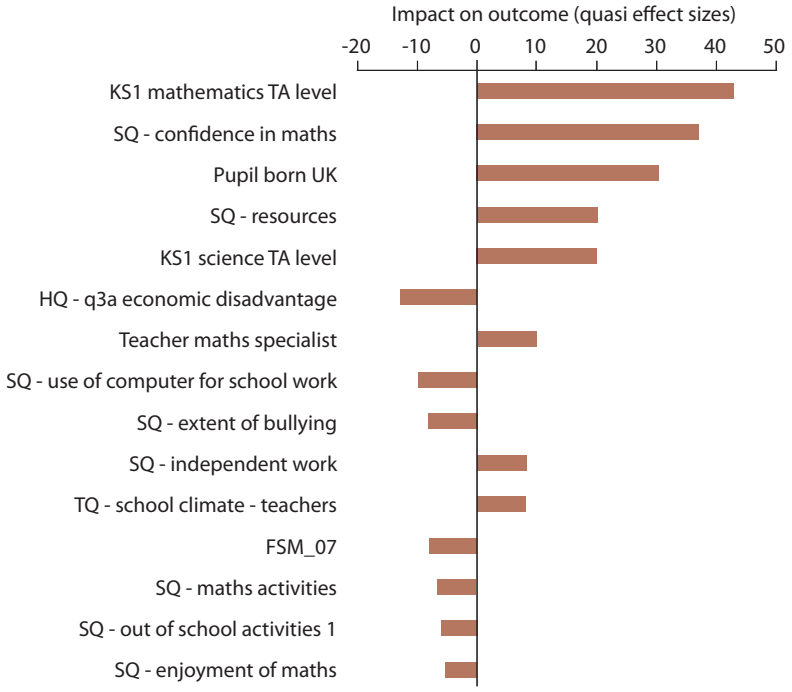
These variables were negatively associated with attainment in mathematics at grade 4 (that is, as the incidence of each of these increased, so attainment decreased). The key findings are reported here. Those variables which were identified in the modelling but felt to be spurious as a result of potential interference or borderline significance are not included, but can be found in Appendix 3.

- Percentage of economically disadvantaged pupils in the school
- Eligibility for free school meals
- Extent of bullying (verbal, physical or social exclusion) in the school as perceived by pupils
- Mathematics activities (frequency of doing the following: calculations, fractions, decimals, measurement, data handling, shape activities, memorising solutions, working with other children)
- Computer use for school work
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, playing sports, using the internet, listening to music).

Again, these are similar to the variables found to be significantly associated with science attainment at this grade. Once again, it is important to remember that the model simply describes associations; it cannot say what caused any given finding. Causality might arise from either associated variable, or might be caused by a third, related, variable. This is particularly important to consider when interpreting the findings about mathematics activities and computer use for school work.

Exhibit 10.2 summarises the associations, in order of effect size (measured as quasi effect sizes; see Appendix 3 for more information).

Exhibit 10.2 Variables significantly associated with grade 4 mathematics attainment



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with higher attainment and a negative relationship that it was associated with lower attainment. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with higher attainment and a negative relationship that it was associated with lower attainment. (i.e., in this case, being born in the UK was associated with higher attainment). Details of the variables and more information on how to interpret them can be found in Appendix 3.

10.3 Attitudes to learning at grade 4

In this section, the positive associations are listed first for all three attitudinal areas, followed by the negative associations. The bar charts for these areas are presented at the end of this section (see Exhibits 10.3 to 10.5).

Positive associations with attitudes to learning at grade 4

The multi-level model (see Appendix 3 for more details) showed that the following variables were positively associated with attitudes to learning at grade 4 (that is, as each of these variables increased, so attitudes to mathematics and/or science became more positive).

Variables positively associated with enjoyment and confidence in science

- Pupils' perception of school climate (the extent to which pupils like being at school, want to do their best and feel that their teachers want them to do their best)

- Having access to various resources in the home (books, a calculator, a computer, a study desk, a dictionary, an internet connection, own bedroom, a mobile phone and an encyclopaedia in book or CD form) and to computers at home and elsewhere
- Science activities (observing, watching experiments, designing and/or carrying out investigations, working with other children, giving explanations in science)
- Giving explanations in mathematics
- Being encouraged to work independently during lessons
- Involvement in the second of two groups of out of school activities (reading a book for fun, helping with jobs at home, doing homework, doing art, playing a musical instrument)
- Pupil gender (boys were more positive than girls about science).

Many of the same variables, but not all, that were associated with higher science attainment are also associated with enjoyment and confidence in science. In this model, the same caveat applies as discussed above in relation to the attainment models: causality cannot be demonstrated.

Two separate models were run for enjoyment and confidence in mathematics, compared with the single model run for science. This is because, during the factor analysis (see Appendix 3), pupils' responses for enjoyment and confidence in science were correlated to form a single factor, whereas their responses for mathematics split into two separate factors: although enjoyment of mathematics and confidence in mathematics were related, they were not correlated as strongly as was the case for science.

Because enjoyment and confidence in mathematics are associated, these two factors might have interacted in the model to create some spurious results. Any suspect results have, therefore, not been reported here, but are outlined in Appendix 3.

Variables positively associated with enjoyment of mathematics

- Being confident in mathematics
- Pupils' perception of school climate (the extent to which pupils like being at school, want to do their best and feel that their teachers want them to do their best)
- Mathematics activities (frequency of doing the following: calculations, fractions, decimals, measurement, data handling, shape activities, memorising solutions, working with other children)
- Computer use for school work
- Involvement in the second of two groups of out of school activities (reading a book for fun, helping with jobs at home, doing homework, doing art, playing a musical instrument)
- Pupil gender (boys were more positive than girls about enjoying mathematics)
- Eligibility for free school meals.

Variables positively associated with confidence in mathematics

- Enjoyment of mathematics
- Key stage 1 mathematics and science attainment
- Mathematics activities (frequency of doing the following: calculations, fractions, decimals, measurement, data handling, shape activities, memorising solutions, working with other children)
- Being encouraged to work independently during lessons
- Giving explanations in mathematics
- School materials and budget (access to enough materials, such as textbooks, pens and papers and money to purchase materials)
- Pupil gender (boys were more positive than girls about their abilities in mathematics)
- Having access to various resources in the home (books, a calculator, a computer, a study desk, a dictionary, an internet connection, own bedroom, a mobile phone and an encyclopaedia in book or CD form) and to computers at home and elsewhere
- Eligibility for free school meals.

