

An awareness of neuroscience in education

Can learning about the brain transform pupils' motivation to learn?

Edited by Alex Elwick



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The research and reporting team

This report has been edited by **Dr Alex Elwick**, the Research Officer at CfBT Education Trust. He has completed an Arts and Humanities Research Council-funded PhD in Learning in the Museum at Newcastle University and undertaken a Research Council UK-funded fellowship at the Library of Congress, Washington DC. He has written on education subjects as diverse as the UK digital divide and international approaches to youth custody.

The original report was written by Dr Ian Devonshire, Dr Ellie Dommatt and Professor Susan Greenfield.

Dr Ian Devonshire is a post-doctoral researcher at Nottingham University, author and science communicator. He has conducted research into drug addiction, environmental influences on the brain and, most recently, pain. Alongside his research responsibilities he is an associate lecturer with the Open University and a director of Fenton Mark Consultancy Ltd, a consultancy firm offering services in neuroscience and education.

Dr Ellie Dommatt is a lecturer in biological psychology and neuroscience at the Open University, an author and science communicator. Her laboratory research focus was developed whilst working with Prof. Greenfield at the Institute for the Future of the Mind, and focuses on the actions of drugs such as methylphenidate (Ritalin) in health and disease. This research resulted in a Junior Research Fellowship at Somerville College and later at Lady Margaret Hall. She is also a director of Fenton Mark Consultancy Ltd.

Prof. Susan Greenfield is Professor of Pharmacology at Oxford University, a neuroscientist, writer and broadcaster. She has been awarded 30 honorary degrees from British and foreign universities and heads a multi-disciplinary research group that explores novel brain mechanisms linked to neurodegenerative diseases and consciousness. She has also developed a keen interest in the impact of modern technologies on how young people think and feel. In 1998 she received the Michael Faraday Medal from the Royal Society, was awarded a CBE in the Millennium New Year's Honours List and was granted a non-political life peerage in 2001. In 2000 she was elected to an Honorary Fellowship of the Royal College of Physicians and in 2007 to an Honorary Fellowship of the Royal Society of Edinburgh. She was Chancellor of Heriot-Watt University from 2005 until 2012.

The authors were assisted in the delivery of the research project by:

- Emma Sewter, Research Assistant, Institute for the Future of the Mind, Oxford University
- Carolyn Plateau, Research Assistant, Institute for the Future of the Mind, Oxford University
- Eva Tutchell, Advanced Skills Teacher, Mentor and Education Consultant
- Geraldine Atkins, Quality Assurance Administrator, Gloucestershire Local Authority.

An academic article based on the research has also been produced by the aforementioned authors. The citation for this article is:

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Foreword

Neuroscience is one of the fastest-growing and one of the most exciting research fields in the world today. It is not surprising, therefore, that there has been so much interest in it from schools, teachers and policymakers. To date, despite the growing literature, there has been little robust research into where to position neuroscience knowledge and how to use it. Even the most ardent enthusiasts have limited themselves to action research-style project designs with groups of enthusiastic teachers. This innovative research project used a randomised controlled trial in order to assess the value of neuroscience teaching amongst Year 7 pupils, and presents some encouraging findings in terms of the effect such teaching might have on pupils' beliefs about their own intelligence.

The report contains important information for teachers, schools and policymakers about where to position neuroscience knowledge for best effect in the system and where not to over-emphasise its importance.

Richard Churches, Principal Adviser for Research and Evidence Based Practice at CfBT Education Trust

Summary

This research was commissioned by CfBT Education Trust and carried out in conjunction with the Institute for the Future of the Mind at the University of Oxford. The project sought to establish whether teaching pupils about the brain could impact upon their beliefs about their own intelligence (amongst other motivational measures) and ultimately positively impact on their academic performance.

The central aims of this research were:

- To assess whether teaching pupils about their own brains (neuroscience training) has an effect on their motivation to learn.
- To assess whether teaching pupils about their brain has an effect on their actual academic performance.
- To assess whether the mode of teaching pupils about the brain (either by a teacher or a computer programme) impacts upon any outcomes of the training.

A randomised controlled trial with Year 7 pupils showed that neuroscience training can positively change pupils' views of their own intelligence, encouraging them to see their own intelligence as flexible.

The study did not show any positive impact on actual academic performance itself, but this was tested over a relatively short time period and within just one subject (mathematics).

The study also tested the mode of delivery, comparing content delivered by a teacher with identical input delivered through an interactive software program. That delivered by the teacher was seen to have a greater impact on pupils' motivation, in both the short and the longer term.

The study makes the following recommendations:

- Additional research is needed to explore the effect of neuroscience teaching on academic performance.
- Neuroscience workshops should be used to positively improve pupils' beliefs about their own intelligence.
- Further research should be undertaken to explore how neuroscience workshops can be used to try and combat the Year 7 learning 'dip'.



