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Does paired mentoring work? A study of the effectiveness and affective value of academically asymmetrical peer mentoring in supporting disadvantaged students in school science

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ABSTRACT

Background: In England, there is a growing need to improve the lives of secondary school students who are defined as disadvantaged and to support these students in their attainment and attitudes to secondary school science.

Purpose: This paper reports on a project designed to support students from disadvantaged backgrounds by pairing them with undergraduate mentors from a university throughout the final year of their compulsory science education in England (Year 11 – aged 15–16) at the end of which students take their public General Certificate of Secondary Education (GCSE) examinations.

Sample: The study, set up as a randomised control trial, involved 86 disadvantaged students – students from low-income families who are eligible for free school meals, or had been looked after for more than six months, or whose parent(s) are currently in the Armed Forces. Four schools were recruited. The schools were similar in terms of the proportion of free school meals, GCSE 5A*-C measures and value-added performance to reduce the likelihood of any effect being attributable to factors other than mentoring.

Design and methods: Students were recruited from four schools and were randomly assigned to experimental and control groups – half in each group. Experimental group students were mentored for one hour per week for 23 weeks up until their GCSE examinations with an intensive six-hour mentoring session just prior to those examinations. Data were collected from the Year 11's mock and actual GCSE examination results as well as questionnaires from Year 11 and undergraduate mentors.

Results: It was found that mentored students did statistically better in terms of attainment in both mock and actual GCSEs examinations and also showed a statistically significantly greater improvement in their attitudes to science than un-mentored students.

Conclusions: These findings indicate the value of academically asymmetrical paired mentoring for disadvantaged students within science.

KEYWORDS
Paired mentoring; attitudes; summative assessment; secondary school

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Introduction

In England there is a growing focus on improving the lives of disadvantaged students whose schools receive additional funding in order to '… to raise the attainment of disadvantaged pupils of all abilities and to close the gaps between them and their peers' (DfE 2016a). In England, a student is classified as disadvantaged if they are:

> Pupils in year groups reception to year 6 recorded as Ever 6 FSM [eligible for free school meals (FSM) in any of the previous 6 years]: Pupils in years 7 to 11 recorded as Ever 6 FSM: Looked-after children (LAC) defined in the Children Act 1989 as one who is in the care of, or provided with accommodation by, an English local authority: Children who have ceased to be looked after by a local authority in England and Wales because of adoption, a special guardianship order, a child arrangements order or a residence order (DfE 2016b)

Currently in England, there is no paired mentoring programme that has been designed, implemented or evaluated, that *specifically* pairs undergraduates studying science subjects with Year 11 students (aged 15–16) studying for their science GCSEs. The initial idea stems from the much emulated Perach project that was established in 1974 in Israel which involved disadvantaged children being mentored by university students (Eisenber, Fresko and Carmeli, 1980b). Today, approximately 12% of all students in Israel's institutes of higher education and tens of thousands of disadvantaged students take part in the project each year (Perach 2016).

The notion of mentoring is characterised as a relationship between an individual with more experience (mentor) – what Vygotsky (1978) refers to as 'more capable peers' (86) with one having less experience (mentee) in which the former provides support and guidance to the latter (Levinson et al. 1978). In this article. we use the term 'academically asymmetrical peer mentoring' to emphasise the asymmetry in the academic capabilities of the mentors (more academically capable) and the mentees (less academically capable. The effectiveness of mentoring in terms of promoting mentee's development in different realms has been widely evidenced in the literature (eg DuBois and Silverthorn 2005; Eby et al. 2008). A mentoring intervention has been generally suggested as an effective way that does not only have the potential to increase academic-related desirable behaviours, like that of academic performance, but has also been associated with positive attitudinal, motivational, emotional and other forms of health-related outcomes (Eby et al. 2008). In terms of positive attitudinal outcomes, for example, it has been shown that mentees develop positive attitudes towards the activity they engage in with their mentors and that there is a psychological attachment developed to the context (for example, school and classroom) in which the mentoring relationship is embedded (Payne and Huffman 2005). Mentors may also act as counsellors offering advice to their mentees during times of stress, like that before and during exam periods, and, in terms of motivation, can help them stay focused on tasks, such as homework and/or exam revision, and set achievable goals, and realise personally relevant outcomes (Eby et al. 2008). Although all of these attitudinal, motivational and socio-emotional positive outcomes are important on their own, they have been also associated with academic competence (Valiente, Swanson, and Eisenberg 2012) reinforcing, this way, the effectiveness of mentoring interventions in terms of improving mentees' academic achievement.

In contrast to peer-tutoring, the sole aim of which is to improve academic achievement by resolving specific problems and encouraging the tutees to become independent learners, peer-mentoring has a broader focus in that it additionally aims to provide students with successful role models and improve their self-esteem (Reisner, Petry, and Armitage 1989). In the light of these differences and, in particular the aim to improve students' attitudes and aspirations towards science, the intervention piloted in this study is considered to be one of mentoring rather than tutoring

Reviews and surveys on paired undergraduates with students on mentoring projects or programmes in schools which have been carried out until late 1990s (see, for example, Cohen, Kulik, and Kulik 1982; Reisner, Petry, and Armitage 1989; Topping 1992, 1996) have provided evidence for the effectiveness of these programmes. For example, the meta study conducted by Reisner, Petry, and Armitage (1989) on domestic (US) tutoring and mentoring programmes in which disadvantaged primary and secondary students were paired up with college and university students indicated that these programmes were effective in terms of students' improvement in academic performance, attitudes towards education as well as self-esteem and self-confidence. There was also evidence that involvement in mentoring projects resulted in an increase in mentees' familiarity with environments other than their own disadvantaged ones (Reisner, Petry, and Armitage 1989).

For example, one of the programmes reviewed in the study by Reisner, Petry, and Armitage (1989) was the City University of New York (CUNY) student mentor programme (Tyler, Gruber, and McMullan 1987) which was designed and implemented in the US serving a population of economically disadvantaged high school students who were at risk of high absenteeism and were struggling to graduate. Although the one-semester limitation that the programme was implemented makes the judgement on the effects on students' academic performance problematic, the evaluation showed that the programme was successful in terms of getting mentees exposed to college, helping them explore future academic and work options. As Gregory and Berley-Mellits (1988), who also reviewed this programme, concluded 'the programme brings people who want to help [mentors] together with those who need it [mentees]. Therein lies its power'. (42–43)

One of the paired-mentoring programmes that has become a source of inspiration for many other programmes, is the Perach Project in Israel. The project was established in 1974 by a handful of students from the Weizmann Institute of Science, who acted as mentors for students of different ages from all sectors of society – Christian, Druze, Jewish and Muslim – with the goals of not only increasing their self-esteem, self-confidence and improving their motivation to learn but also their experiences and general knowledge. Mentoring activities that have the aim of improving the mentees' academic achievement are part of the programme but only, as would be expected of a mentoring rather than tutoring programme, as a one type of activity among many others through which a relationship is built between the mentor and mentee.

