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Confidence as motivational expressions of interest, utility, and other influences: Exploring under-confidence and over-confidence in science students at secondary school

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ABSTRACT

An enhanced understanding of how students' self-confidence is influenced benefits educational practice and motivational theories. For 1523 students in 12 secondary schools in England, science self-confidence was predicted by various factors: current self-confidence (self-concept) was most strongly predicted by received praise, current grades, and interest in science; self-confidence for future attainment (self-efficacy) was most strongly predicted by current grades and perceived utility of science. For both measures of self-confidence, reported subject-comparisons (science being harder than other subjects) predictively associated with under-confidence, while reported utility predictively associated with over-confidence. Under-confident students reported consistently lower than other students, highlighting that under-confidence may ultimately be motivationally detrimental.

1. Introduction

Self-confidence is integral to psychological theories of motivation (Bandura, 1997; Eccles, 2009) and has practical relevance to education: students' self-confidence has associated with their interest in particular subjects (Viljaranta, Tolvanen, Aunola, & Nurmi, 2014), for example, and with their choices of what subjects to study (Regan and DeWitt, 2015). Students' self-confidence and motivations are then highly relevant to teaching and policy within science education in England and many other countries, especially as higher numbers of science students are sought (The Royal Society, 2014).

Students' self-confidence does not necessarily correspond to their actual attainment, however: reviews have consistently found only modest associations between various indicators of each (Hansford and Hattie, 1982; Zell & Krizan, 2014) and further research has revealed and explored 'confidence biases' towards under-confidence or over-confidence. Under-confidence has generally been inferred or shown to be motivationally detrimental (Bandura, 1997; Bouffard & Narciss, 2011), which has important educational implications; under-confident students may not select subjects that they might otherwise succeed in and enjoy, for example, which may limit numbers of students who study non-compulsory subjects (Sheldrake, Mujtaba, & Reiss, 2014). However, it remains unclear as to what influences may associate with or potentially lead to either under-confidence or over-confidence. An enhanced understanding of the area could lead to practical benefits: someone's degree of over-confidence or under-confidence could potentially be amended via teachers or wider interventions, assuming that the area is sufficiently understood.

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1.1. Conceptualising self-confidence: historical perspectives and prior research

Self-confidence, used here as a simple and intuitive term for inclusivity and brevity, may refer to someone's various beliefs of their abilities and capabilities, which have been formally defined and measured in different ways. Within educational research, self-confidence has often been conceptualised and measured as 'self-concept' and 'self-efficacy' beliefs (Bong and Clark, 1999; Bong & Skaalvik, 2003), usually specific to particular academic subjects. Self-concept broadly considers someone's beliefs about their abilities, integrating historical experiences (such as receiving particular grades or accomplishing difficult work) and current evaluative or interpretative beliefs (such as whether the student is 'doing well' or is 'good' at the subject). Alternately, self-efficacy considers someone's evaluative beliefs about their future capacities, such as their confidence in being able to gain a particular examination grade or to successfully accomplish a particular type of exercise.

Such terms may inadvertently allow misinterpretations: self-concept has no clear relation to someone's identity as conceptualised within science education (e.g. Archer et al., 2010), for example, and research may sometimes use self-concept, self-efficacy, or other terms interchangeably due to varying or unclear definitions (e.g. Marsh et al., 2015b). Using such terminology is nevertheless unavoidable when contextualising against prior research. Expressed more intuitively, self-concept reflects someone's current self-confidence regarding their attainment, while self-efficacy reflects someone's self-confidence for their future attainment. Fig. 1 provides a simple conceptual overview. Historically, however, self-concept and self-efficacy have been considered within relatively-independent research traditions.

Self-concept evolved from general psychological measures (such as self-esteem), rather than within a motivational theory, and was originally conceptualised as a person's perceptions of their self, formed through experiences and interactions with and within the environment (Shavelson, Hubner, & Stanton, 1976). Self-concept was considered to have various characteristics, such as being structured, hierarchical, and being both descriptive and evaluative; however, someone's perceptions of their self are many and varied, and it perhaps remained unclear regarding what, exactly, should be measured. Subsequently, the operationalization of self-concept became increasingly focused on someone's beliefs of their academic ability; for example, interest and enjoyment were originally assumed to be integral but were later considered to be a separate factor (Arens, Seeshing Yeung, Craven, & Hasselhorn, 2011; Marsh, Craven, & Debus, 1999). Nevertheless, higher self-concept has been associated with higher subsequent interest (Viljaranta et al., 2014) and with higher subsequent attainment, sometimes over and above the influence of prior attainment itself (Huang, 2011; Marsh & Martin, 2011), suggesting a potential motivational role for self-concept beliefs.

Students' self-concept has been theorised to be influenced by numerous factors, including mastery experiences (such as gaining particular grades or results), self-comparisons over time, self-comparisons across subjects, comparisons with other students, causal attributions (factors attributed to success or failure, such as being due to the student or being due to outside forces), social persuasions, psychological centrality (how important an area is to the student), and potentially various other factors (Bong and Skaalvik, 2003). Extensive research has focused on particular areas, specifically peer-comparisons (e.g.