1 Introduction

This report is based on work by neuroscientists at the Institute for the Future of the Mind at the University of Oxford. Building on previous research, the team investigated whether providing knowledge about the brain to pupils could influence beliefs about four aspects of learning: their own intelligence; the value of making an effort; the importance of academic achievement and actual academic performance.

Neuroscience is the study of the nervous system and, in particular, of the brain. It is a relatively new science in which research has advanced dramatically over the last 20 years, particularly as a result of the advent of brain-imaging techniques which allow scientists to observe the brain in action. This has allowed neuroscientists to learn much about how children's brains develop and how the brain processes information. This research looked at whether this new scientific knowledge is of practical value to teachers and others involved in school education.

The project had three key aims:¹

1. To assess whether teaching pupils about the brain had an effect on three motivational measures:
 - pupils' beliefs about the plasticity of their own intelligence
 - their beliefs about the effectiveness of making an effort
 - their beliefs about the importance of academic achievement.
2. To assess whether teaching pupils about their brain had an effect on actual academic performance.
3. To assess whether the mode of delivery (e.g. identical content delivered by a computer program or a teacher) effected changes in pupils' motivation or academic performance.

An experimental design was used to address the first two of these aims. A total of 383 Year 7 pupils from five different schools in Gloucestershire were randomly divided into three groups. Members of one of the groups took part in a series of workshops on the topic of neuroscience (learning about the different parts of the brain, its plasticity and the role it plays in controlling behaviour and decision making); a second group took part in workshops based on study skills (but which made no overt references to the brain itself); and the third group took no part in workshops at all. These three groups are referred to throughout this report as the intervention group, the active control group and the passive control group.

The third aim reflected the interest in exploring issues to do with the cost of delivering training about the brain to pupils. Built into the research design was a comparison between two modes of delivery: the first was a more expensive option of delivering training through workshops led by Advanced Skills Teachers (ASTs) and the second option, the cheaper of the two, involved the delivery of identical content through a computer software program.

¹ The original study by Dommett et al. also studied the effect of neuroscience and study skills workshops on teachers, but this is not reported on here.



This edited report presents:

- a discussion explaining the relationship between neuroscience and education, based upon a concise literature review of the field (Section 2)
- a description of the research design and method used (Section 3)
- the findings from the research (Section 4)
- conclusions and recommendations (Section 5).

2 The relationship between neuroscience and education

2.1 How can neuroscience and education work together?

Over the last 10 years there has been growing international interest in exploring the relationship between neuroscience, psychology and education. In the UK, the Economic and Social Research Council seminar series 'Collaborative frameworks on neuroscience and education' made important steps in fostering dialogue between neuroscientists and school educators. It also revealed the depth of public interest when, within the first six months of publication, there were 110,000 downloads of the associated commentary.

The relevance of neuroscience to education (alongside the related field of psychology) and its potential impact on pedagogy has been recognised by scientists, educators and policymakers. In discussions between these disciplines many questions have been raised about the potential of neuroscience and education. For example:

- How can the growing understanding of the brain emanating from the field of neuroscience help to address current inequalities in learning and skills development?
- What, aside from learning itself, could help boost the capacity to learn in adult life? (The Royal Society, 2011).

Despite the widespread recognition that neuroscience and education could forge an effective partnership, to date the relationship between the two disciplines has largely failed to fulfil the initially perceived potential (Lagemann, 2000).

2.2 Neuroscience and pupils' educational outcomes

The work of the American psychologist Carol Dweck has been influential in the area of student motivation. Research by Dweck and colleagues has recently provided some evidence to suggest that changing adolescent pupils' understanding of the brain, via workshops delivered by undergraduate psychology students, may alter their academic outcomes (Blackwell et al., 2007).

Dweck's research is a key marker and provides the underlying framework for the study design adopted and reported in this document. Her research has been concerned with a number of motivational measures, and in particular assessing whether learning about the brain can effect such measures amongst pupils. Furthermore, Dweck's work on the nature of intelligence and in particular on the beliefs that people have about the nature of intelligence, (Dweck, 1999) has influenced the intention to explore how pupils view their own intelligence (as either fixed or flexible) as well as the implications of these beliefs for learning.

Pupils in Year 7 are particularly vulnerable in terms of educational progress. It is widely accepted that adolescence is a period of great change, including shifting societal demands, conflicting role demands, increasingly complex social relations and new educational expectations (Eccles et al., 1993, 2004). Moreover, adolescents often show a decrease in school engagement and academic performance (Simmons et al., 1987), particularly at periods of transition such as moving into Year 7 (Evangelou et al., 2008). It has been suggested that one contributing factor to this decrease in school engagement is the nature of the transition from primary to secondary school education (Eccles et al., 2004; Montemayor et al., 1990; Wigfield et al., 2006). Eccles and colleagues (1993) found several differences between the elementary school and junior high school contexts that may



account for the impact on the transition between the two phases. For example, they found the latter to be a more competitive environment featuring greater social comparison and self-assessment of ability. In addition, changing school disrupted support networks that had developed at the previous school. Given the upheaval associated with this transition it is perhaps unsurprising that many pupils experience a decline in grades, from which some will not recover (Eccles et al., 1993; Gutman & Midgley, 2000; Midgley et al., 1989).