Since its initiation the Perach Project has been evaluated numerous times. Whilst initial findings found no significant impact (Eisenberg, Fresko, and Carmeli 1980a, 1980b, 1981) subsequent evaluations (Eisenberg, Fresko, and Carmeli 1982, 1983a, 1983b; Fresko and Eisenberg 1985) have reported that mentees possessed improved aspirations, were less likely to drop out of school, and showed improvement in terms of social skills, academic achievements and motivation to learn.

Another mentoring programme which has been promoted with the aim of raising both academic achievement and attitude towards study post-compulsion is the MATES (Mentoring And Tutoring Education Scheme) programme introduced in New Zealand (Starpath 2006). The programme, based on the Perach Project, is currently in its 15th year and serves secondary school students from disadvantaged communities who are matched with mentors from various universities (called 'mates'). The role of the 'mates' being to assist mentees address barriers to educational success by encouraging their academic achievement and supporting their transition into continued study promoting, at the same time, individual responsibility for learning.

Evaluations of the programme (Starpath 2006, 2007) reported improvements in objective measurable academic achievement outcomes. A more recent evaluation showed that 78% of the Year 13 mentees studying in low band decile schools in 2012 were awarder their NCEA level 3 certificate (Dunphy 2013) in comparison to the national average which was of about 64% for students of the same type of schools (NZOA 2013). Dunphy (2013) also reported that students who took part in the programme were not only less likely to drop out from school but that about 40% of the mentees, who provided tracking information after completing the programme, progressed to tertiary education with 10% of them being scholarship recipients. The effectiveness of the programme led to the development and implementation of the MATES junior programme which serves primary education students in need since 2008 with similar, positive, results being reported (Great Potentials Foundation 2014).

A programme which shares many similarities with the two previous ones is the Baloo and You mentoring programme implemented in Germany. The terms, which reveal the intended mentoring relationship between the mentor and the mentee, are based on the characters of the well-known 'Jungle Book' (Kipling 1902) involving a young child named Mowgli who was abandoned in the jungle, and his big bear friend Baloo, who is thoughtful, witty, clever, wise and protective. The Baloos taking part in the programme are mainly high school, college or university students, whereas the Mowglis are unprivileged primary school children ranging from 6 to 10 years of age. The main aims of the programme being to help mentees develop skills, increase self-esteem, improve aspirations, increase their motivation to learn – so as to enable them to become successful in school and, more generally, in life. Therefore, as with the Perach project, the enhancement of academic achievement was only one of a number of aims (Müller-Kohlenberg and Drexler 2013).

An evaluation of the Baloo and You programme indicated several positive results in different areas (Müller-Kohlenberg and Drexler 2013). These include the development of mentee' ability to concentrate, and to cope with stress in addition to which their teachers reported that the relationship with the mentors enhanced their self-organisation and self-assessment skills as well as improved their motivation to study and participation in school activities. It was also reported that the mentoring relationship increased mentees' awareness of personal hygiene health-related issues.

In the United Kingdom, student mentoring and/or tutoring programmes have been implemented in which students from universities and colleges mentor school students under the supervision, or guidance, of the classroom teacher. This model of mentoring reflects a growth in these particular types of programme in England due to a recent rise in funding from a number of external organisations (Goodlad 1998). Amongst these programmes is the Oxford–Jacari project which has been in existence, in one form or another, since the mid-1950s (ESOL n.d.). The Oxford University students are matched up with students aged 4–16 who are not native speakers of English with the aim of providing them with out of school, one-on-one support for subjects in which the student is struggling as a result of inadequate English. Results from the project evaluation indicated both a positive effect of on students' attitudes towards learning and an improved performance at school – as reported by the teachers and mentees' parents – as well as an increase in confidence outside the classroom (ESOL n.d.).

A similar programme, established at the University of York during the mid-1970s (Reisner, Petry, and Armitage 1989),offered mentoring to immigrant students and slow learners of the English language by coaching them using a range of different activities (for example, language exercises, discussion of passages from books) either on one-on-one basis or in groups. Whilst the aim of the programme was the improvement of these students' language skills its effectiveness was never evaluated (Reisner, Petry, and Armitage 1989).

The PIMLICO Connection is an example of a peer-mentoring project that was developed at Imperial College London in which university students are paired up with a group of either 2–3 primary (aged 11) or state secondary school students (aged 12–17) who might either be struggling academically or gifted and talented. Since its establishment in 1975 the primary goals of the PIMLICO Connection project has been to increase students' knowledge and interest in Science, Technology, Engineering and Maths (STEM) subjects. This aim has now been expanded to incorporate raising students' aspirations to progress to higher education and to help to prepare the secondary students for GCSE examinations (Annalisa 2006). Analysis of forms completed by the undergraduate volunteers, and teachers, over the years indicated an increase in students' interest during STEM lessons, particularly when an undergraduate was present in the class (Goodlad et al. 1979; Goodlad 1985; Annalisa 2006). In addition, mentees reported believing that their academic performance had improved – an opinion supported by their teachers who similarly believed that those students were learning more although no empirical data were reported to substantiate any of these claims.

The STIMULUS project is a community programme in which the Cambridge University students are paired up with primary (aged 5–11), secondary (aged 12–15) and sixth form college students (aged 16–19 studying for advanced school-level qualifications). The primary aim of the project is to help the tutees with maths, science, computer, science and technology lessons. University students work mostly alongside teachers in the classrooms offering support in the classroom, assisting mentees with practical work and enhancing the understanding of their tasks. An evaluation by Beardon (1990) reported that for some of the tutees associated lessons became more interesting (30% of the tutees), easier to follow (38%) and more enjoyable (29%) when an undergraduate was present. More recent evaluations (STIMULUS 2013/2014) have focused more on the benefits for undergraduates with the results indicating an increase in their own confidence in their subject knowledge and improvement of their communication skills. In addition, more than half of the undergraduates involved in that project claimed that taking part made them more likely to consider teaching as a future career.