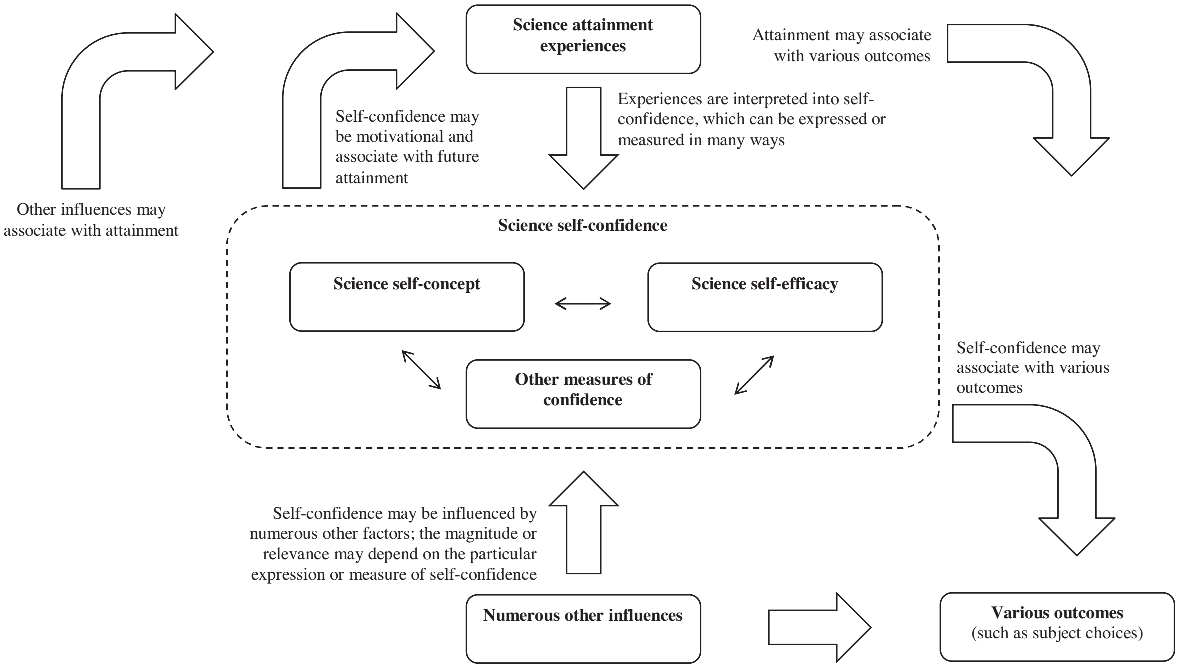

Fig. 1. A conceptual model of science self-confidence.

Marsh and Parker, 1984; Marsh et al., 2015a) and subject-comparisons (e.g. Marsh, 1986; Marsh et al., 2015b). Much research has focused on specific structural models, for example where the influence of peer-comparisons has been inferred by modelling only student-level attainment and class-level or school-level average attainment (e.g. Nagengast and Marsh, 2011). Accordingly, influences on self-concept have generally been considered in isolation so that the relative effects of peer-comparisons, subject-comparisons, and other factors, cannot easily be compared.

Self-efficacy forms an integral aspect of social-cognitive theory (Bandura, 1977, 1997), which assumes that high self-efficacy may be beneficial in allowing individuals to surpass their normal performance and to overcome initial barriers through persistence or other motivational approaches, but low self-efficacy may mean that some actions are not even attempted. In accordance with these theoretical assumptions, higher self-efficacy has indeed been associated with higher motivations to learn and master academic work (mastery goals or goal orientations; Jiang, Song, Lee, & Bong, 2014; Phillips and Gully, 1997), persistence (Multon, Brown, & Lent, 1991), and self-regulation for learning (Usher and Pajares, 2008a). Students' self-efficacy has also predicted important educational outcomes such as their intentions to study courses (Bong, 2001), for example, and to enter university (Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2014).

Students' self-efficacy has been theorised to be influenced by four sources or antecedents (Bandura, 1977, 1997): mastery experiences (successfully completing tasks or not, or gaining particular grades or results); vicarious experiences (seeing others succeed); social persuasions (such as praise or reassurance from teachers or other people); and physiological states (such as physical and emotional responses such as anxiety). From these, mastery experiences have generally been the most influential, while the influences of the others have been lower and have varied across studies (Britner and Pajares, 2006; Usher & Pajares, 2008b). Potential influences such as peer-comparisons and subject-comparisons have seldom been explored as influences on self-efficacy; conversely, the influences of praise and vicarious experiences have seldom been explored as influences on self-concept, suggesting that contemporary understanding of students' self-confidence is only partial.

Nevertheless, theoretical perspectives have also emerged that integrate both self-concept and self-efficacy. Following from social-cognitive theory, the expectancy-value model of motivated behavioural choices (Eccles, 2009; Wigfield & Eccles, 2000) proposes that students interpret their own background and their context, including their own personal experiences, which forms and influences their beliefs about their own abilities (akin to self-concept) and their own identity; these beliefs then inform the students' expectations of success (akin to self-efficacy) and subjective task values ('subjective-values' for brevity); these beliefs in turn then inform students' actions and choices. Such factors are assumed to reciprocally influence one another; for example, students' expectations of success may influence their subjective-values, and students' subjective-values may influence their expectations of success.

The subjective-values are associated with various areas or activities and are conceptualised as (Eccles, 2009): 'interest value' (interest and enjoyment in activities or areas in themselves); 'utility value' (valuing activities or areas as a means towards gaining a further goal); 'attainment value' (how activities or areas are personally valued in relation to someone's own identity); and 'perceived cost' (which may cover various aspects including expected time and effort). For intuitive clarity, attainment value will be referred to as 'personal value'.