In line with the specific challenges identified in adolescence, research has investigated what makes some pupils resilient to the difficulties of this period and allows them to meet the challenges (Blackwell et al., 2007; Gutman & Midgley, 2000; Dweck & Sorich, 1999). Particular focus has been placed on the use of motivational models of achievement which consider the kinds of core beliefs that determine positive outcomes in response to such challenges. Previous work by Dweck and colleagues demonstrated that pupils may hold different core beliefs about the nature of intelligence, their so-called 'theory of intelligence' (Dweck, 1999; Dweck & Leggett, 1988). This theory can be divided into beliefs about intelligence and effort; both of these beliefs can be divided into two distinct types. For intelligence beliefs, pupils may see intelligence either as a fixed entity (entity intelligence) or as something that can increase and is therefore flexible (incremental intelligence). Dependent on effort beliefs, pupils will either recognise the value in making an effort or see effort as fruitless. Pupils who subscribe to an entity view or do not believe in the value of effort will engage in learning only for the sake of demonstrating their abilities in relation to other pupils, to gain recognition, avoid punishment and obtain better grades – therefore learning is a means to an end (Abdullah, 2008). Additionally, entity believers are more inclined to give up in response to a challenge, such as that presented by adolescence, than incremental believers (Dweck & Leggett, 1988); consequently, they have limited use of learning strategies. By contrast, pupils who adopt an incremental view of intelligence or believe in making an effort, learn to gain understanding, insights, skills and knowledge. They are interested in mastering new things and in developing novel skills and abilities (Abdullah, 2008). As a consequence, these pupils tend to have more active learning strategies including note-taking, elaboration, paraphrasing, summarising and question-asking strategies (Hong et al., 1999). Perhaps unsurprisingly, pupils adopting an incremental view of intelligence are more likely to also believe in the effectiveness of making an effort (Abdullah, 2008).

Evidence also suggests that belief in incremental intelligence has a tangible impact on actual academic performance, with research showing that pupils holding such beliefs during the transition to junior high school achieve significantly higher grades (Henderson & Dweck, 1990). Despite extensive investigation into the belief structures and their relationship to academic performance, until relatively recently studies investigating the impact of different educational interventions did not consider long-term performance or the possible mediators and mechanisms of any change in beliefs.

These issues were addressed by Blackwell, Dweck and colleagues (Blackwell et al., 2007) who collected data from pupils over a prolonged period whilst at junior high school. Pupils were exposed to a specific classroom intervention to examine the relationship between the theory of intelligence and academic performance, and to test mediators of this relationship. They reported that incremental beliefs in intelligence can be developed in learners through just eight 25-minute lessons devoted to cultivating an optimistic 'I am what I choose' attitude. The key messages of this intervention programme were focused on teaching participants about the flexibility of intelligence. There were three main messages: firstly, learning changes connectivity within the brain through a process called plasticity; secondly, this process takes place throughout our

lives; and thirdly, active learners can be in charge of that process. In a rigorous, randomised controlled study, this intervention programme was shown to have a catalytic effect on motivation, which resulted in a reversal in downward academic trajectories for mathematics grades and thus removed the downturn in academic performance associated with the transition to secondary education. Critically, however, the lessons devised were very broad, and whilst they encompassed neuroscience content, they also addressed study skills and stereotyping. Therefore it is not possible to ascertain which of these elements were critical in the development of flexible 'mindset'. Furthermore, the workshops were delivered by psychology undergraduates, not qualified teachers, which may have had some limiting bearing on the effect size. The assumed difference between the pedagogical knowledge and experience between the psychology undergraduates and trained teachers raises questions about the role that instructional effectiveness may play in the process.

There are three key points from the literature that have been particularly influential in shaping the focus and methods of this research. Firstly, pupils may hold different core beliefs about the nature of intelligence, viewing it as either a fixed entity or as flexible and able to increase. Dependent on these beliefs, pupils will either recognise the value in making an effort or see effort as fruitless. Secondly, adolescence is a key stage where educational vulnerability has been identified. Altering adolescent pupils' understanding of the brain, and in particular their views about incremental intelligence, may alter their academic outcomes and offer a means by which they can either avoid or recover from this academic and motivational 'dip'. Lastly, evidence suggests that belief in incremental intelligence can have a tangible impact on actual academic performance, with research showing that pupils holding such beliefs during the transition to junior high school achieve significantly higher grades.



3 Research methods

3.1 Aims

The project had three key aims:

1. To assess whether teaching pupils about the brain had an effect on three motivational measures:
 - pupils' beliefs about the plasticity of their own intelligence
 - pupils' beliefs about the effectiveness of making an effort
 - pupils' beliefs about the importance of academic achievement.
2. To assess whether teaching pupils about their brain had an effect on actual academic performance.
3. To assess whether the mode of delivery (e.g. identical content delivered by a computer program or a teacher) effected changes in pupils' motivation or academic performance.