Within England there have been numerous government initiatives to widen participation and increase the number of students continuing onto science-related courses at further education (FE) and higher education (HE) level. Similarly, Thornton et al. (2014) note that there is a need for schools and colleges to raise aspirations amongst disadvantaged students to continue on to HE. There is a growing need to directly increase students' attainment in both GCSE and A-level science examinations given that the latest report on GCSE results has shown the proportion of students achieving A*–C has dropped by 2.4 percentage points in comparison to similar examination in 2014 (DfE 2015). Statistics have shown that students who are classed as disadvantaged are far less likely to obtain high marks in their GCSE examination (DfE 2013). This focus has an important implication for secondary schools in

England in which the performance of such students in GCSE examinations, is one of the measures used to compile school league tables. In addition, there is a shortage of specialist science teachers, particularly in physics and chemistry, within schools and thus there is a need to increase the number of trained science graduates to train to teach science.

Although there are various mentoring and/or tutoring programmes in the UK that focus on science education there is currently no paired mentoring programme that has been designed, implemented or evaluated, which *specifically* pairs undergraduates studying science subjects, with Year 11 disadvantaged students aged 15–16 studying for their science GCSE examinations.

Research questions and methodology

This study aimed to investigate whether academically asymmetrical paired mentoring of Year 11 students from disadvantaged backgrounds with undergraduate students studying science subjects could improve those students' academic attainment and attitude towards science. The main aims of this project were therefore to address the following research questions:

1. To what extent does the paired mentoring support the goal of narrowing the gap by raising the attainment of disadvantaged students in science?
2. To what extent does the paired mentoring improve students' attitudes towards science?

In order to address these research aims, four secondary schools were approached. These four school were all of similar socio-demographic character in terms of being matched on their proportion of free school meals, GCSE 5A*–C measures, value-added performance in order to reduce the likelihood of any effect, if found, being attributable to any factors other than the mentoring project. Initially, the project set out to recruit 30 Year 11 disadvantaged students from each of the four schools with half of these being allocated to the experimental mentoring group, whilst the other half were to be allocated to a control group. After permission slips and acceptance letters were obtained from students and their parents the final sample consisted of 86 disadvantaged Year 11 students across the four schools who were then were then randomly assigned to the control and experimental groups (see Table 1).

Whilst students in the experimental group were mentored for a total duration of 23 weeks for one hour per week with an intensive six-hour mentoring session just prior to their GCSE examination. Students in both the experimental and control were also exposed to the same

Table 1. Number of students in each school and in each group.

	Number of Year 11 students	
	Control group	Experimental group
School A	15 (14)	15 (14)
School B	13	13
School C	6	6
School D	9 (8)	9 (8)
Total number of students recruited	43 (41)	43 (41)

Note: Figures in the table show the initial number of students recruited, whereas those in the parenthesis give the actual number of students participating in the study with the difference being due to attrition.

outreach university programmes as well as any in-house school events outside of their normal science GCSE course.

Undergraduate mentors all undertook training, provided by staff from the schools, about professionalism as, unlike the Perach Project in which mentors and mentees refer to each other on a first name basis and meet outside of the school framework, in this project mentees referred to their mentors as Miss or Mr and mentors were under strict instructions not to communicate with their Year 11 student in any way outside of the mentoring hour within the school. In addition, each undergraduate was required to undertake Disclosure Barring Checks (DBS) – police checks for past criminal and/or civil convictions. Each undergraduate mentor was randomly allocated to a single Year 11 student with their first meeting taking place during the first timetabled mentoring session in the school under the supervision of the school teachers who would be overseeing the project. Each of the schools had allocated a regular space for the mentor meeting with sufficient space for the pairs to sit and work together at a table on their own. However, it is important to note here that whilst undergraduates were informed of the general arrangements of a mentoring session – ie for the sessions to focus solely on science – the actual science content for each meeting was not pre-determined. Indeed, the mentor was able to help their mentee with any particular aspect of the science GCSE curriculum that the mentee felt they needed help with. Teachers of the mentees were also able to pass suggestions of work to be covered in a particular mentoring hour to the supervising school teacher who, in turn, would pass this on to the mentor at the start of the mentoring session. Mentors were asked to share these suggestions with the mentee but only to work on them if the mentee wanted to do so – if the mentee had other science work they preferred to work on then it was the mentee's choice of work that was prioritised. The breakdown of the subject the undergraduates studied are shown in Table 2.

As a result of the withdrawal of two students from the experimental group (Table 1) and three mentors (Table 2) in the first term, one undergraduate mentored two Year 11 students, one in School C and one in School A.

In the light of claims by DuBois et al. (2011), that students on mentoring programmes of less than three months showed declines in certain areas, such as self-esteem, compared to those mentored for a longer period it was decided that this intervention should exceed three months. In discussions with the schools, it was decided that the mentoring in this study

Table 2. Mentors numbers by subject and Year group.

Undergraduate subject	Year 2	Year 3	Total for subject
Adult nursing	0	1 (0)	1 (0)
Animal behaviour and welfare	2	1	3
Biochemistry	0	4	4
Biology	5	3	8
Biomedical science	2 (1)	4	6
Bio-veterinary science	2	2	4
Chemistry	1	1	2
Forensic science	1	1	2
Pharmacy	3	0	3
Psychology	3	4 (3)	7
Psychology with forensic	1	0	1
Zoology	0	2	2
Total for undergraduate year	20 (19)	23 (21)	43 (40)

Note: Figures in the table show the initial number of mentors recruited, whereas those in the parenthesis give the actual number of mentors participating in the study with the difference being due to attrition.

would take place for one hour per week during a 23-week period over the course of one academic year in addition to which there was also an intensive six-hour mentoring session held at the university just prior to the GCSE examinations. These visits also provided an opportunity for the Year 11 students to gain an insight into the university environment with a tour of the engineering and science buildings during which they were provided with a talk about the opportunities available for students in HEs. For the control and the experimental groups, the data that we collected involved a mix of standardised tests and questionnaire. In terms of test data, we collected Year 11 students' Key Stage 2 (KS2) Standard Attainment Tests (SATS) which are taken in the final year of primary school at aged 11 and these results are used to predict students' GCSE results – known as target grades. We also collected GCSE mock exam results in January and GCSE final exam results in August. In terms of students' attitudes, these were analysed through a questionnaire the development of which is discussed below.