The various subjective-values, whether considered alone or within the expectancy-value model, have been increasingly applied within international science and mathematics research and have indeed been found to closely relate to students' subject choices and attainment (Bøe and Henriksen, 2015; Bøe, Henriksen, Lyons, & Schreiner, 2011; Wang and Degol, 2013). Given their relevance within education, it is then important to determine whether and how the subjective-values predictively associate with self-confidence, and also whether under-confidence and over-confidence associate with lower or higher subjective-values and other beliefs.

1.2. Motivational benefits and detriments of confidence biases: prior research

The motivational benefits of high self-confidence (whether self-concept or self-efficacy) appear to be clear, as assumed within social-cognitive theory and the expectancy-value model. However, it remains unclear whether any motivational benefits occur regardless of whether someone is accurate in their beliefs (they have correspondingly high attainment) or is over-confident (they have lower attainment than would be expected given their high beliefs); someone may also be under-confident, and hold lower beliefs than would be expected given their attainment, and it is unclear whether this is always detrimental or limiting. Less research has explicitly explored confidence biases and results have varied across studies and contexts.

Studies of secondary school students have often associated higher accuracy (not being over-confident or under-confident) with higher performance (Chen, 2003; Chen & Zimmerman, 2007; Möller and Pohlmann, 2010; Pajares & Graham, 1999), but have also conversely associated over-confidence with lower performance and under-confidence with higher performance (Chiu & Klassen, 2010). Studies with undergraduate students (the majority undertaken in the United States of America) have usually revealed higher accuracy but slight under-confidence in higher-performing students and over-confidence in lower-performing students (Ackerman & Wolman, 2007; Bol, Hacker, O'Shea, & Allen, 2005; Hacker, Bol, Horgan, & Rakow, 2000; Kruger & Dunning, 1999). Less research appears to have explored differences in interest or other potentially motivational factors. Nevertheless, for Grade 9/10 students (age 15/16) in Greece, for example, over-confidence across both mathematics and languages associated with higher persistence and mastery goals than accuracy and under-confidence, while over-confidence in mathematics considered alone associated with higher interest in mathematics (Gonida & Leondari, 2011). In

England, over-confidence associated with higher interest and utility value for mathematics at Year 8 (age 13), while accuracy associated with higher positive affective responses and intentions to study mathematics further at Year 10 (age 15; Sheldrake et al., 2014). Despite differences in results concerning the benefits of either over-confidence or accuracy, it seems apparent that under-confidence may be detrimental or limiting in various ways (Bouffard & Narciss, 2011).

Nevertheless, the value of further research into the area is clear: prior research has focused on exploring benefits and detriments via differences in reported experiences and beliefs, and has not focused on what might predict under-confidence or over-confidence.

1.3. Research aims

Ultimately, students' self-confidence is central to many educational areas, including subject choices, which have strong relevance to educational policies (The Royal Society, 2014); an increased understanding of students' self-confidence also gives insight into or helps refine assumptions within motivational theories, which benefits international researchers and educators. While much prior research has been undertaken, there are fundamental areas that remain unclear.

Firstly, it remains unclear whether under-confidence and over-confidence necessarily associate with motivational detriments or benefits for science, considered through lower or higher reported experiences and beliefs; prior research has considered various different academic subjects and student ages.

Secondly, it remains unclear as to what best predicts students' self-confidence; little research has considered consistent sets of predictive influences across both self-concept and self-efficacy, and/or included the influence of factors such as students' interest and utility value despite these having theoretical links to self-confidence via the expectancy-value model.

Thirdly, it remains unclear whether any such predictive influences on self-confidence may associate with under-confidence or over-confidence; if confidence biases are detrimental or beneficial, then they need to be understood so that they could be amended via interventions or other actions. Intuitively, some influences on self-confidence may potentially lead to confidence biases: for example, undertaking relative comparisons against peers may lead someone to believe that they are doing better or worse than their attainment might indicate when considered nationally, and so introduce a bias towards over-confidence or under-confidence; however, any such associations remain unconfirmed through empirical research.

The research presented here aimed to address these areas by considering the views of secondary school students in England concerning the subject of science. In England, during Year 9 (age 14) students select various subjects to study during Years 10 and 11 (ages 14–16) at General Certificate of Secondary Education (GCSE) or equivalent level. Students can subsequently undertake upper-secondary education in Years 12 and 13 (ages 16–18), at Advanced Level General Certificate of Education (A-Level) or equivalent level, prior to university entry. Science is currently a compulsory subject until the end of Year 11, and is presented within the National Curriculum as a discrete subject, covering the domains of biology, chemistry, and physics (Department for Education, 2013); students may study science inclusively, especially at younger ages, or in separate classes for biology, chemistry, and physics.

Accordingly, the views of students in Years 9–11 were sought; their self-confidence or expected attainment may influence their studies and choices at GSCE and/or A-Level. Science was considered holistically in accordance with the National Curriculum and for comparability and contextualisation against international research; the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), for example, consider science as a whole rather than separate areas such as physics.

2. Methods

Data collection occurred during the 2014/2015 academic year. Secondary schools within England were randomly sampled; schools were invited regardless of type, admissions policies, and other school features, except that schools supporting only those with special educational needs were excluded. The presented research covered 12 participating schools, of which seven were mixed-admissions comprehensive schools (admitting boys and girls, and not selecting students based on their achievement); mixed-admissions comprehensive schools form the majority (68%) of all secondary schools within England as of 2014 (Department of Education, 2015). Selective schools (admitting students based on their achievement) and boys-only and girls-only schools were also represented in the sample. The 12 schools covered a range of geographical locations and prior performance, although considered together (on average, from publicly-available achievement tables) 60% of their students were reported to have achieved five or more A*-C grades (including in both English and mathematics) or equivalents for GCSE level, compared to a national average of 47% as of 2014 (Department of Education, 2015). The presented research explored the views of 1523 students (685 in Year 9, 489 in Year 10, and 349 in Year 11; 635 girls and 871 boys) from these schools.