3.2 Study design

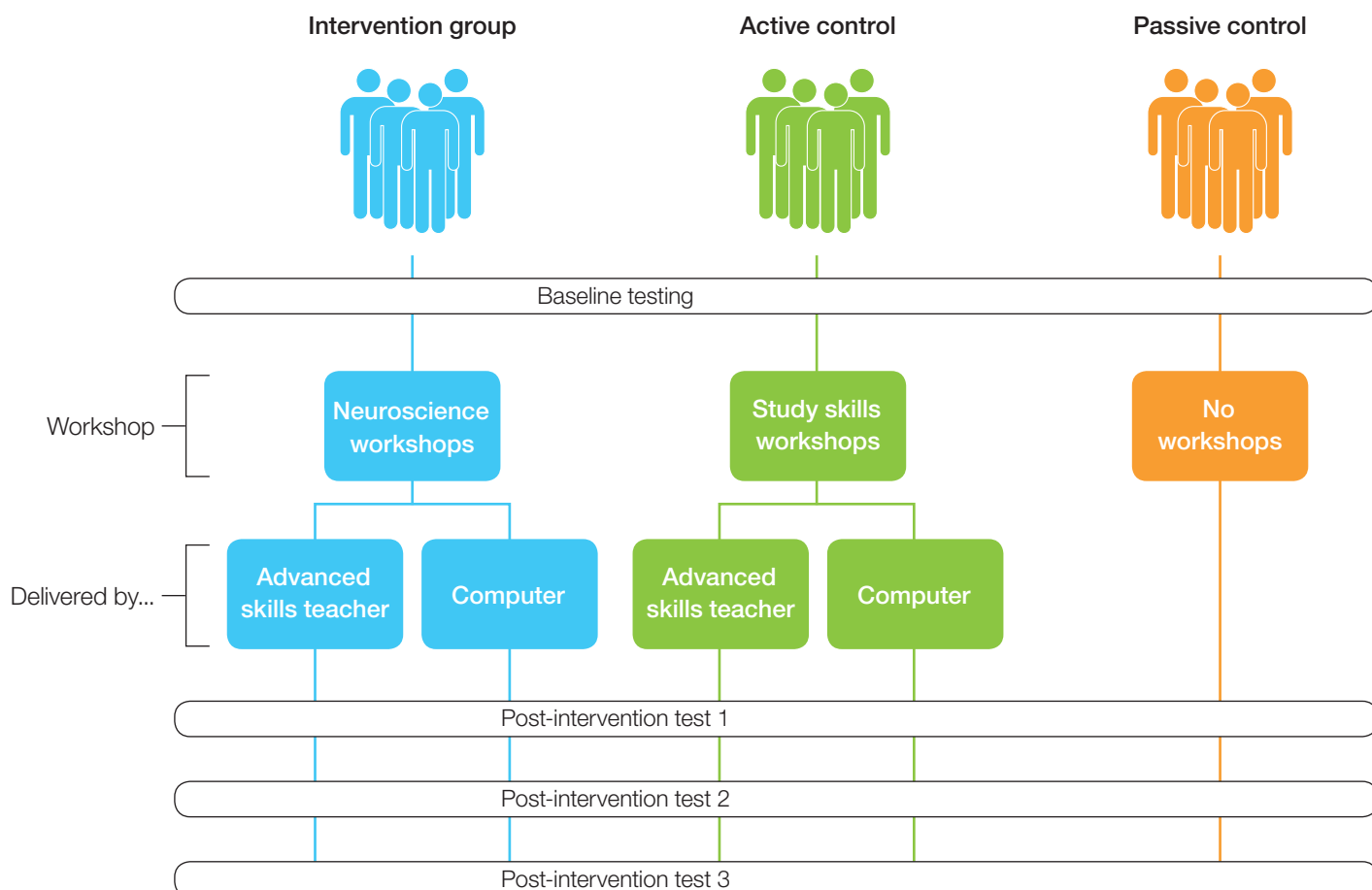
The study used an experimental design. In order to test the effects of neuroscience workshops three groups of pupils were needed. These groups were:

- the intervention condition (those who would receive neuroscience workshops)
- the active control condition (those who would receive study skills workshops which contained no neuroscience component)
- the passive control (who received no intervention of any kind).

Pupils in the intervention group and the active control were then split – with half receiving the workshops delivered by ASTs and half receiving the workshop via a computer program. Figure 1 presents an overview of the research design diagrammatically.



Figure 1: Research method, showing which groups pupils were assigned to, which workshop they received, the modes of delivery of these workshops and at which point the pupils were tested/measured (as described below)



The workshops were delivered in two ways, to explore the effectiveness of each method. Delivering workshops by computer is a cheaper alternative to training and using ASTs and for budgetary reasons may be favourable to schools. However, if there were differences in any positive impact of the workshops delivered by ASTs or computer then this information would also be needed to help school leaders to decide how best to implement training in their schools.