Attitudes measurement instrument

Attitudes towards science has been a major topic in science education over the last four decades with authors critically reviewing the research approaches used as well as the definition of attitudes adopted (eg Francis and Greer 1999; Barmby, Kind, and Jones 2008). There appear to be as many definitions as there are different concepts related to attitudes that someone might include, or may not, in the definition of the term attitude.

We view the term attitudes in a similar way with that of Fishbein and Ajzen (1975), who suggested that attitudes are inevitably and spontaneously created when an individual forms beliefs about an object and its attributes. This way, students' attitudes towards science could be defined as their cognitive and emotional opinions about various aspects of science (Kind, Jones, and Barmby 2007). These aspects could be split into more detailed areas like that of science inside school or science in society.

For the purposes of this study, we focused upon four of those areas that correspond to the aim of our peer-mentoring project. These are: (a) school science (learning science in school), (b) science outside of school, (c) self-concept in science (the focus was on students' beliefs of self with respect to achievement and ability to master school science) and (d) attitudes in future participation in science. The first three areas were related to the project aim of instilling a sense of confidence in doing science as well as encouraging a positive image of science through the mentors who were expected to act as role models for their mentees. The focus on the fourth area was adopted to address another aim of the project, that of encouraging mentees to study science post-compulsion and raising their aspiration to continue education and study science at a university level.

We developed our attitudes questionnaire using more than one question for each one of these four areas in order to increase the reliability of the questionnaire (Gardner 1996). These questions were in the form of statements in which students had to choose their level of agreement. A choice from the following five responses was given to them: 'Strongly disagree', 'Disagree', 'Neither agree nor disagree', 'Agree' and 'Strongly agree'. A limited set of statements meaningful to the Year 11 students was regarded as being crucial and as such, in deciding which statements to be included in the questionnaire, we adopted and modified some from existing questionnaires that have been proven to work with students of a similar age. These include items from the study conducted by Fraser (1978) and Kind, Jones, and

Barmby (2007), whereas there was also some adopted from the ROSE project (Sjøberg and Schreiner 2010) and the PISA programme (OECD 2015). The statements used are presented in the left-hand column of Table 4 and are separated and grouped together according to the four attitude areas. The ordering is: Learning science in school (five statements), self-concept in science (four statements), science outside school (four statements) and attitudes in pursuing further a scientific education and scientific career (3 statements).The same order was followed in the original questionnaire students were presented with.

Unidimensionality and reliability of the instrument

In order to assess the unidimensionality – ie whether questionnaire items put together to measure students' attitudes in one of the four areas actually measure that same attitude – and internal reliability – ie whether the several questionnaire items used to measure the same area of attitudes produce similar results – of the designed questionnaire we adopted a similar approach with that suggested by Kind, Jones, and Barmby (2007). Reliability calculations and factor analysis was carried out on the responses collected from both groups before and upon completion of the project.

Pre-intervention attitude data

As can be seen in Figure 1, the factor analysis indicated the extraction of four factors (four distinct areas of attitude) and that the questionnaire items we put together as measuring attitudes in one area were loaded on one single factor (Table 3). This confirms that each set of attitude statements was actually measuring attitudes in one of the four areas only.

The internal reliability of each set was also found to be greater than the threshold level of Cronbach α = 0.7 (Field 2013), confirming this way the internal reliability of the attitudes measurement instrument.

Table 3. Factor analysis results for the pre-intervention attitudes data.

	Factor			
	1	2	3	4
I like coming to science classes	0.891			
I think science classes are exciting	0.805			
Science is interesting	0.556			
Science is my favourite school subject	0.476			
We should have more science lessons at school each week	0.374			
In my science lessons, I struggle to complete my science assignments		0.788		
I often struggle to complete my science assignments		0.693		
I don't get high marks in science homework		0.623		
Science is one of my difficult subjects		0.575		
I would choose to study science at a university			0.964	
I would like to become a scientist			0.777	
I would like to study at least one science at A-level			0.603	
I find it interesting watching science programs on TV at home				−0.795
I am interested in learning more about science outside school				−0.692
I would enjoy visiting science museums				−0.488
I like to read books, magazines, newspapers or online articles on topics related to science				−0.485

Note: Items with a loading value less than 0.3 are not shown.

Table 4. Cronbach's a reliability values for the four attitude areas: pre- and post-intervention attitudes data.

	Cronbach's α	
Measure	Pre-intervention attitudes data	Post-intervention attitudes data
Learning science in school (5 questionnaire items)	0.850	0.871
Self-concept in science (4 questionnaire items)	0.787	0.853
Science outside school (4 questionnaire items)	0.811	0.836
Attitudes in pursuing further a scientific education and scientific career (3 questionnaire items)	0.860	0.924

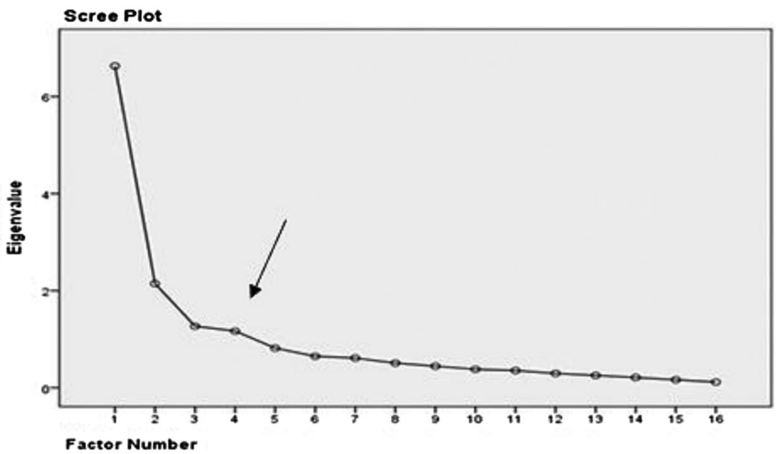

Figure 1. Scree plot from the factor analysis of the pre-intervention attitudes data.
Note: The black arrow in the figure plot indicates the point of inflexion of the curve that, according to Field (2013), is indicative of the factors to be extracted and in this case, suggests the extraction of four factors.