2.1. Measuring students' experiences and beliefs

Students completed science-specific questionnaires. The questionnaire items were designed to be comparable with a broad range of international research, including TIMSS (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009). Most areas were measured through agreement scales with categories of (1) 'strongly disagree', (2) 'disagree', (3) 'slightly disagree', (4) 'slightly agree', (5) 'agree', and (6) 'strongly agree'. All responses/items were subsequently coded (reversing category scores as necessary) so that high item/factor scores (e.g. 6) indicated a positive belief or experience (e.g. doing well, being interested, the absence of anxiety). When applicable, theorised factors were calculated through averages of the relevant items; single-factor structures (via confirmatory factor analysis via maximum likelihood estimation) and acceptable indicators of reliability (Cronbach's α coefficients) were confirmed (Table 1).

2.1.1. Self-confidence (self-concept, self-efficacy)

Students' subject-level self-confidence was measured through expressions of:

- self-concept (agreement/disagreement with e.g. 'I usually do well in science', 'I have always been good at science');
- and self-efficacy ('What grade do you think you will be able to get at GCSE (or equivalent) science?' and 'What grade do you think you would be able to get if you studied your best science subject at A-Level?', with categories of (1) 'E' and 'Lower', (2) 'D', (3) 'C', (4) 'B', (5) 'A', and (6) 'A*').

This expression of self-efficacy has contextual relevance to students in England who may need to gain specific grades in order to study on particular courses or to enter university.

2.1.2. Theorised influences on self-confidence

Students' reported experiences or beliefs were measured for various theorised sources, antecedents, or influences on their self-confidence:

- current grades (scaled to 1–6 as above for consistency), which can be formally conceptualised as 'mastery experiences';
- perceptions of attainment standards ('What grade do you think people need to get in order to be "good" at science?', scaled as before), which can be conceptualised as 'mastery norms';
- subject-comparisons (agreement/disagreement with 'Science is harder for me than any other subject', reverse-scored);
- peer-comparisons ('Science is harder for me than for many of my classmates', reverse-scored);
- positive vicarious experiences ('When I see how another student solves a science problem, I can see myself solving the problem in the same way');
- positive social persuasions (e.g. 'My science teacher tells me I am good at science'), which can intuitively be called 'praise';
- and anxiety (e.g. 'Science makes me confused and nervous', reverse-scored).

These covered the four theorised antecedents to self-efficacy (Bandura, 1997) and covered the subject-comparisons and peer-comparisons (phrased as per TIMSS for comparability) that are assumed to be relevant to self-concept. Self-reported grades are generally considered sufficiently reliable indicators of actual grades although may still be (unavoidably) misreported to some extent (Kuncel, Credé, & Thomas, 2005); it was operationally unfeasible to collect grades in other ways (which would require non-anonymous questionnaires and schools to provide attainment lists, for example).

2.1.3. Wider potential influences on self-confidence

To measure wider potential influences on self-confidence, the subjective-values within the expectancy-value model were measured as:

- interest value (e.g. 'I am interested in the things I learn in science');
- utility value (e.g. 'I need to do well in science to get the job I want');

Table 1
Factor reliabilities.

Item/factor	Items	Cronbach's α
Self-concept	5	.896
Self-efficacy	2	.827
Mastery experiences (current grade)	1	NA
Mastery norms (what is a good grade)	1	NA
Subject-comparison	1	NA
Peer-comparison	1	NA
Anxiety (absence of)	5	.905
Praise (social persuasions)	3	.797
Vicarious experiences	1	NA
Interest value	7	.936
Utility value	7	.908
Personal value	2	.886
Cost value (absence of)	2	.686
Teacher perceptions	8	.904
Task-score	10	.645
Task-confidence	10	.897

- personal value (e.g. 'Thinking scientifically is an important part of who I am'), which is formally called 'attainment value' within the expectancy-value model;
- and cost (e.g. 'I have to give up a lot to do well in science', reverse-scored).

Interest and utility are sometimes alternately conceptualised as intrinsic and extrinsic motivation within self-determination theory (Deci & Ryan, 1985); the questionnaire items could therefore generalise across different theoretical perspectives and prior research. Additionally, as further potential influences on self-confidence:

- students' views of their teacher and immediate learning context were also gathered (e.g. 'My science teacher is easy to understand', 'My science teacher gives me interesting things to do'), referred to as 'teacher perceptions' for brevity;
- and the students' reported gender was also considered.

Following social-cognitive theory and the expectancy-value model, students do not necessarily have 'innate' differences depending on their personal characteristics such as their gender; any self-confidence differences across girls and boys might reflect that they interpret their contexts differently or receive different levels of praise, for example.

2.2. Measuring students' confidence biases

Students completed a selection of tasks as used in TIMSS, which have been internationally validated as reliable indicators of performance (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009). The tasks covered areas within the National Curriculum, including photosynthesis, atomic structures, changes of state, electricity and current, and various other areas (broadly covering biology, chemistry, and physics); the tasks variously used multiple-choice and also free-text responses, which were scored following TIMSS documentation. For each task, students rated their confidence in their answers ('How confident are you that you solved this correctly?'), providing a retrospective self-evaluation of their performance.