3.3 Participants

Participants in the project comprised pupils from five ability-matched schools in south-west England (three classes from each school), who had recently made the transition from primary to secondary school (age 11–12 years). Schools were selected on the basis of their Ofsted rating, their levels of attainment, their size and location, in order to try to ensure that they were equivalent, as much as was possible. A total of 383 pupils took part (the original sample was 389 but six were removed due to SEN diagnosis). The sample comprised 190 male and 193 female pupils, all from Year 7. Table 1 shows the breakdown of pupils in each condition (intervention, active control and passive control). The schools were randomly allocated to each of these conditions (two schools to the intervention condition, two schools to the active control condition and one school to the passive control condition).

Table 1: Number of pupils involved in each condition

		Number of pupils	
Intervention	Neuroscience workshop (delivered by AST)	159	89
	Neuroscience workshop (delivered by computer)		70
Active control	Study skills workshop (delivered by AST)	142	68
	Study skills workshop (delivered by computer)		74
Passive control	No intervention	82	82
Total		383	

3.4 The workshops

3.4.1 The intervention group workshops (neuroscience workshops)

The neuroscience workshops were designed to develop pupils' motivation to learn by presenting information in enjoyable, engaging and interactive ways on the topics of brain plasticity, incremental intelligence and emotional aspects of learning. Pupils either received this information from experienced ASTs or from computer software packages.

The workshops led by ASTs enabled pupils to get involved in activities and memory games as well as handle models of the brain. The workshops were developed by the ASTs after they had undergone training in neuroscience. Interaction and enjoyment were key components of the sessions.

Given the wealth of information that exists on how the brain develops and functions to enable us to navigate around our world, think new thoughts and remember events, the workshop sought to carefully distil this information to provide only what would convey a sense of the plasticity of the brain. After consideration, it was decided to create four separate workshops with the following themes:

- What does the brain do?
- How does the brain work?
- What happens when we learn?
- How do we remember things?

The computer-based workshops were devised by neuroscientists based at the University of Oxford. These were included in the study in order to compare the AST-led workshops with a less interactive, but more practical and cost-effective mode of delivery. The software contained some interactive elements as well as video and audio features and was presented in a straightforward manner using non-technical language.

As far as possible the content and multimedia were the same for the AST-led session and the computer program. Both workshops led by ASTs and software-based sessions were delivered over a four-week period. All workshops (and assessment sessions) were one hour in duration and scheduled into mathematics classes.

3.4.2 The active control group workshops (study skills workshops)

The introduction of new teaching practices or workshops can often superficially improve pupil performance due to the combined effect of the enthusiasm of the participating teachers and/or merely the fact that it is novel. Therefore, in order to ensure that any effects of the intervention could be directly attributable to the neuroscience workshops, it was necessary for one half of the study's participants to receive a similarly novel (and enthusiastically-delivered) series of workshops on a different subject, namely study skills.

Study skills workshops were designed to encourage the same study strategies as the neuroscience workshops without the provision of information about the neuroscientific basis of the practices. As such, the following areas were covered in each workshop:

- How can we prepare for learning?
- How do emotions affect learning?
- How do we remember things?
- How can we improve our memory?

The study skills workshops used the same process of development and aimed to inculcate the same strategies as the neuroscience workshops, but with the absence of any neuro-scientific knowledge base. Again, as far as possible the content of the AST-led sessions and those delivered via computer were identical. All workshops (and assessment sessions) were one hour in duration and scheduled into mathematics classes.

3.4.3 The passive control group workshops

Pupils involved in the passive control received no additional workshops, but were subject to the same baseline and post-intervention tests administered to the other two groups.



3.5 Assessment

The effectiveness of the workshops was measured in two ways. One was assessment of motivational measures (including pupils' beliefs about their own intelligence and the importance of achievement) and the other was actual academic performance (specifically in mathematics tests, but also through comprehension quizzes).

The tests were administered at four different points in time for all conditions. Baseline data was gathered before the intervention commenced and on a further three occasions post-intervention (one week after the intervention concluded, approximately seven months after, and approximately 19 months after). See Table 2.

Table 2: Project timescale including timing of intervention workshops and pre-post-intervention tests

	When	Activity
Year 7	Immediately after October half term	Baseline testing
	2 November – 18 December	Intervention workshops x4
	End of Winter term	Post-intervention Test 1
	End of Year 7	Post-intervention Test 2
Year 8	End of Year 8	Post-intervention Test 3

3.5.1 Measuring motivation and views on the plasticity of intelligence

A standard test was used to assess pupil attitudes towards intelligence, specifically examining their views on fixed and flexible intelligence. The test also sought to assess beliefs regarding the importance of academic achievement and the effectiveness of making an effort. High scores on these measures would indicate that a pupil valued academic achievement and believed that making an effort would be effective in changing their learning outcomes and demonstrate agreement that intelligence is not fixed. These tests used a Likert scale to collect responses, where pupils indicated their agreement with a series of statements (from 1 – agree strongly to 6 – disagree). Some examples of statements can be seen below, in Table 3.