In these models, enjoyment and confidence in mathematics, the same caveat applies as discussed above in relation to the attainment models: causality cannot be demonstrated.

It is noticeable that, in these models, the frequency of mathematics activities factor is acting positively, where it acted negatively in both attainment models at grade 4. In terms of attitudes, the more often that pupils do this range of activities, the more positive they are about enjoying mathematics and being confident in it. Eligibility for free school meals, unusually, is also a positive variable in these models. This might be related to the link between economic background and attainment, and might reflect positive encouragement given by teachers to support pupils in schools with higher proportions of pupils eligible for free school meals.

These results for mathematics reveal that, although enjoyment and confidence in mathematics are related and share some associated variables, these associated variables are not identical; enjoyment and confidence are clearly not a single construct in mathematics in the same way that they appear to be in science.

Negative associations with attitudes to learning at grade 4

These variables were negatively associated with attitudes to learning at grade 4 (that is, as the incidence of each of these increased, so attitudes to mathematics and/or science became more negative).

The key findings are reported here. Those variables which were identified in the modelling but felt to be spurious as a result of potential interference or borderline significance are not included, but can be found in Appendix 3.

Variables negatively associated with enjoyment and confidence in science

- Extent of bullying (verbal, physical or social exclusion) in the school as perceived by pupils
- Using calculators in mathematics lessons
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, playing sports, using the internet, listening to music).

Variables negatively associated with enjoyment of mathematics

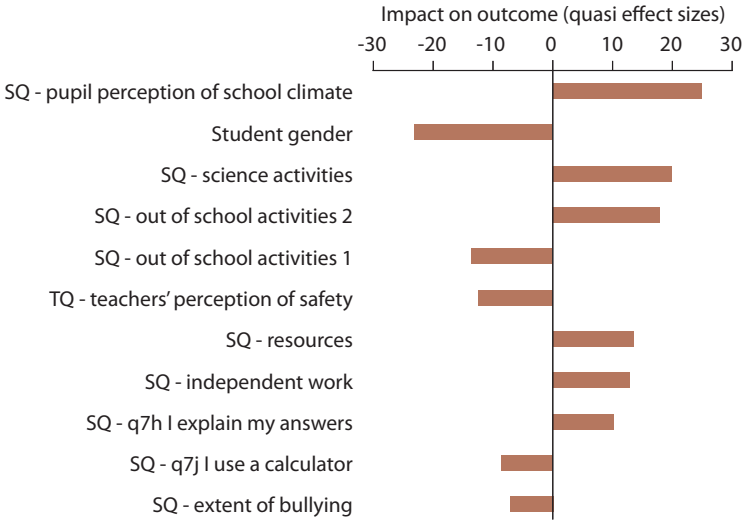
- The extent of perceived severity of behaviour problems (the second of two groups of factors: truanting, breaking uniform rules, cheating, vandalism, theft)
- Science activities (observing, watching experiments, designing and/or carrying out investigations, working with other children, giving explanations in science); this was a borderline effect
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, playing sports, using the internet, listening to music).

Variables negatively associated with confidence in mathematics

- Using calculators in mathematics lessons
- Using a textbook in mathematics lessons
- Extent of bullying (verbal, physical or social exclusion) in the school as perceived by pupils
- Pupils' perception of school climate (the extent to which pupils like being at school, want to do their best and feel that their teachers want them to do their best)
- Percentage of pupils with English as an additional language.

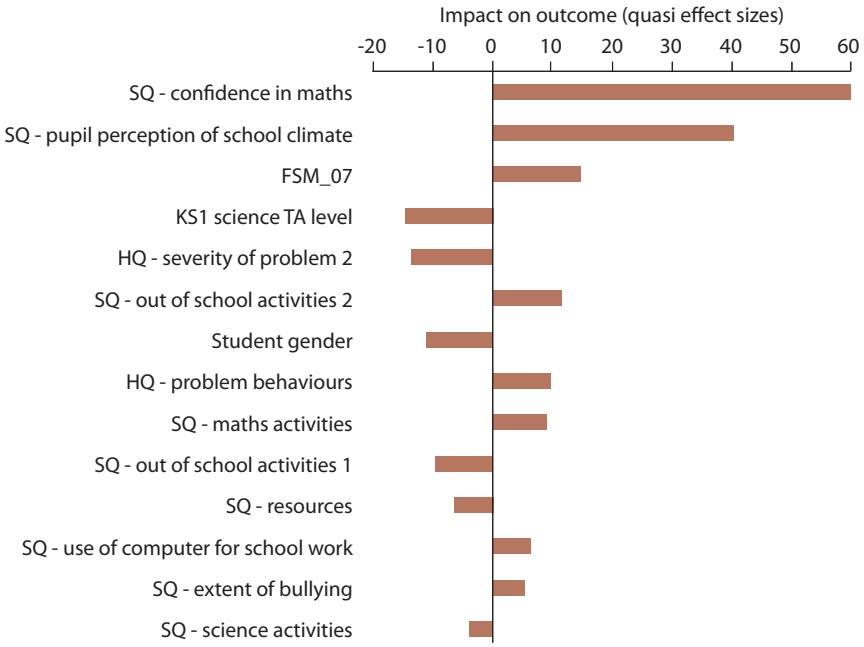
Fewer of these variables were associated negatively with enjoyment and confidence in science and mathematics, compared with those associated positively with each area. As described earlier, it is important to remember that the model simply describes associations; it cannot say what caused any given finding. Causality might arise from either associated variable, or might be caused by a third, related, variable. Some apparently counter-intuitive findings can be explained when thought of in this way. For example, use of calculators and textbooks might be negatively associated with confidence because their use reduces confidence, or because they are used more often by less confident pupils. Alternatively, a third, related, variable might explain this association.