Post-intervention attitude data

To confirm the results obtained from the pre-intervention attitude data, we conducted the same analysis with the data collected from both groups at the end of the project. The analysis provided further confirmation that there were four distinct attitude areas (Figure 2) and that each set of attitude statements was actually measuring one attitude area only (Table 5). As it was the case with the pre-intervention data, the internal reliability of each set was also found to be greater than the threshold level of Cronbach $\alpha = 0.7$, confirming once again the internal reliability of the instrument.

Data analysis

We used the data from the standardised tests and the attitudes questionnaire to compare the results between the control and experimental group to determine whether these 23 weeks of mentoring had any positive impact on improving Year 11 disadvantaged students' achievement in science and students' attitudes to science. In terms of analysis, we

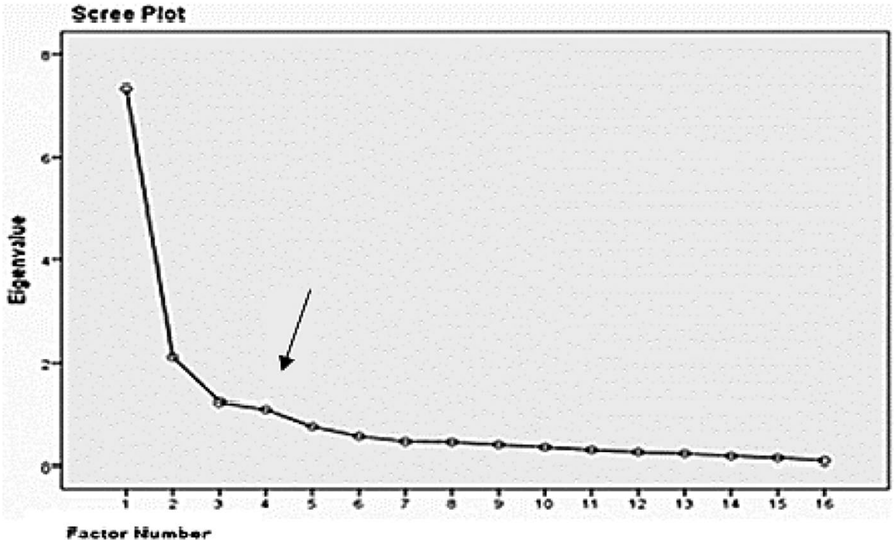

Figure 2. Scree plot from the factor analysis of the post-intervention attitudes data.
Note: The black arrow in the figure plot indicates the point of inflexion of the curve that, according to Field (2013), is indicative of the factors to be extracted and in this case, suggests the extraction of four factors.

Table 5. Factor analysis results for the post-intervention attitudes data.

	Factor			
	1	2	3	4
I like coming to science classes	0.978			
I think science classes are exciting	0.671			
Science is interesting	0.667			
We should have more science lessons at schools each week	0.574			
Science is my favourite school subject	0.475			
I don't get high marks in science homework		0.800		
I often struggle to complete my science assignments		0.788		
In my science lessons, I struggle to understand		0.729		
Science is one of my difficult subjects		0.710		
I find it interesting watching science programs on TV at home			0.821	
I like to read books, magazines, newspapers or online articles on topics related to science			0.710	
I would enjoy visiting science museums			0.602	
I am interested in learning more about science outside school				0.891
I would choose to study science at university				0.858
I would like to study at least one science at A-level				0.789
I would like to become a scientist				0.710

Note: Items with a loading value less than 0.3 are not shown.

used applied bivariate analysis, using *t*-tests to look at the effects of the mentoring by making comparisons between the achievements of the control and experimental groups of students and by separately comparing the grades that students in each group achieved in KS2 SATS to those they achieved in their mock GCSE exams in January and their final GCSE in August. The results in this study are from all four schools that took part and names are withheld for anonymity purposes. We report *p*-values in the spirit of exploring data, but we do not view a significant (or otherwise) *p*-value as proving any causal mechanism underlying the data. In a similar vein, we do not see *p*-values as statements providing explanations of the data but rather as statements about the data in relation to hypothetical explanations (Wasserstein and Lazar 2016).

Results

Academic attainment: mock GCSE examination results

The difference between the means of both the predicted target grades and mock GCSE results for each of the two groups was analysed separately (see Figures 3 and 4). As can be seen both groups achieved statistically significantly better in their mock GCSE examinations than was predicted. A paired *t*-test was used to compare the two means of these target and mock exam grades in order to ascertain whether the differences between these two results, *within* each group, were statistically significant. The analysis found that, on average, students in the experimental group achieved statistically significantly better in their mock exams ($M = 5.08$, SE = 0.197) than predicted ($M = 2.58$, SE = 0.133, $t\,(39) = -13.43$, $p < 0.05$) with the difference, according to Cohen's (1988, 1992) guidance, representing a large effect ($r = 0.9$). Similarly with the control group, students achieved statistically significantly better in their mock exams ($M = 4.18$, SE = 0.282) than their target grades ($M = 2.68$, SE = 0.104, $t\,(39) = -5.701$, $p < 0.001$) and the difference, according to Cohen's (1988, 1992) guidance, represented a large effect ($r = 0.7$).

To test whether the students who were mentored achieved better than their peers who were not the means of the mock GCSE examination grades for both groups were compared using the *t*-test for independent samples. Analysis of the data showed that students who had been in the mentoring group achieved, on average, better in their mock examination results ($M = 5.08$, SE = 0.197) than those who were not mentored ($M = 4.18$, SE = 0.282). The difference between the two groups was statistically significant $t\,(70) = -2.67$, $p = 0.011$ and the difference, according to Cohen's (1988, 1992) guidance, represented a medium-sized effect $r = 0.3$.

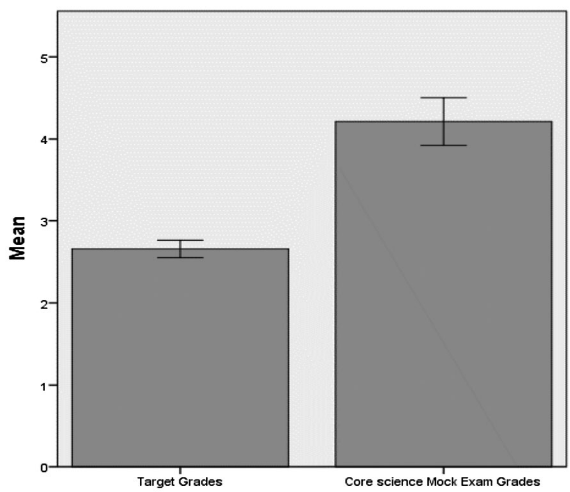

Figure 3. Means of target/predicted and mock exam grades in science for the control group.