Table 3: Examples of statements used to assess motivational measures

Motivational measure	Example of statements
Intelligence beliefs	You have a certain amount of intelligence and you can't do much to change it.
Effort beliefs	It doesn't matter how hard you work, if you are not smart, you won't do well.
Academic beliefs	I think it is important to work hard and spend a lot of time on schoolwork.



3.5.2 Assessing actual academic performance

In order to assess academic performance throughout the experiment, age-appropriate mathematics tests were conducted at baseline and at three points post-intervention. This test was based on a test created by the National Foundation for Educational Research (NFER) which was altered to be completed within a single lesson.² It included questions assessing comprehension of numeracy, shape and space and data handling. New versions of the test were carried out on each of the four occasions so that the same topics were included but questions were not repeated.

Mathematics tests were chosen so as to provide an objective measure against which pupils' academic performance could be assessed without being affected by teachers' knowledge or pupils' condition, or by teachers' subjective opinions (Dommett et al., 2013). Mathematics knowledge can be objectively assessed and is a core part of the curriculum which all pupils study.

3.5.3 Workshop delivery mode

In order to judge the differences between the delivery modes of the workshops (ASTs and computer software) two distinct methods were employed. Comprehension tests were carried out with those pupils who had been involved in workshops as part of the post-intervention assessments. These tests were directly related to the content of the workshops (in the form of multiple-choice questions) and designed to ascertain whether pupils had understood the content that had been delivered.

3.5.4 Questionnaires

A questionnaire was administered to all ASTs and pupils who had delivered and received the workshops. This questionnaire asked the respondents to rate the workshops that they had been involved with, in terms of enjoyment, interest and understanding, and included questions on which aspects were most and least liked.

² GL Assessment, see <http://www.elevenplusexams.co.uk/advice/gl-assessment-nfer-and-letts> for more information on these tests.



4 Findings

The results of this research project are divided into three broad areas: the impact on motivation, the impact on academic performance and the differences resulting from the mode of delivery. In each case the intervention group is compared with the active and passive control groups in order to establish whether changes were as a result of the neuroscience intervention specifically, or simply as a result of receiving an intervention of some kind.

In the first two sections (4.1 and 4.2) no distinction is made between mode of delivery of the interventions – that is to say that the group who received the neuroscience workshop, whether they received it by AST or computer, are treated as one (with the same for the group receiving the study skills workshop). There were no statistically significant differences between the AST-led or software-led workshops in either condition with regard to the effect on motivational measures or academic performance. Any further differences between these two modes of delivery are teased apart in section 4.3.

4.1 The impact on motivation

4.1.1 Belief in incremental intelligence

- Prior to any intervention, all three groups (the intervention group, the active control and the passive control) held similar beliefs about the incremental nature of intelligence. The group who received neuroscience workshops (the intervention group) showed an increase from their baseline results at the final two assessment points, indicating there was a statistically significant increase in the strength of their beliefs about intelligence and its flexible nature which was maintained in the final assessment.
- The active control group (those receiving study skills workshops) showed an increase at the second post-intervention test, but their beliefs returned to the baseline levels in the final test – indicating only a temporary, and mild, effect.
- There were only small (non-significant) changes in the results from the passive control group (who received no workshops) over the experiment, with levels returning to baseline by the final post-intervention test.
- These results would suggest that learning about the brain through neuroscience workshops can result in longer-lasting changes to pupils' beliefs about the flexible and incremental nature of intelligence.

4.1.2 Belief in the effectiveness of making an effort

- Prior to the interventions, the passive control group viewed making an effort as more worthwhile than the two groups assigned to receive workshops (a statistically significant difference). However, following the intervention there was no longer a difference between any of the groups in the final test. This suggests that the workshops had an effect in terms of raising the beliefs of the pupils regarding the effectiveness of making an effort (but this effect was mild and not statistically significant).