Exhibit 10.3 Variables significantly associated with grade 4 enjoyment and confidence in science



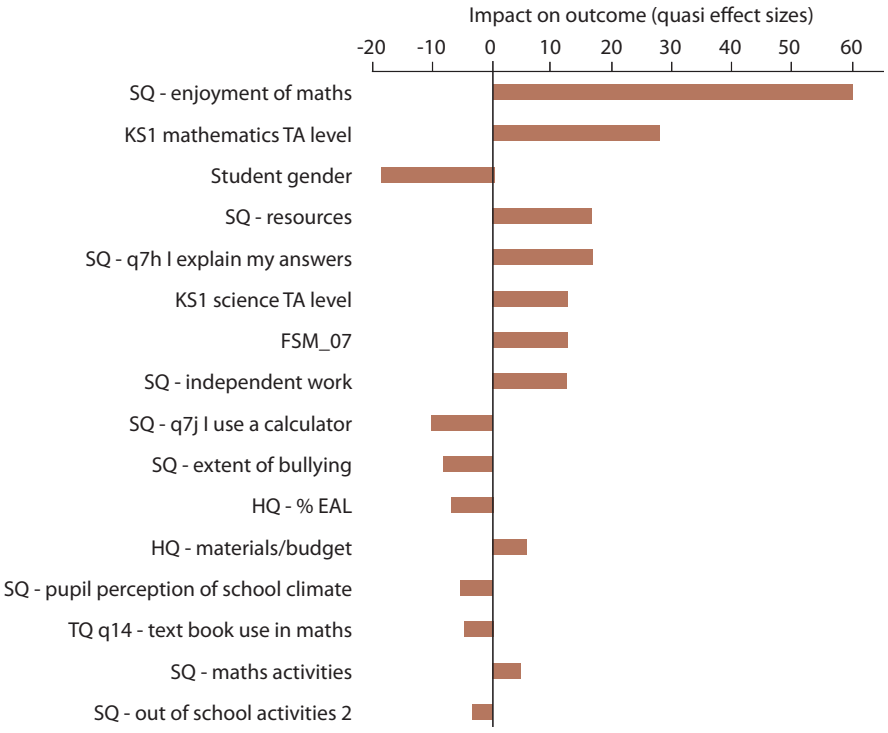
For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude (i.e., in this case, being a boy was associated with more positive attitudes than being a girl). Details of the variables and more information on how to interpret them can be found in Appendix 3.

Exhibit 10.4 Variables significantly associated with grade 4 enjoyment of mathematics



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude (i.e., in this case, being a boy was associated with more positive attitudes than being a girl). Details of the variables and more information on how to interpret them can be found in Appendix 3.

Exhibit 10.5 Variables significantly associated with grade 4 confidence in mathematics



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude (i.e., in this case, being a boy was associated with more positive attitudes than being a girl). Details of the variables and more information on how to interpret them can be found in Appendix 3.

10.4 Attainment in grade 8 science

Positive associations with grade 8 science attainment

The multi-level model (see Appendix 3 for more details) showed that the following variables were positively associated with attainment in science at grade 8 (that is, as each of these variables increased, so too did attainment in science).

- Being confident in mathematics
- Enjoyment and confidence in science
- Prior attainment as measured by key stage 2 test results in science and mathematics
- Use of a whole class teaching mode
- Use of a calculator for complex calculations
- Being encouraged to work independently during lessons
- Number of books at home

- Resources available in the home (a calculator, a computer, a study desk, a dictionary, an internet connection, own bedroom, a mobile phone and an encyclopaedia in book or CD form)
- Educational aspiration (as measured by how far in their education pupils expect to go)
- Involvement in the second of two groups of out of school activities (reading a book for enjoyment, doing homework, playing a musical instrument).

Once again, it is important to remember that the model can only describe, not explain. Findings such as the relationship between attainment and independent work or use of a whole class teaching mode might work in either direction, or be caused by a third, related, variable.

As was the case for science at grade 4, several mathematics variables were highlighted as significant in science attainment at grade 8. Six positive variables are common between the models in science at grade 4 and at grade 8: attainment in the preceding key stage, enjoying science and being confident in it, being confident in mathematics, being encouraged to work independently during lessons, having access to key resources (which may perhaps be seen as a measure of socio-economic status) and involvement in leisure activities such as reading for fun, doing homework and playing a musical instrument.

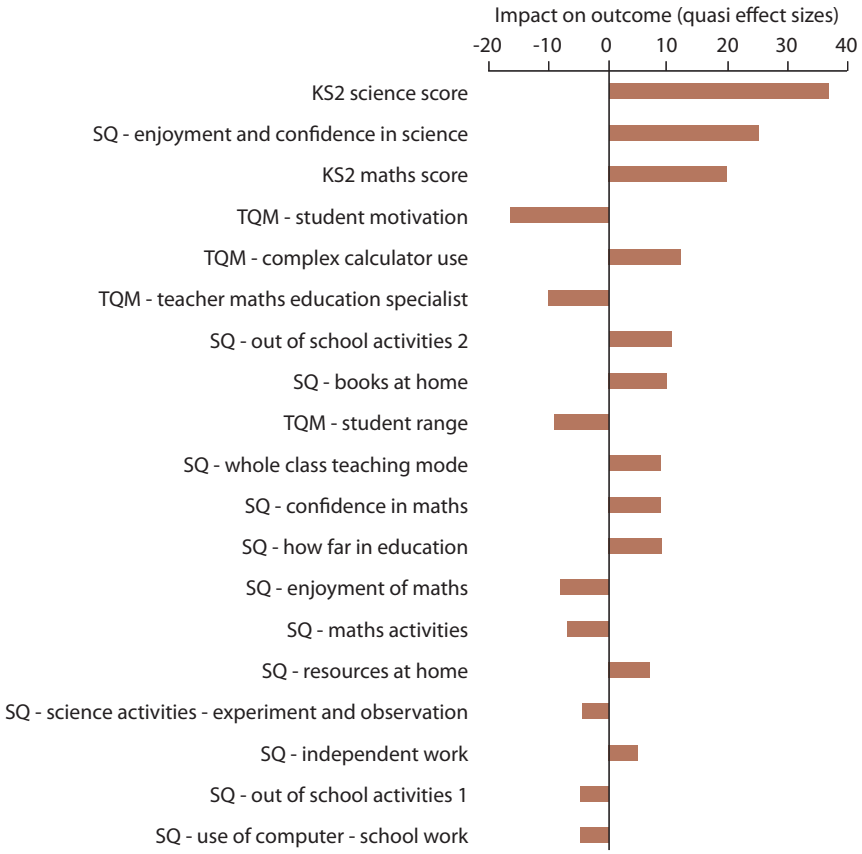
Other variables associated with attainment in science in either grade were unique to that grade. The effect of being born in the UK was only significant at grade 4. Similarly, being taught mathematics by a mathematics specialist was more important for science attainment at grade 4 than at grade 8: by grade 8, the association was weaker and borderline negative. The borderline effect might arise from the fact that, at grade 8, most mathematics teachers will be mathematics specialists, and are unlikely to be also teaching science. In contrast, at grade 4 the same teacher is likely to take pupils for both mathematics and science lessons and a mathematics specialism would therefore be useful in teaching aspects of investigative science.