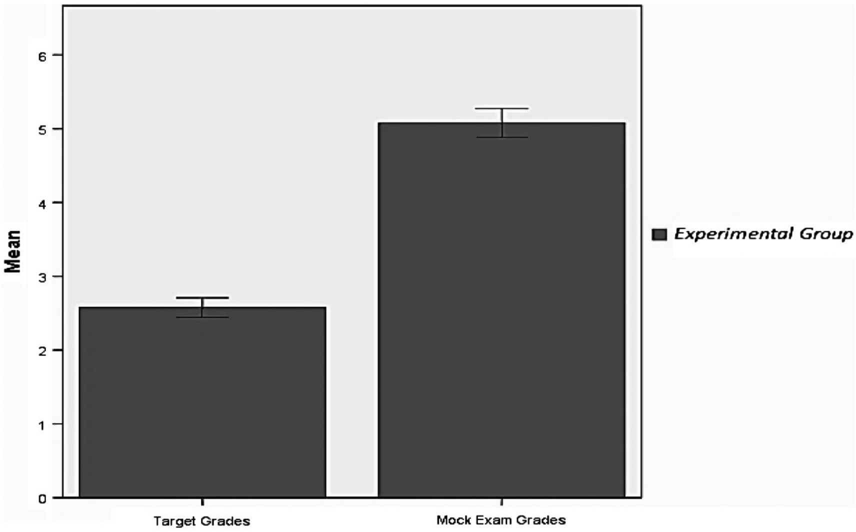

Figure 4. Means of target/predicted and mock exam grades in science for the experimental group.

An independent *t*-test was also used to test whether the differences in the means of the predicted grades between the two groups shown in Figure 4 were significant. The analysis showed that students who were mentored had, on average, been predicted to achieve slightly lower grades for their mock GCSE examinations ($M = 2.58$, SE = 0.133) than those who were not mentored ($M = 2.68$, SE = 0.104). This difference was not statistically significant $t\ (78) = 0.592$, $p = 0.556$. This result shows that the statistically significant differences in the mock exams grades between the two groups was not as a result of any difference in their pre-intervention ability in science as measured by their teachers' predicted target GCSE grades.

Thus, although there was an improvement in both groups' attainment in terms of their mock GCSE examination results when compared to their predicted target grades, that of the students in the mentored group was statistically significantly higher that of the students in the control group suggesting that mentoring had a positive impact on students' achievement in their mock GCSE science examinations (Figure 5).

Academic attainment: GCSE examination results

Whilst the mock GCSE examination were marked by teachers within each the school the actual GCSE examinations are externally marked. Following the same procedure as was used with the mock GCSE examinations the difference between the means of both the predicted target grades and actual GCSE examination results for each of the two groups were considered separately (see Figures 6 and 7). Again both groups achieved better in their GCSE science examinations than had been predicted. A paired *t*-test was used to compare the two means of the predicted target and GCSE examination grades from each one of the groups in order to ascertain whether the differences were statistically significant. On average, students in the experimental group achieved statistically significantly better in their GCSE examinations ($M = 5.98$, SE = 0.145) than had been predicted ($M = 2.58$, SE = 0.133, $t\ (39) = -21.340$,

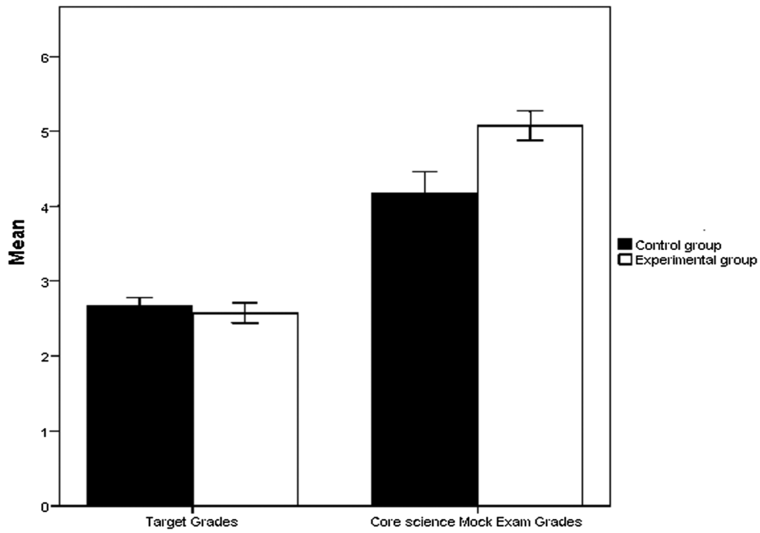

Figure 5. Means of target/predicted and mock exam grades in science for both groups.

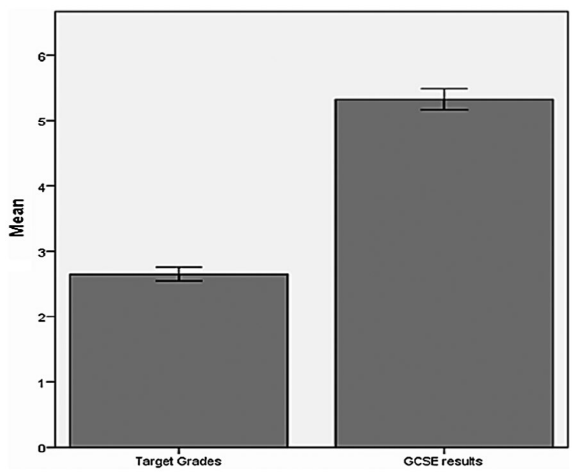

Figure 6. Means of target/predicted and GCSE exam grades in science for the control group.

$p < 0.001$) with the difference, according to Cohen's (1988, 1992) guidance, representing a large effect ($r = 0.9$). Similarly with the control group, students achieved statistically significantly better in their GCSE exams ($M = 5.33$, SE = 0.158) than their target grades ($M = 2.68$, SE = 0.105, t (39) = −15.128, $p < 0.05$) and the difference, according to Cohen's (1988, 1992) guidance, represented a large effect ($r = 0.9$).