An indicator of 'confidence bias' (also referred to as 'calibration bias', or the degree of under-confidence through accuracy through to over-confidence) was then calculated via the difference between the students' average task-confidence and average task-score. Groups were then created via standardising the confidence bias indicator: below −.5 was classified as 'under-confident'; between −.5 and +.5 as 'accurate' (one standard deviation range); and above +.5 as 'over-confident'. This general approach has been reliably applied within various prior research (e.g. Chen & Zimmerman, 2007; Gonida & Leondari, 2011).

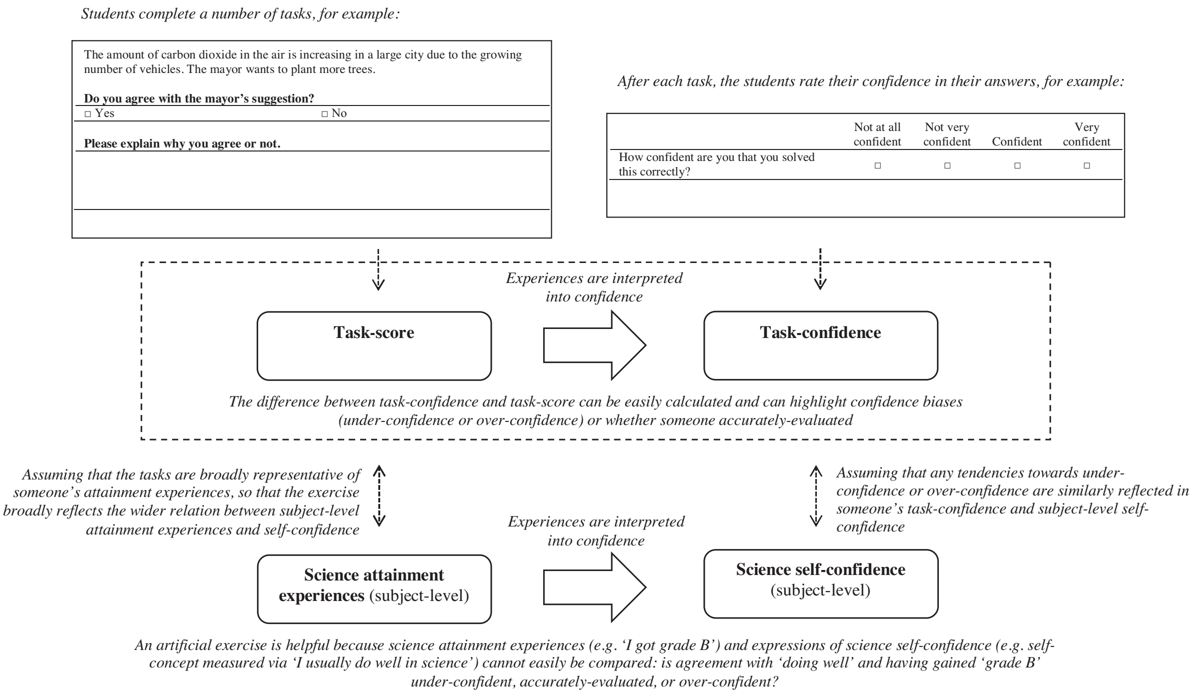

Fig. 2. A conceptual model of using science tasks to reveal and explore confidence biases.

Table 2
Students' reported experiences/beliefs (item/factor scores).

			Gender						Confidence bias							
	All		Girls		Boys		*T*-test		Under-confident (U)		Accurate (A)		Over-confident (O)		ANOVA	
Item/factor	M	SD	M	SD	M	SD	Sig.	D	M	SD	M	SD	M	SD	Sig.	$P\eta^2$
Self-concept	3.82	1.10	3.58	1.06	4.01	1.09	<**.001**	.403	[UA UO] 3.55	1.07	[UA] 3.95	1.06	[UO] 3.91	1.14	<**.001**	.026
Self-efficacy	4.43	1.18	4.05	1.08	4.73	1.15	<**.001**	.609	[UA] 4.34	1.16	[UA AO] 4.60	1.13	[AO] 4.28	1.21	<**.001**	.015
Mastery experiences (current grade)	3.57	1.64	3.08	1.48	3.97	1.66	<**.001**	.560	[UO] 3.62	1.53	[AO] 3.72	1.66	[UO AO] 3.26	1.69	<**.001**	.013
Mastery norms (what is a good grade)	4.34	1.02	4.17	.96	4.48	1.04	<**.001**	.305	4.33	1.01	4.37	.94	4.34	1.13	.775	<.001
Subject-comparison	3.99	1.55	3.58	1.54	4.28	1.50	<**.001**	.458	[UA UO] 3.74	1.52	[UA] 4.12	1.56	[UO] 4.03	1.54	<**.001**	.011
Peer-comparison	4.14	1.36	3.86	1.41	4.33	1.30	<**.001**	.351	[UA UO] 3.85	1.42	[UA] 4.28	1.31	[UO] 4.20	1.35	<**.001**	.019
Anxiety (absence of)	4.18	1.24	3.80	1.23	4.47	1.18	<**.001**	.555	[UA UO] 3.92	1.21	[UA] 4.31	1.22	[UO] 4.26	1.27	<**.001**	.019
Praise (social persuasions)	3.85	1.18	3.64	1.15	4.01	1.19	<**.001**	.310	[UA UO] 3.64	1.16	[UA] 3.96	1.15	[UO] 3.91	1.24	<**.001**	.014
Vicarious experiences	4.00	1.29	3.82	1.25	4.13	1.30	<**.001**	.244	[UA UO] 3.83	1.26	[UA] 4.05	1.26	[UO] 4.09	1.37	**.007**	.007
Interest value	4.05	1.25	3.76	1.24	4.28	1.20	<**.001**	.422	[UA UO] 3.83	1.26	[UA] 4.18	1.21	[UO] 4.08	1.27	<**.001**	.014
Utility value	4.11	1.20	3.96	1.22	4.22	1.17	<**.001**	.222	[UA UO] 3.90	1.23	[UA] 4.18	1.17	[UO] 4.21	1.17	<**.001**	.012
Personal value	3.40	1.48	3.05	1.42	3.65	1.47	<**.001**	.411	[UA UO] 3.02	1.42	[UA] 3.51	1.46	[UO] 3.59	1.49	<**.001**	.025
Cost value (absence of)	3.60	1.34	3.57	1.32	3.63	1.36	.422	.045	3.62	1.32	3.66	1.32	3.50	1.37	.221	.002
Teacher perceptions	4.33	1.03	4.23	.98	4.40	1.06	**.004**	.164	[UA] 4.21	.98	[UA] 4.37	1.00	4.38	1.12	**.027**	.006
Gender (1 = male)	.58	.49	.00	.00	1.00	.00	NA	NA	[UA UO] .47	.50	[UA] .63	.48	[UO] .62	.49	<**.001**	.021
Task-score (0–1)	.56	.29	.49	.27	.61	.29	<**.001**	.394	[(ALL)] .75	.19	[(ALL)] .58	.25	[(ALL)] .31	.24	<**.001**	.336
Task-confidence (0–1)	.53	.23	.44	.19	.60	.24	<**.001**	.758	[(ALL)] .44	.19	[(ALL)] .56	.25	[(ALL)] .60	.22	<**.001**	.078
Task confidence bias (−1 to +1)	-.02	.26	-.06	.27	.00	.25	<**.001**	.208	[(ALL)] −.31	.14	[(ALL)] -.02	.08	[(ALL)] .29	.17	<**.001**	.761
Students (number)	1523		635		871				444		653		405			