Negative associations with grade 8 science attainment

The key findings are reported here for variables that were negatively associated with attainment in science at grade 8 (that is, as the incidence of each of these increased, so attainment decreased). Those variables which were identified in the modelling but felt to be spurious as a result of potential interference or borderline significance are not included, but can be found in Appendix 3. Some borderline effects are also reported only in Appendix 3.

- Unmotivated pupils in the mathematics class
- Range of pupils in the mathematics class (in terms of ability, special needs and background, such as language spoken, economic background, etc.)
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, using the internet, listening to music)
- Use of a computer for school work.

Exhibit 10.6 Variables significantly associated with grade 8 science attainment



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with higher attainment and a negative relationship that it was associated with lower attainment. No binary variables (i.e. those measured as yes/no) were significant in this model. Details of the variables and more information on how to interpret them can be found in Appendix 3.

Two factors with negative associations to science attainment related to mathematics teachers. There were no parallel effects for science teachers and no such negative effects at grade 4 (although being taught by a mathematics specialist was related positively to grade 4 science attainment). This might be an effect of the sampling mechanism used in TIMSS at grade 8, whereby pupils are sampled by their mathematics class/set. This means that each grade 8 class may have only one or two mathematics teachers associated with it, but potentially more science teachers (assuming that the target pupils are organised into different classes for science). Thus, response patterns from grade 8 science teachers may have become diluted because of their relatively larger number, and teacher effects might therefore have shown up more clearly among mathematics teachers. At grade 4, pupils were sampled by form/class and usually it was the same teacher who responded to questions about both mathematics and science. This might explain why such effects were seen at grade 8 but not at grade 4.

Two of these four negatively-associated variables are common to both grades, computer use for schoolwork and out of school activities including watching television/videos, playing computer games, playing/talking with friends, using the internet and listening to music. The range of pupils and lack of motivation among pupils were only associated negatively with attainment at grade 8.

It should be remembered that the model simply describes associations; it cannot say what caused the findings. So, for example, the link between out of school activities and lower attainment does not necessarily imply that lower attainment is a result of doing these activities. Involvement in these activities might depress attainment, might arise from the lower attainment, or both might be caused by a third, related, factor such as low motivation for learning. The same would be true of the association between increased use of a computer for schoolwork and lower attainment.

Exhibit 10.6 summarises the associations, in order of effect size (measured as quasi effect sizes; see Appendix 3 for more information).

10.5 Attainment in grade 8 mathematics

Positive associations with grade 8 mathematics attainment

The multi-level model (see Appendix 3 for more details) showed that the following variables were positively associated with attainment in mathematics at grade 8 (that is, as each of these variables increased, so too did attainment in mathematics).

- Frequency of whole class teaching mode in mathematics and science (pupil reported)
- Frequency of use of a calculator for complex calculations (teacher reported)
- Frequency of activities in geometry, data-handling and algebra (teacher reported)
- Prior attainment as measured by key stage 2 test results in science and mathematics
- Being confident in mathematics
- Number of books at home
- Educational aspiration (as measured by how far in their education pupils expect to go)
- Involvement in the second of two groups of out of school activities (reading a book for enjoyment, doing homework, playing a musical instrument).

Unlike science, only two positive variables are common between mathematics at grade 4 and at grade 8: attainment in the preceding key stage, and being confident in mathematics. The number of books in the home was also a common variable (at grade 8, on its own, and at grade 4 as part of the resources factor). Other resources did not have an impact at grade 8. This might be because pupils can more independently access resources elsewhere by that age and so are less reliant on resources at home. Alternatively, it might be because fewer resources are required for pupils to complete their mathematics homework: access to other resources was a significant variable for science attainment at grade 8, but science homework can potentially require a wider range of resources than mathematics.

Other variables associated positively with attainment in mathematics at either grade were unique to that grade. As with science, being taught by a mathematics specialist was more important to mathematics attainment at grade 4 than at grade 8: by grade 8, the association between attainment and having a mathematics education specialist as a teacher was weaker and borderline negative. The borderline effect might arise from the fact that, at

grade 8, most mathematics teachers will be specialists. Similarly, the effect of being born in the UK was only significant at grade 4. Teachers' perception of school climate was associated with mathematics attainment at grade 4 but not at grade 8, and the same was true of being encouraged to work independently.

This latter variable illustrates the caution to be taken in describing the direction of any effect between two variables: independent work might be a cause of higher attainment, or might be a consequence of it. The same caveat applies to the frequency of the whole class teaching mode: teachers might use this mode more because pupils are capable of responding to it, or attainment might be higher because the teacher uses this mode. The model cannot say which is the case, or whether a third variable might cause the association.

Negative associations with grade 8 mathematics attainment

These variables were negatively associated with attainment in mathematics at grade 8 (that is, as the incidence of each of these increased, so attainment decreased). The key findings are reported here. Those variables which were identified in the modelling but felt to be spurious as a result of potential interference or borderline significance are not included, but can be found in Appendix 3.