These results are similar with those for the mock GCSE examinations. Using *t*-tests the means of the GCSE examination grades between the two groups were compared in order to test whether the students mentored achieved better than their peers. Using the test for independent samples, it was found (see Figure 8) that students who were mentored achieved better in their GCSE examinations ($M = 5.95$, SE = 0.143) than those who were not ($M = 5.30$,

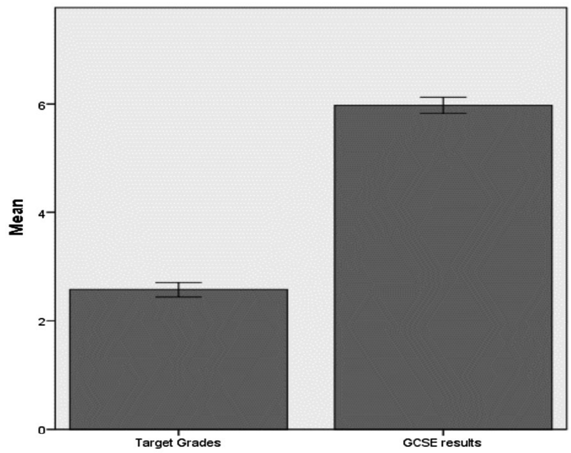

Figure 7. Means of target/predicted and GCSE exam grades in science for the experimental group.

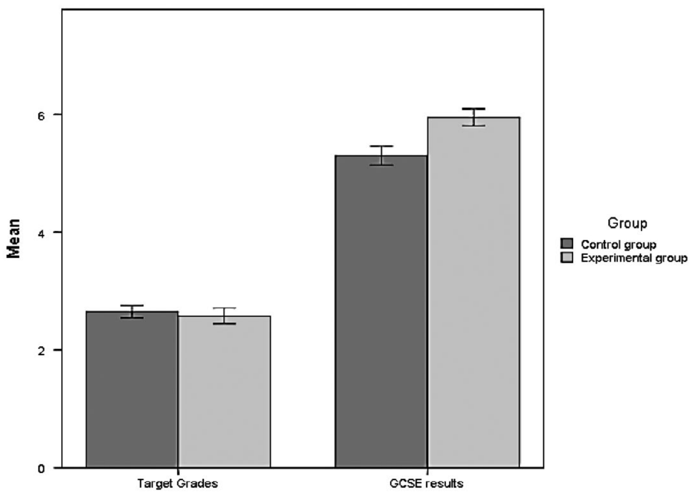

Figure 8. Means of target/predicted and GCSE exam grades in science for both groups.

SE = 0.161). The difference was significant $t(78) = -2.67$, $p < 0.001$ and the difference, according to Cohen's (1988, 1992) guidance, represented a medium-sized effect $r = 0.3$.

Thus, although there was an improvement in both groups, the mentored students showed a significant improvement in terms of achievement over their control group. Also, on the basis of the comparison of the target grades between the two groups described above (first phase data analysis), these findings suggest that mentoring had a positive impact on students' achievement and that any differences in their achievement had little to do with the students' ability in science.

Findings on Year 11 students' attitudes to science

Students' attitudes towards science was measured in terms of learning science, self-concept in science, science outside school and pursuing further a science education. All 41 students from both the experimental and control group responded to all items in the attitudes questionnaire. Figures 9 and 10 present the mean scores in the four attitudinal constructs for the experimental and control group, pre- and post-interventions, respectively.

Results of the analysis of the data relating to the four attitudinal constructs are shown in Tables 6 and 7 from which it can be seen that none of the differences are statistically significant.

As it can be seen from Figure 8, after the end of the mentoring intervention differences emerged between the two groups in the post-scores of the attitudinal questionnaire. An analysis of these results is presented in Table 8.

It should be noted that whilst students who were mentored scored lower than their peers in the control group on the 'self-concept in science' construct. This should not be interpreted as meaning that students who were mentored had, on average, a lower level of self-concept in science than students who were not mentored as this attitudinal construct was composed of only *negative* items[1] (for example, 'I don't get high marks in science'; 'Science is one of my difficult subjects'; 'In my science lessons, I struggle to understand'; 'I often struggle to complete my science assignments') and, as such, the difference in the means between the two groups shows that students who were mentored had a lower *negative* self-concept in science, ie their self-concept was more *positive*.

A dependent *t*-test was used to compare the two means of attitudes coming from the experimental group before and after students had been mentored. This approach was adopted to examine whether, except from any differences in students' achievement, there was any impact of the mentoring in terms of their attitudes towards science. Figure 11 presents the results of this comparison and Table 8 presents the results of the statistical analysis of the data.

Although there was not any difference identified in terms of self-concept in science for the students who were mentored ($M = 2.99$ prior being mentored and $M = 2.98$ post), it is interesting to note that at the same time there was a decrease in the level of self-concept in science for the control group. The mean was 3.09 pre- and 3.41 post-intervention and given that all the questionnaire items in this construct were *negative* this should be interpreted as a drop of these students' self-concept in science by 0.32 points.

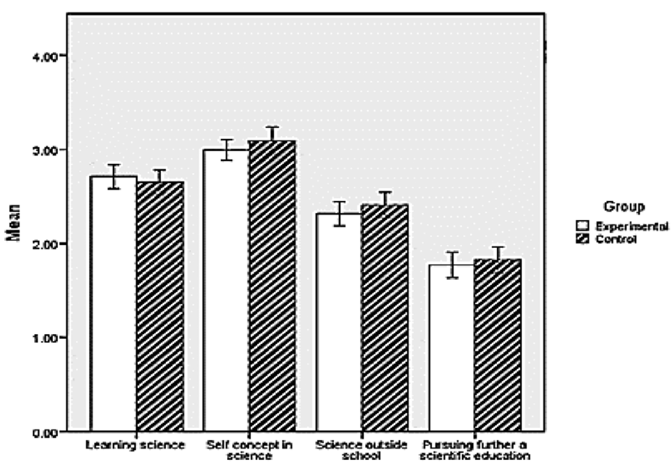

Figure 9. Pre-intervention students' attitudes towards science.