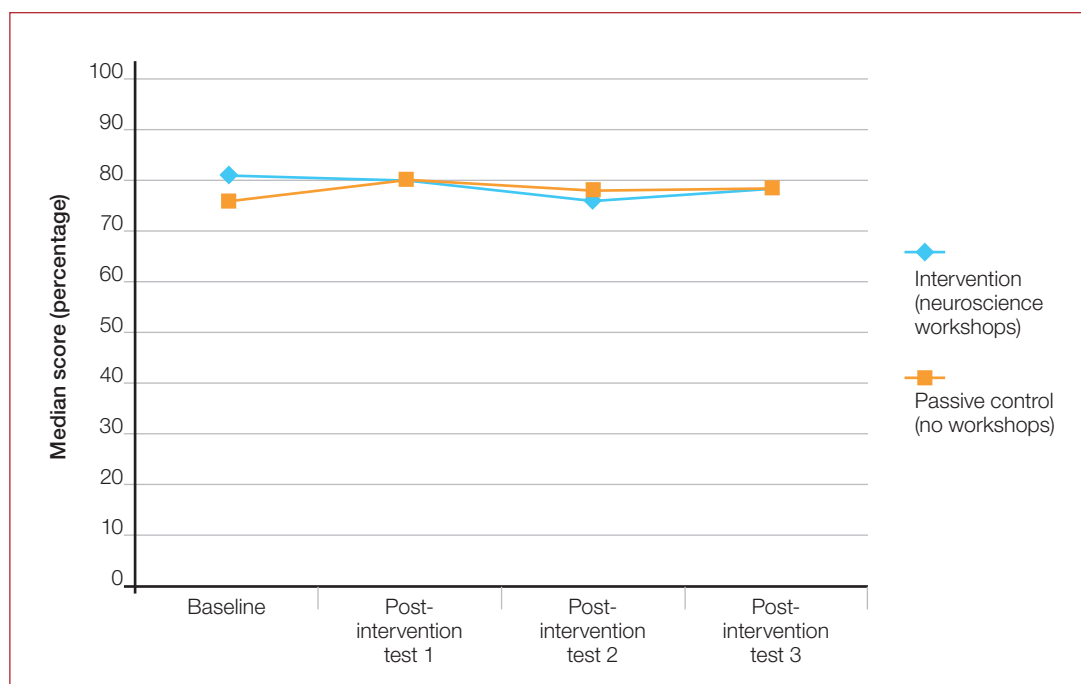
4.1.3 Belief in the importance of academic achievement

- Prior to any intervention all groups held similar beliefs about the importance of academic achievement.
- At all post-intervention time points the belief strength remained similar.
- All groups showed a slight change in belief strength across time: this took the form of an initial decrease in belief strength followed by a return to baseline. These identical patterns of change indicate no effect from either of the workshops (intervention or active control) on academic achievement beliefs. Hence neither neuroscience teaching nor study skills workshops impact on the importance pupils place on academic achievement.

4.2 The impact on academic performance

- Prior to the intervention there were small differences between groups at the baseline point in terms of their academic performance on the mathematics tests, and over the course of the experiment the intervention group did not improve in comparison with either of the control groups.
- Figure 2 (below) shows the comparison between the intervention group and the passive control group. The slight 'dip' in performance is attributable to the learning 'dip' often experienced by pupils transitioning into secondary school.

Figure 2: Pupils' performance in mathematics tests (comparison between intervention group and passive control group)





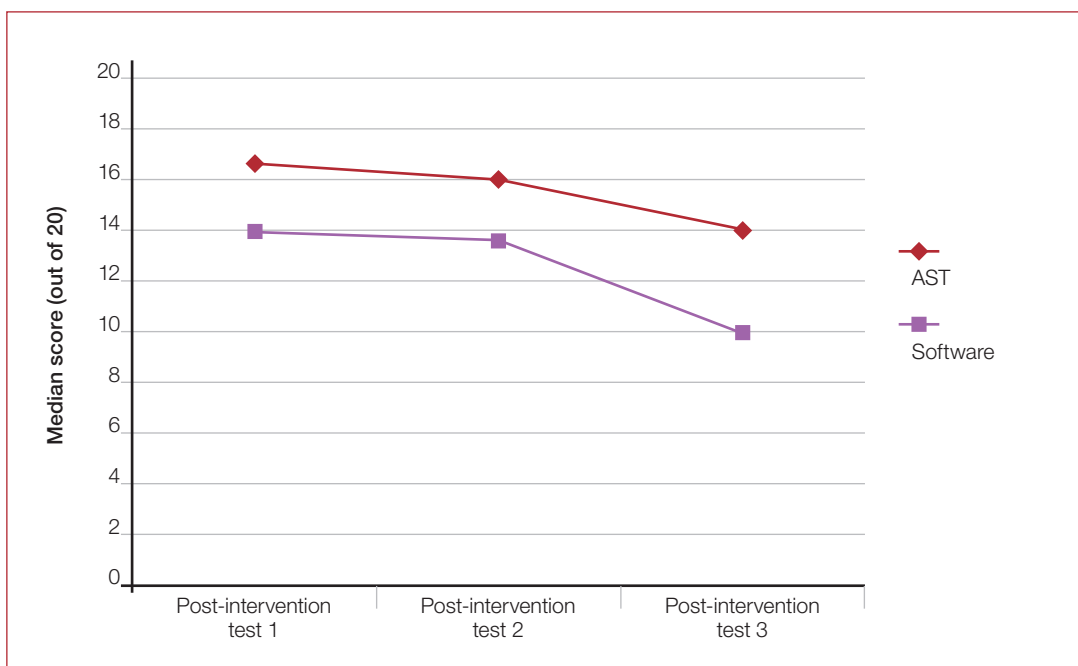
4.3 The impact of the mode of workshop delivery

For the purposes of this section all groups receiving an AST-delivered workshop have been combined and all groups receiving a workshop delivered by computer have been combined (regardless of whether this was on the topic of neuroscience or study skills).