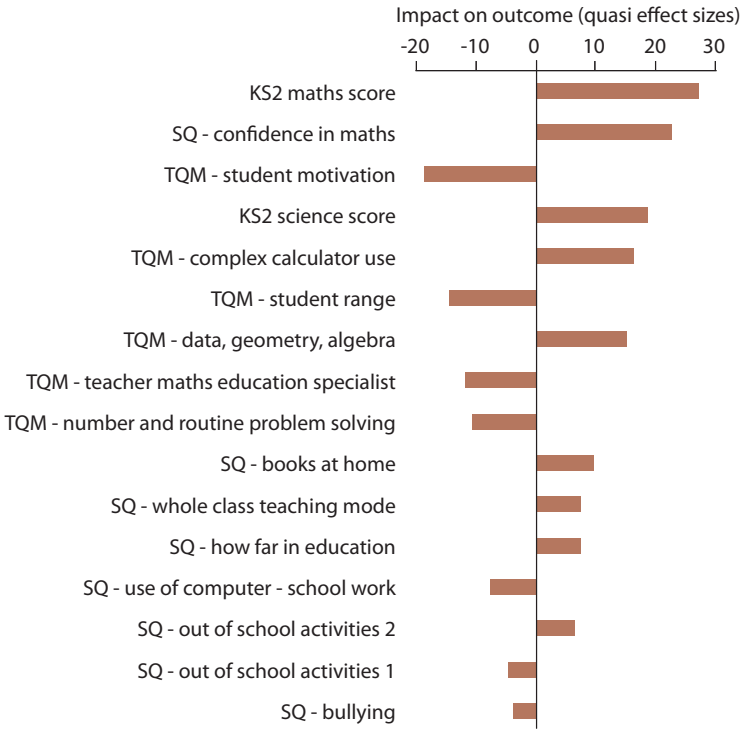
- Unmotivated pupils in the mathematics class
- Range of pupils in the mathematics class (in terms of ability, special needs and background, such as language spoken, economic background, etc)
- Extent of bullying (verbal, physical or social exclusion) in the school as perceived by pupils
- Computer use for school work
- Frequency of number and routine problem-solving activities in the classroom (teacher reported)
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, using the internet, listening to music).

Only three of the negatively-associated variables are common to both grades: extent of bullying, computer use for school work and out of school activities (including watching television/videos, playing computer games, playing/talking with friends, using the internet and listening to music). It is important to remember that these variables do not necessarily cause lower achievement, but might be a consequence of it. So, for example, higher computer use might be associated with lower attainment because lower attaining pupils are given more opportunities to use a computer to practise their skills.

Economic deprivation and eligibility for free school meals were only associated negatively with mathematics attainment at grade 4, as was the frequency of carrying out particular mathematics activities, as reported by pupils. Again, doing these activities more often might not cause lower attainment at grade 4, but might follow from it as pupils are given more opportunity to practise.

Exhibit 10.7 summarises the associations, in order of effect size (measured as quasi effect sizes; see Appendix 3 for more information).

Exhibit 10.7 Variables significantly associated with grade 8 mathematics attainment



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with higher attainment and a negative relationship that it was associated with lower attainment. No binary variables (i.e. those measured as yes/no) were significant in this model. Details of the variables and more information on how to interpret them can be found in Appendix 3.

10.6 Attitudes to learning at grade 8

In this section, the positive associations are listed first for all three attitudinal areas, followed by the negative associations. The bar charts for these areas are presented at the end of this section (see Exhibits 10.8 to 10.10).

Positive associations with attitudes to learning at grade 8

The multi-level model (see Appendix 3 for more details) showed that the following variables were positively associated with attitudes to learning at grade 8 (that is, as each of these variables increased, so attitudes to mathematics and/or science became more positive).

Variables positively associated with enjoyment and confidence in science

- Prior attainment as measured by key stage 2 test results in science
- The extent to which pupils value mathematics and science (in how it can help them in their daily lives and in the future)

- Frequency of a range of science activities, including experiments and observation, theory and explanation (by pupil report); and explaining and relating learning to daily life (by science teacher report)
- Frequency of the use of a whole class teaching mode, and use of computers for schoolwork (by pupil report)
- Pupils' perception of school climate (the extent to which pupils like being at school, want to do their best and feel that their teachers want them to do their best)
- Adequacy of school infrastructure and availability of special equipment
- Number of books at home
- Educational aspiration (as measured by how far in their education pupils expect to go)
- Involvement in the second of two groups of out of school activities (reading a book for enjoyment, doing homework, playing a musical instrument)
- Time spent on mathematics and science homework
- Pupil gender (boys were more positive than girls about science).

Two of the variables that were associated with enjoyment and confidence in science at grade 4 also applied at grade 8: pupils' perception of school climate and the second group of out of school activities. The number of books in the home was also a common variable (at grade 8, on its own, and at grade 4 as part of the resources factor). Other resources did not have an impact at grade 8. Science activities were pertinent at each grade, though the relevant combinations were different.

Other variables associated positively with enjoyment and confidence in science, at either grade, were unique to that grade. Pupils were only asked about educational aspiration and the value placed on mathematics and science at grade 8, hence there are no outcomes for those factors at grade 4.

Variables positively associated with enjoyment of mathematics

- Being confident in mathematics
- The extent to which pupils value mathematics and science (in how it can help them in their daily lives and in the future)
- Frequency of mathematics activities from pupils' reports (frequency of doing the following: calculations, fractions, decimals, geometry, data handling, equations, memorising solutions, explaining answers, relating learning to daily life, deciding on problem-solving procedures, having a test)
- Whole class teaching mode
- Use of computers for school work
- Time spent on homework
- Pupils' perception of school climate (the extent to which pupils like being at school, want to do their best and feel that their teachers want them to do their best)

- Percentage of pupils from relatively affluent families
- Resources available in the home (a calculator, a computer, a study desk, a dictionary, an internet connection, own bedroom, a mobile phone and an encylopaedia in book or CD form)
- Involvement in the second of two groups of out of school activities (reading a book for enjoyment, doing homework, playing a musical instrument).

Several of these variables acted in the same way at both grades: confidence in mathematics, pupils' perception of school climate, mathematics activities, computer use for school work and involvement in the second of the groups of out of school activities. Other variables were unique to one or other grade.