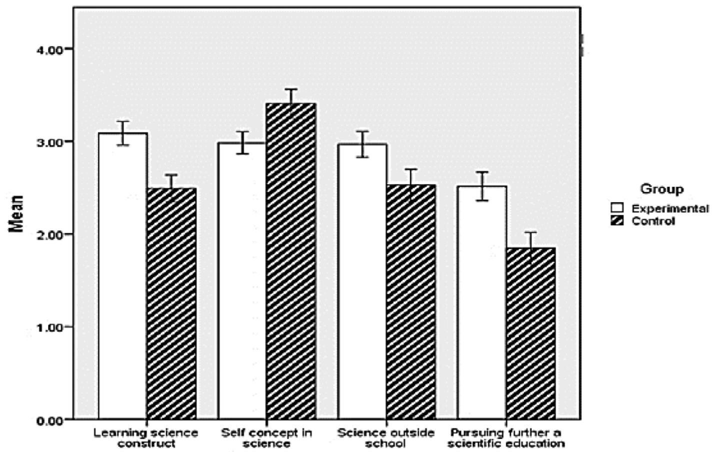

Figure 10. Post-intervention students' attitudes towards science.

Table 6. Means, standard deviation, *t* and *p*-value for both groups pre-intervention.

Attitude construct	Group	Means	Standard Deviation	*t*-test	*p*-value
Learning science	Experimental	2.71	0.79	0.32	0.75
	Control	2.65	0.78		
Self-concept in science	Experimental	2.99	0.67	−0.54	0.59
	Control	3.09	0.89		
Science outside school	Experimental	2.31	0.79	0.49	0.59
	Control	2.40	0.84		
Pursuing further a scientific education	Experimental	1.77	0.83	−0.273	0.79
	Control	1.82	0.85		

Note: A *p* value of less than 0.05 was considered statistically significant.

Table 7. Means, standard deviation, *t* and *p*-value for both groups post-intervention.

Attitude construct	Group	Means	Standard deviation	*t*-test	*p*-value
Learning science	Experimental	3.09	0.78	3.10	0.003
	Control	2.49	0.87		
Self-concept in science	Experimental	2.98	0.73	2.14	0.036
	Control	3.41	0.95		
Science outside school	Experimental	2.97	0.84	2.12	0.038
	Control	2.50	1.04		
Pursuing further a scientific education	Experimental	2.51	0.93	2.91	0.005
	Control	1.85	1.03		

Note: A *p* value of less than 0.05 was considered statistically significant.

Table 8. Means, standard deviation, *t* and *p*-value for the experimental group pre- and post-intervention.

Attitude construct	Pre-and post-intervention	Means	Standard deviation	*t*-test	*p*-value
Learning science	Pre	2.71	0.79	−2.25	0.031
	Post	3.09	0.78		
Self-concept in science	Pre	2.99	0.69	0.07	0.946
	Post	2.98	0.73		
Science outside school	Pre	2.31	0.80	−3.46	0.001
	Post	2.97	0.84		
Pursuing further a scientific education	Pre	1.77	0.84	−3.64	0.001
	Post	2.51	0.93		

Note: A *p* value of less than 0.05 was considered statistically significant.

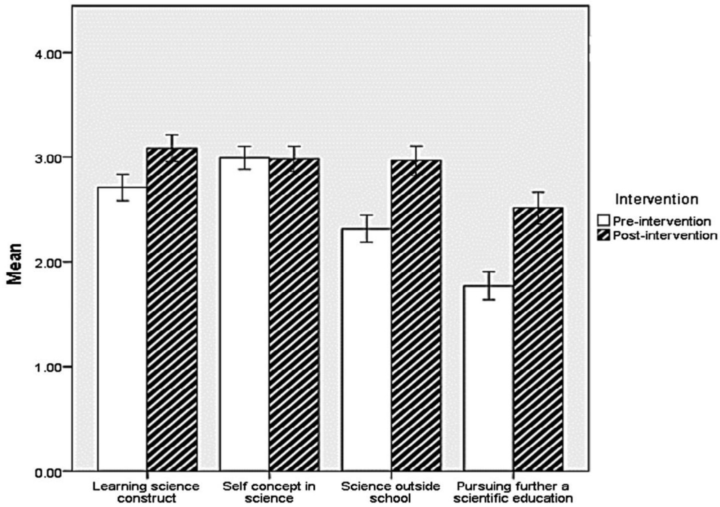

Figure 11. Post-intervention mentored students' attitudes towards science.

The evidence suggests that as in three out of the four attitudinal constructs those students who were mentored improved more than those who were not mentored and that this difference was statistically significant the mentoring programme had a statistically significant positive impact on students' attitudes towards science. The evidence also suggests that whilst there was no positive improvement in mentored students' attitude to self-concept in science mentoring did, compared to those students in the control group, help those students to retain their level of self-concept in science.

Conclusions and implications

The aim of this study was to evaluate whether this intervention could improve the GCSE examination attainment and attitude to science of Year 11 disadvantaged students by pairing them with undergraduates who would mentor them through the final year of their GCSE science. What has emerged from this RCT study is that the impact of the intervention was, in its entirety, statistically significant both in terms of increased academic attainments and in terms of attitude towards science. What is less clear, and requires further research, is the extent to which the same and/or similar results could be obtained either using a reduced number of weekly mentor sessions – subject to the lower limit of three months below which DuBois et al. (2011) has reported that mentoring becomes ineffective – in conjunction with the final revision session, or just the revision session alone. Furthermore, additional research needs to be undertaken to determine whether similar results can be replicated across a much broader and diverse group of schools and students.

Another result that emerged from this study, that is of particular interest in terms of recruiting undergraduates to train to be science teachers, was that 6 of the 21 undergraduates who were in their third year of study at university have since gone on to train to become secondary science teachers. In post-intervention communications with the researchers all six attributed their decision to undertake teacher training directly to their positive mentoring experience as, prior to that experience, none had contemplated a career as a science teacher.

In addition, three of the 19 undergraduates, who were in their second year, are now, having commenced their third year of study, considering training to become secondary science teachers and, likewise, attributed this interest in a science teaching career to their mentoring experience. This unexpected positive outcome could demonstrate a new way to encourage science undergraduates to consider undertaking teacher training in science subjects where uptake is currently lower than required (UK Government 2015).

For teachers and university lecturers, there is a potential exciting challenge of how a similar project could be maintained, potentially through a volunteering approach, to encourage links between school and universities in order to work with a wider body of students rather than only those who are disadvantaged given the current to recruit more scientists (UK Government 2015).

Note

1. These were not mixed with positive items and given their phrasing, it was decided to keep them as negative items, as meaningful analyses at the sub-scale level could be conducted without the need to be reverse scored.

Disclosure statement

No potential conflict of interest was reported by the authors.

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