Notes: items/factors used 1–6 scales unless otherwise indicated. Means (M) and standard deviations (SD) are shown. For gender, two-tailed significance values (Sig.) and the associated effect size via Cohen's *d* (D) from *t*-tests are shown; equal variances were not assumed for consistency (regardless of the results from Levene's tests for the equality of variances). For the confidence bias groups, significance values (Sig.) and the associated effect size via partial η^2 ($P\eta^2$) are shown from ANOVA (analysis of variance) tests; significant Bonferroni post-hoc tests ($p < .05$ or below) have been highlighted in superscript (for brevity, '(ALL)' indicates where all pairs were significantly different).

Fig. 2 provides a conceptual illustration of the process and assumptions. Task-scores and task-confidences can be directly and efficiently compared in various ways to form measures of confidence bias (e.g. someone with an average task-score of .50 and an average task-confidence of .75 can intuitively be said to be over-confident). Someone could have any degree of bias at any magnitude of task-score or task-confidence depending on the combination: someone could be over-confident with a low task-score while someone else could be over-confident with a high task-score, for example; students could have accurately-evaluated their task-confidence at any magnitude of task-score (e.g. low task-score with low task-confidence, high task-score with high task-confidence, etc.).

Fundamentally, the process assumed that tendencies towards under-confidence and over-confidence were similarly reflected in someone's task-confidence and subject-level self-confidence (e.g. self-concept); this assumption was explored by considering the students' average grades and self-concept for each (task-level) confidence bias group.

2.3. Predictive models of influences on self-confidence

In order to reveal influences on (subject-level) self-confidence, students' self-concept and self-efficacy were predicted using their reported beliefs and experiences: models were applied for all students and also applied separately for each confidence bias group. As a sensitivity check, preliminary analysis used single-level linear regression (via ordinary least squares estimation) and also multi-level linear regression (via maximum likelihood estimation with variable intercepts per school, i.e. 'random intercepts') to account for students studying within different schools (Snijders and Bosker, 2012); there were no substantial differences in estimated parameters. The results from the multi-level linear regression models were reported for consistency with prior research: the explained/unexplained variance was calculated as proportional reductions compared to models with no predictors (Snijders and Bosker, 2012); effect sizes were calculated to represent Cohen's *d* when comparing the predicted outcome for students one standard deviation below and one standard deviation above the mean of the predicting variable (Tymms, 2004). Such effect sizes are essentially twice the coefficient that would be given by standardised variables (i.e. the multi-level effect sizes are twice the size of β coefficients from ordinary least squares regression).

3. Results

3.1. Students' reported experiences and beliefs across confidence bias groups

Students reported moderately positive experiences and beliefs about science (Table 2), but on average tended to only 'slightly agree' with the various items/factors (i.e. around 4 on the 1–6 scales). Girls reported significantly lower than boys (Table 2), including reporting lower self-confidence (self-concept and self-efficacy) and lower current grades, for all areas except science cost value; girls also scored lower than boys and reported lower task-confidence. Additionally, boys and girls held significantly different magnitudes of confidence bias, with girls tending towards slight under-confidence, although the difference (effect size) was small.

Table 3
Science items/factors predicting students' science self-concept beliefs.