Variables positively associated with confidence in mathematics

- Enjoyment of mathematics
- Key stage 2 mathematics score
- Frequency of mathematics activities from pupils' reports (frequency of doing the following: calculations, fractions, decimals, geometry, data handling, equations, memorising solutions, explaining answers, relating learning to daily life, deciding on problem-solving procedures, having a test)
- The extent to which pupils value mathematics and science (in how it can help them in their daily lives and in the future)
- Sufficiency of computers in the school
- The extent of perceived severity of behaviour problems (first of two groups of factors: lateness, absenteeism, truanting, breaking uniform rules, disruption in class, swearing, intimidation of other pupils)
- Educational aspiration (as measured by how far in their education pupils expect to go)
- Pupil gender (boys were more positive than girls about their abilities in mathematics).

One apparent oddity here is that, as perceptions of the severity of problem behaviours increased, so confidence in mathematics increased. This factor is the first of two factors about perceived severity of behaviour problems: this factor contains the less serious of the two sets of behaviour problems and it may be that schools with the lesser set of problems are considered generally positive learning environments, thus promoting confidence in learning.

Frequency of mathematics activities was positively associated with both enjoyment and confidence in mathematics. This was true across all the attitudinal models: science activities predicted enjoyment and confidence in science at both grades, while mathematics activities did the same for both enjoyment and confidence in mathematics. There was no such widespread effect for the attainment models. Frequency of mathematics activities was a negative predictor of attainment in both science and mathematics at grade 4 (possibly because of extra practice being given to weaker pupils). There was no similar effect for grade 8 science and only one activities factor predicted mathematics attainment at grade 8:

frequency of geometry, data and algebra activities was positively associated with grade 8 mathematics attainment (causality might be in either direction).

As noted for grade 4, although enjoyment and confidence in mathematics are related and share some associated variables, these associated variables are not identical; there are many differences between the two at grade 8, and also many differences between the variables that are significant for each of confidence and enjoyment at each separate grade.

Negative associations with attitudes to learning at grade 8

These variables were negatively associated with attitudes to learning at grade 8 (that is, as the incidence of each of these increased, so attitudes to mathematics and/or science became more negative).

The key findings are reported here. Those variables which were identified in the modelling but felt to be spurious as a result of potential interference or borderline significance are not included, but can be found in Appendix 3.

Variables negatively associated with enjoyment and confidence in science

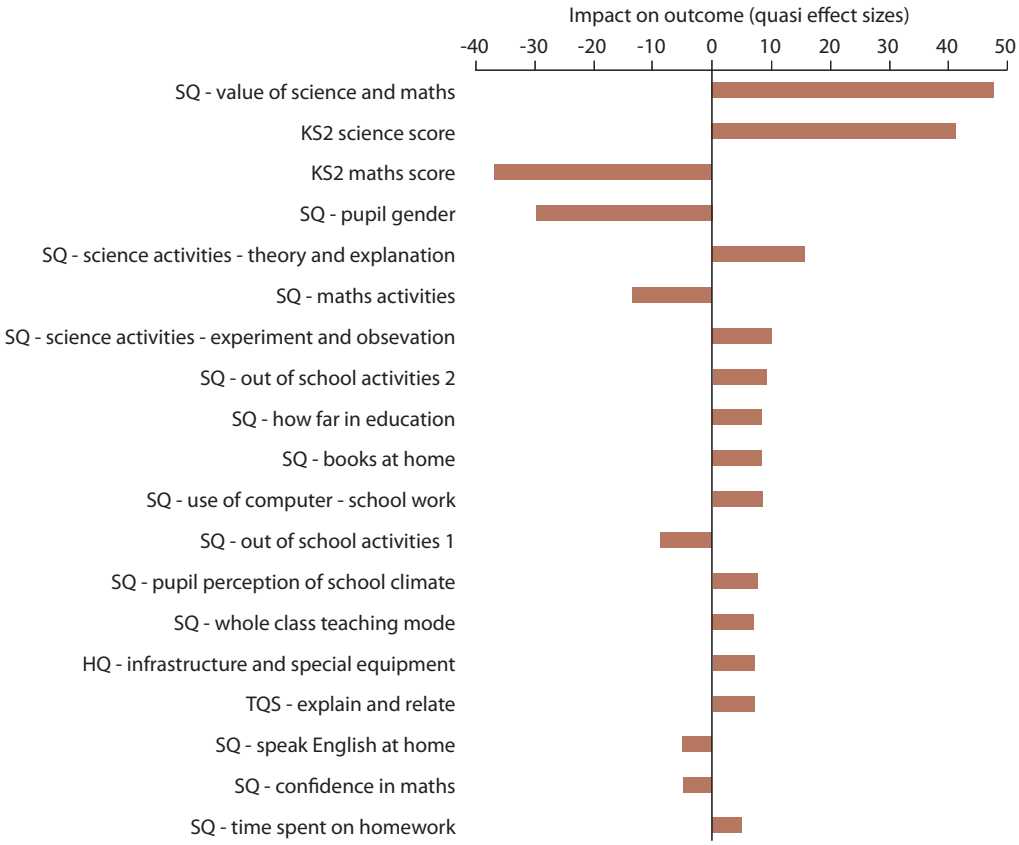
- Frequency of mathematics activities in the mathematics class
- Prior attainment in mathematics, as measured by key stage 2 test score (this might be a spurious effect caused by a correlation between the mathematics score and science score, the latter having a positive relationship with attitudes to science)
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, using the internet, listening to music)
- Frequency of use of English at home (most pupils, however, reported speaking English at home always or almost always).

Only one of the three negatively acting variables was significant at both grades: the first group of out of school activities.

Variables negatively associated with enjoyment of mathematics

- Key stage 2 science score
- Science experiments and observation
- Independent work
- Wide pupil range
- Science teacher being a mathematics specialist (borderline effect)
- Access to computers at home or elsewhere (excluding gaming)
- Involvement in the first of two groups of out of school activities (watching television/videos, playing computer games, playing/talking with friends, using the internet, listening to music)
- Percentage of pupils with English as an additional language.

Exhibit 10.8 Variables significantly associated with grade 8 enjoyment and confidence in science



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude (i.e., in this case, being a boy was associated with more positive attitudes than being a girl). Details of the variables and more information on how to interpret them can be found in Appendix 3.

As before, caution must be exercised in assigning causality, for example, the relationships between independent work and enjoyment and confidence in mathematics might work in either direction.

Once again, the common negatively-acting factor at grades 4 and 8 was the first out of school activity group. Other significant variables were different at each grade.