4.3.1 Comprehension quizzes

- Pupils taught by ASTs scored higher at all assessment points than did those taught by the computer software. Figure 3 (below) shows the results of these comprehension scores and the difference between those taught by AST over computer software (although this was not statistically significant).
- Both AST-taught and computer-taught scores decreased as the time since the workshops increased.

Figure 3: Pupils' performance in workshop comprehension tests (comparison between those taught by AST and those taught by computer software)



4.3.2 Motivational measures

- The mode of delivery made no difference in pupils' beliefs in incremental intelligence or in the importance of academic achievement. There were, however, stronger beliefs in the effectiveness of making an effort in the AST-led group by the final post-intervention test.

4.3.3 Pupil questionnaires

- Pupils who undertook the neuroscience workshops delivered by ASTs rated this higher in terms of both 'interest' and 'enjoyment' than those who had undertaken the software-led workshops or either of the study-skills workshops.
- Pupils (those who had experienced workshops delivered by ASTs and computer) preferred the most interactive elements of the workshops. The exact elements referred to by the term 'interactive' differed by mode of delivery – in AST-led workshops the quizzes were the least interactive and were the least-liked aspect, whilst in the computer-led workshops these quizzes were the most interactive element and were most preferred.
- Pupils and teachers reported enjoyment of, and new learning in, all workshops. Pupils reported particular enjoyment of the neuroscience sessions. Additionally, ASTs reflected favourably on the whole experience, also recognising the challenges of working as part of a study with many factors involved:

'We would never have had the chance to learn anything like what we did through any other means. It was fascinating and allowed us to make links between what we already knew was good practice and the scientific reason behind how and why children learn. What an amazing opportunity to be part of a real scientific study!' (Advanced Skills Teacher)



5 Conclusions and recommendations

This section revisits the aims of the research and summarises the key findings in relation to each.

5.1 The impact of learning about the brain on pupils' motivation

The first aim of the study was to assess whether teaching pupils about the brain had an effect on three motivational measures:

- **Pupils' beliefs about the plasticity of their own intelligence**

The findings suggest that learning about the brain through neuroscience workshops can result in longer-lasting changes to pupils' beliefs about the flexible and incremental nature of intelligence.

- **Pupils' beliefs about the effectiveness of making an effort**

Both types of workshop (neuroscience and study skills) had equal, and positive, effects on pupils' beliefs about the effectiveness of their own effort. This effect was not statistically significant so the impact is only suggestive that teaching pupils about neuroscience or study skills will positively affect their belief about the importance of making an effort.

The changes that were evident, although not statistically significant, also suggest that positive impact on pupil beliefs about the importance of making an effort are not dependent on the content of the workshops, and importantly, not dependent on increased knowledge of neuroscience. Both groups (neuroscience and study skills) showed equal change.

- **Pupils' beliefs about the importance of academic achievement**

All groups showed a slight change in belief strength across time: this took the form of an initial decrease in belief strength followed by a return to baseline. These identical patterns of change indicate no effect of either workshop (intervention or active control) on academic achievement beliefs. Hence neither neuroscience teaching nor study skills workshops appear to impact on the importance pupils place on academic achievement.

5.2 The impact of teaching pupils about the brain on academic performance

The second aim of the study was to assess whether teaching pupils about their brain had an effect on actual academic performance.

There was no impact on academic performance (as tested by performance on NFER mathematics assessment papers). This study was perhaps limited by its focus on only one subject and its limitation to a relatively short time period. Given the effects of neuroscience workshops on intelligence beliefs, other research would indicate that it is plausible that these changes in pupils' beliefs will, in the longer term, predict an improvement in academic performance. Such an effect was demonstrated in earlier work reported by Blackwell et al., (2007) that showed pupils who had a flexible view of intelligence outperformed their peers.



5.3 Differences in effectiveness of the mode of delivery of training

The third aim of the study was to assess whether the mode of delivery (e.g. identical content delivered by a computer program or by a teacher) effected changes in pupils' motivation or academic performance.

The study revealed that delivery by an AST was more effective than delivery by a computer software program even where the content was identical.

5.4 Recommendations

Based upon the findings described above, the research team made the following recommendations:

- Neuroscience workshops should be used by schools to address and improve intelligence beliefs amongst pupils specifically identified as having fixed views of intelligence.
- Additional research should be carried out into neuroscience teaching, particularly in order to establish its effect on academic performance across a range of subjects and over a longer period of time.
- Further research should be undertaken into how neuroscience workshops can be used to try and combat the Year 7 learning 'dip' or other transitions undergone between key stages in schooling.

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CfBT Education Trust
60 Queens Road
Reading
Berkshire
RG1 4BS

+44 (0)118 902 1000
www.cfbt.com