	Step 1				Step 2				Step 3				Step 4			
Item/factor	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect
Constant/intercept	**2.56**	**.10**	**<.001**	**NA**	**2.80**	**.15**	**<.001**	**NA**	**1.59**	**.15**	**<.001**	**NA**	.13	.18	.453	NA
Mastery experiences (current grade)	**.37**	**.02**	**<.001**	**1.094**	**.37**	**.02**	**<.001**	**1.110**	**.26**	**.02**	**<.001**	**.783**	**.16**	**.02**	**<.001**	**.467**
Mastery norms (what is a good grade)					**−.06**	**.03**	**.042**	**−.110**	−.02	.03	.351	−.045	−.03	.02	.208	−.054
Subject-comparison									**.17**	**.02**	**<.001**	**.488**	**.05**	**.02**	**.028**	**.128**
Peer-comparison									**.18**	**.02**	**<.001**	**.450**	**.08**	**.02**	**.001**	**.188**
Anxiety (absence of)													**.11**	**.03**	**<.001**	**.245**
Praise (social persuasions)													**.22**	**.03**	**<.001**	**.475**
Vicarious experiences													.02	.02	.305	.047
Interest value													**.15**	**.03**	**<.001**	**.350**
Utility value													**.11**	**.03**	**<.001**	**.249**
Personal value													.01	.02	.749	.020
Cost value (absence of)													.03	.02	.162	.062
Teacher perceptions													.04	.03	.144	.077
Gender (1 = male)													.09	.05	.079	.080
Explained variance	27.4%				27.6%				43.8%				63.0%			
Unexplained variance, school level	1.7%				1.4%				.8%				1.1%			
Unexplained variance, residual	70.9%				71.0%				55.4%				35.9%			

Notes: estimated coefficients (Est.), standard errors (SE), significance (*p*-values; Sig.), and effect sizes (Effect) are shown. Items/factors used 1–6 scales unless otherwise indicated. Significant predictors ($p < .05$ or below) have been highlighted in bold for clarity. Unexplained variance at the residual level can be assumed to reflect the student level.

When grouped by task-level confidence biases (Table 2), students' confidence biases on the task-level were similarly reflected in their subject-level self-concept beliefs: accurately-evaluating and over-confident students reported similar self-concept beliefs, yet accurately-evaluating students reported significantly higher current grades; accurately-evaluating and under-confident students reported similar current grades, yet under-confident students reported significantly lower self-concept beliefs.

Across the confidence bias groups (Table 2), under-confident students generally reported the lowest experiences and beliefs, while accurately-evaluating and over-confident students generally reported similarly, including for the subjective-values of interest, utility, and personal value, although there was no significant difference across the groups for cost value or mastery norms (what grade meant 'being good' at science).

3.2. Predicting students' self-concept and self-efficacy beliefs

The correlations (Pearson *R* coefficients) between the students' reported experiences and beliefs are appended for brevity (Appendix A in the Supplementary material).

Within predictive models, the students' current grades (representing 'mastery experiences') strongly predicted the students' self-concept (Table 3, step 1) and self-efficacy (Table 4, step 1), as intuitively and conceptually assumed: students' perceived self-confidence in their current abilities and future attainment is unsurprisingly likely to be fundamentally predicted by their perceived attainment experiences. However, the sequential inclusion of various other influences (steps 2–4) greatly reduced the apparent predictive effect of the students' grades: students' self-confidence does not simply reflect their grades, and other influences are relevant; expressed conceptually or technically, the various other influences (with the exceptions of mastery norms and gender) were 'mediators' of the underlying association between someone's grades and their self-confidence (see Appendix B for technical details in the Supplementary material).

Students' mastery norms (what grade meant 'being good' at science) were negatively predictive of self-concept (Table 3, step 2) but positively predictive of self-efficacy (Table 4, step 2) when modelled alone with the students' mastery experiences (reported grades); however, mastery norms subsequently lost significance for predicting self-concept when further influences were modelled (Table 3, steps 2–4) but remained predictive of self-efficacy (Table 4, steps 2–4). This potentially highlighted their motivational nature: higher beliefs of what 'good' performance entails may motivate or lead students to believe that they can similarly achieve well in the future.

The inclusion of previously-theorised influences confirmed their predictive nature (peer-comparisons and subject-comparisons for self-concept in Table 3, step 3; social persuasions, vicarious experiences, and anxiety for self-efficacy in Table 4, step 3). However, anxiety and vicarious experiences then lost significance for predicting self-efficacy once further influences were included (Table 4, step 4), highlighting that prior research has often only gained a partial understanding of what may influence students' self-efficacy. Vicarious experiences were not predictive of self-concept (Table 3, step 4), but anxiety and praise (social persuasions) were.

Ultimately, students' science self-concept beliefs (Table 3, step 4) were most strongly predicted by received praise (social persuasions), their mastery experiences (current grades), and by their interest in science. Students' science self-efficacy beliefs (Table 4, step 4) were most strongly predicted by their mastery experiences (current grades) and their perceived

Table 4
Science items/factors predicting students' science self-efficacy beliefs.