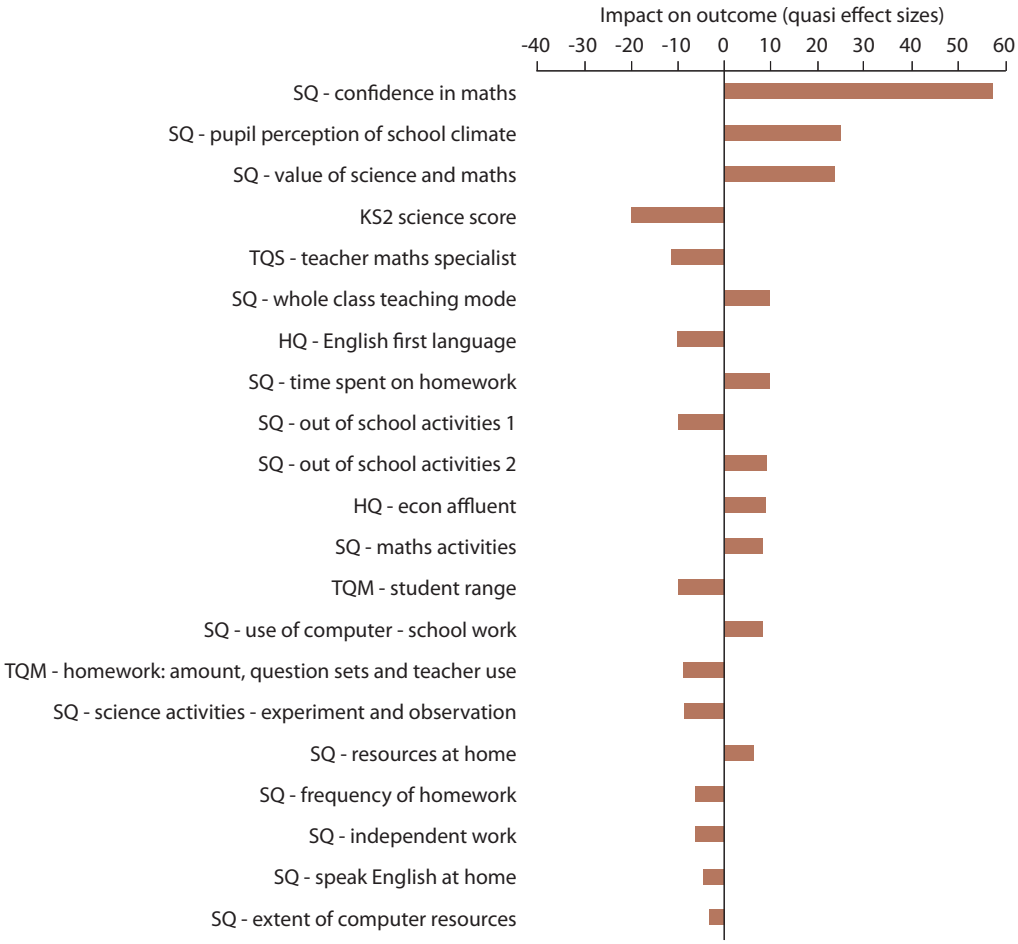
Variables negatively associated with confidence in mathematics

- Extent of bullying (verbal, physical or social exclusion) in the school as perceived by pupils
- The extent of perceived severity of behaviour problems (second of two groups of factors: cheating, vandalism, theft, verbal abuse of teachers, physical injury to other pupils)
- Time spent on homework.

Only one factor was common to both grades regarding confidence in mathematics: the extent to which pupils perceive bullying to affect their school.

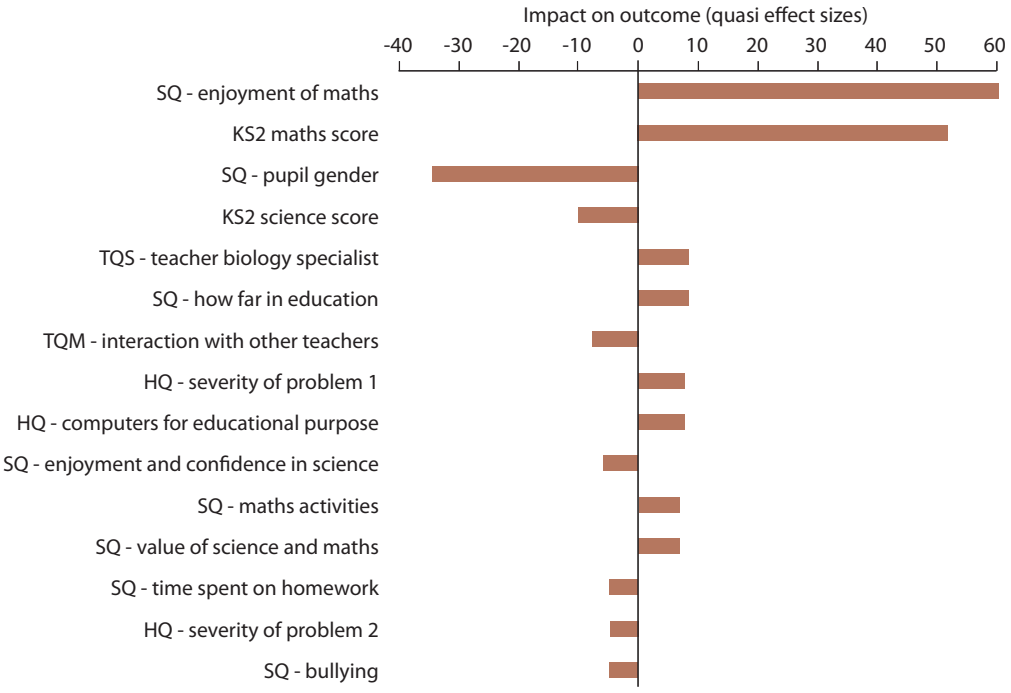
As described earlier, it is important to remember that the model simply describes associations; it cannot say what caused any given finding. Causality might arise from either associated variable, or might be caused by a third, related, variable.

Exhibit 10.9 Variables significantly associated with grade 8 enjoyment of mathematics



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude. No binary variables (i.e. those measured as yes/no) were significant in this model. Details of the variables and more information on how to interpret them can be found in Appendix 3.

Exhibit 10.10 Variables significantly associated with grade 8 confidence in mathematics



For continuous variables (i.e. those measured on a continuum from less to more) a positive relationship means that an increase in the variable was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude. For binary variables (i.e. those measured as yes/no), a positive relationship means that being one thing rather than the other was associated with a more positive attitude and a negative relationship that it was associated with a more negative attitude (i.e., in this case being a boy was associated with more positive attitudes than being a girl). Details of the variables and more information on how to interpret them can be found in Appendix 3.

10.7 Summary

The multi-level modelling has produced a large number of findings. Key patterns across the models are summarised below. Appendix 3 gives more information about these and other significant variables. It is important to remember, when reading these findings, that the direction of causality cannot be stated. The relationships described might work in either direction, or be caused by a third, related, variable.

Attainment models

- Three variables predicted attainment across all four models (grade 4 mathematics and science attainment and grade 8 mathematics and science attainment). These variables were:
  - prior attainment in mathematics and/or science
  - confidence in mathematics
  - access to resources and/or books in the home (these variables correlated slightly differently at each grade, but as indicators of socio-economic status, worked in similar ways at each grade).

In all four attainment models, as each of these factors increased, so too did attainment.

- In addition to confidence in mathematics, confidence and enjoyment in science was also important for attainment in science at both grades.
- Two variables were positively related in three of the four attainment models:
  - the second group of out of school activities (these were slightly different at each grade, but covered the frequency of leisure activities such as reading a book for enjoyment, doing homework and playing a musical instrument)
  - independent working in lessons.

  In all but the grade 8 mathematics attainment model, as the frequency of independent working increased, so too did attainment. For the second group of out of school activities, the same was true in all models except grade 4 mathematics. The reasons for these exceptions are not clear.
- Two variables were negatively associated with all four attainment models. These were:
  - extent of computer use for schoolwork
  - the first of two groups of out of school activities (these were slightly different at each grade, but covered the frequency of leisure activities such as watching television/videos, playing computer games, playing/talking with friends, using the internet and listening to music).

  In all four attainment models, as the frequency of these variables increased, so attainment decreased.
- A further variable was negatively related in three of the four attainment models:
  - extent of bullying (verbal, physical or social exclusion), as perceived by pupils.

  In all but the grade 8 science attainment model, as the perception of bullying increased, so attainment decreased. It is not clear why this was not a relevant factor for grade 8 science only.

  In addition to the variables associated with all four attainment models, some were associated with attainment at one grade only. These are outlined below.
- At grade 8 only, three factors were positively associated with attainment in both subjects:
  - whole class teaching mode
  - using calculators for complex calculations
  - pupils' educational aspirations.

  As these increased, so too did attainment.
- Also at grade 8 only, three factors were negatively associated with attainment in both subjects, so that, as these variables increased according to teachers' reports, so attainment declined. These factors were:
  - teachers' rating of the limitations caused to their teaching by having to teach:
    - unmotivated pupils
    - pupils from a range of backgrounds (economic, language, etc.)
  - the teacher being a mathematics education specialist (although this was a borderline and possibly spurious result for each subject).

- At grade 4 only, two factors were positively associated with attainment in both subjects:
  - being born in the UK
  - being taught by a mathematics specialist.

  Pupils who experienced these tended to attain more highly in both mathematics and science, but these effects did not continue into grade 8. At grade 8, most pupils would be taught by a specialist. The effect of birth, however, appears to become weaker as pupils become older.

- Also at grade 4 only, two factors were negatively associated with attainment in both subjects:
  - economic disadvantage
  - eligibility for free school meals

  As these variables increased as measured by teachers' reports, so attainment declined. It would appear that these matter at grade 4 more than at grade 8.

Attitudinal models

There were fewer clear patterns across the six attitudinal models (at each grade, enjoyment and confidence in science, enjoyment of mathematics and confidence in mathematics). Some clear findings were:

- Enjoyment of mathematics and confidence in mathematics were correlated, albeit less strongly than the parallel variables for science.

- Boys generally held more positive attitudes to their learning. Boys were more positive than girls about science and more confident about mathematics at both grades. They also enjoyed mathematics more at grade 4. Despite this, there were no overall differences in attainment in either subject at either grade.

- In all six attitudinal models, one set of factors was positively associated with enjoyment and confidence:
  - The frequency of mathematics activities was positively associated with attitudes to mathematics at both grades.
  - The frequency of science activities was positively associated with attitudes to science at both grades.

  As the frequency of these ranges of activities increased, so pupils enjoyed their lessons more and were more confident in their learning of the subject. It is not possible to say whether the positive attitude followed from a greater frequency of the activities, or whether the reverse was true.

- No variables acted negatively across all six attitudinal models.

- At both grades, in the attitude to science models and also in the enjoyment of mathematics models (but not in the confidence in mathematics models), the second group of out of school activities was associated with positive attitudes. Conversely, in these same models, the first group of out of school activities was associated with negative attitudes. The second group comprises the frequency of leisure activities such as reading a book for enjoyment, doing homework and playing a musical instrument, while the first includes the

frequency of leisure activities such as watching television/videos, playing computer games, playing/talking with friends, using the internet and listening to music. The exact composition of each group of activities was slightly different at each grade, but most activities were common to both grades.

- Independent working was a positive predictor of attitudes to science and confidence in mathematics at grade 4, but a negative predictor of enjoyment of mathematics at grade 8. The direction of causality cannot be defined.
- Pupils' perception of the extent of bullying in their school was a negative predictor of:
  – attitudes to science at grade 4
  – confidence in mathematics at grade 4 and at grade 8.

  As pupils perceived the extent of bullying (verbal, physical or social exclusion) to increase, so attitudes became less positive. It is not clear why grade 8 science should be an exception.
- Prior attainment was a significant positive predictor of:
  – attitudes to science at grade 8
  – confidence in mathematics at both grade 4 and grade 8.

  These findings provide evidence of significant variables related to attainment in, and attitudes towards, learning in mathematics and science. The statistical models cannot say whether the attainment and attitudes are caused by the relevant variable, whether the reverse is true, or whether another factor is responsible for the association. Nevertheless, these findings give further insight into the complex process of education in mathematics and science in England.