	Step 1				Step 2				Step 3				Step 4			
Item/factor	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect
Constant/intercept	**3.29**	**.12**	**<.001**	**NA**	**2.74**	**.16**	**<.001**	**NA**	**1.62**	**.18**	**<.001**	**NA**	**1.45**	**.21**	**<.001**	**NA**
Mastery experiences (current grade)	**.35**	**.02**	**<.001**	**.980**	**.35**	**.02**	**<.001**	**.967**	**.24**	**.02**	**<.001**	**.672**	**.20**	**.02**	**<.001**	**.551**
Mastery norms (what is a good grade)					**.13**	**.03**	**<.001**	**.221**	**.13**	**.03**	**<.001**	**.219**	**.12**	**.03**	**<.001**	**.209**
Subject-comparison													**.05**	**.02**	**.035**	**.132**
Peer-comparison													**.09**	**.03**	**.001**	**.198**
Anxiety (absence of)									**.16**	**.02**	**<.001**	**.346**	.02	.03	.482	.048
Praise (social persuasions)									**.14**	**.02**	**<.001**	**.292**	**.10**	**.03**	**.001**	**.194**
Vicarious experiences									**.06**	**.02**	**.002**	**.142**	.02	.02	.349	.046
Interest value													**.10**	**.04**	**.010**	**.208**
Utility value													**.15**	**.04**	**<.001**	**.304**
Personal value													−.02	.03	.533	−.041
Cost value (absence of)													.03	.02	.218	.059
Teacher perceptions													**−.09**	**.03**	**.006**	**−.155**
Gender (1 = male)													**.16**	**.06**	**.008**	**.132**
Explained variance	35.2%				37.6%				46.0%				50.1%			
Unexplained variance, school level	5.9%				4.6%				3.9%				3.2%			
Unexplained variance, residual	58.9%				57.8%				50.1%				46.7%			

Notes: estimated coefficients (Est.), standard errors (SE), significance (*p*-values; Sig.), and effect sizes (Effect) are shown. Items/factors used 1–6 scales unless otherwise indicated. Significant predictors ($p < .05$ or below) have been highlighted in bold for clarity. Unexplained variance at the residual level can be assumed to reflect the student level.

utility value of science. The assumption of subjective-values predicting self-concept and self-efficacy (Eccles, 2009) was therefore empirically confirmed.

3.3. Predicting students' self-concept and self-efficacy beliefs across confidence bias groups

Task-level confidence biases were confirmed to be reflected in the students' subject-level self-concept beliefs (Table 2); undertaking predictive modelling for each task-level confidence bias group (and considering differences across groups) would then help to reveal what might associate with subject-level confidence biases. Essentially, revealing any different predictors, or predictors with different magnitudes, across the different groups might help explain why the groups reported biases in their self-confidence (e.g. one group might be influenced by a factor that was irrelevant to the other groups; that factor might then help explain or be a potential cause of a particular confidence bias).

Students' self-concept and self-efficacy beliefs were predicted separately for each confidence bias group, and differences across groups were explored through an additional process that tested for moderation. Conceptually, 'moderators' significantly affect the direction and/or strength of the relations between predictors and outcomes (Baron & Kenny, 1986). Moderation was explored via additional interaction models considering two groups in turn (e.g. under-confident and accurate students only), via the same predictive models but including an indicator of group membership (e.g. accurate = 0 or 1), the predictors, and the interactions between the predictors and the group membership indicator; the significance associated with the interaction terms then represented differences in the coefficient magnitudes across the two groups (i.e. if significant, then confidence bias acted as a moderator; the moderating effect of other factors such as gender would be considered in the same way via interactions).

Students' could be under-confident, accurate, or over-confident at different levels of task-score/task-confidence; preliminary analysis highlighted that the same fundamental results occurred regardless of whether task-score and task-confidence were also included as predictors when modelling per group (i.e. also controlling for task-score and task-confidence did not affect the presented results/conclusions).

Various influences were confirmed to differentially predict students' self-concept (Table 5) and self-efficacy (Table 6) when considered per confidence bias group. The different confidence biases were also revealed to be moderators in some cases (highlighted in superscript in Table 5 and Table 6, representing $p < .05$ or below): tendencies towards different confidence biases therefore significantly affected (i.e. moderated) the strength of the relations between various influences and self-concept or self-efficacy.

Substantive new insights are revealed through focusing on these instances of moderation. For self-concept (Table 5), mastery norms (what grade meant 'being good' at science) were negatively predictive for accurate (and under-confident) students but non-significant for over-confident students. The self-concept beliefs of under-confident students were positively predicted by perceived subject-comparisons (science as being easier than any other subject), together with other influences, but were not predicted by the students' utility or interest value. Conversely, the self-concept beliefs of over-confident students were not predicted by subject-comparisons, but were strongly (and positively) predicted by utility value, and other influences including interest value, praise, and mastery experiences. For self-efficacy (Table 6), subject-

Table 5
Science items/factors predicting students' science self-concept beliefs across confidence bias groups.

	Under-confident (U)				Accurate (A)				Over-confident (O)			
Item/factor	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect	Est.	SE	Sig.	Effect
Constant/intercept	.44	.30	.145	NA	.50	.27	.065	NA	.12	.31	.689	NA
Mastery experiences (current grade)	**.14**	**.03**	**<.001**	**.393**	**.17**	**.03**	**<.001**	**.539**	**.15**	**.03**	**<.001**	**.443**
Mastery norms (what is a good grade)	**−.08**	**.04**	**.038**	**−.158**	[AO] **−.08**	**.04**	**.022**	**−.150**	[AO] .02	.04	.705	.030
Subject-comparison	[UA] **.15**	**.04**	**<.001**	**.419**	[UA] −.01	.03	.692	−.034	.04	.04	.293	.118
Peer-comparison	**.10**	**.04**	**.008**	**.268**	**.09**	**.03**	**.014**	**.211**	.00	.05	.983	.002
Anxiety (absence of)	**.14**	**.05**	**.006**	**.316**	**.14**	**.04**	**.001**	**.318**	.03	.05	.537	.075
Social persuasions	**.19**	**.05**	**<.001**	**.405**	**.22**	**.04**	**<.001**	**.484**	**.19**	**.05**	**<.001**	**.411**
Vicarious experiences	.02	.04	.562	.050	.02	.03	.498	.043	.03	.04	.416	.077
Interest value	.12	.07	.070	.293	**.15**	**.05**	**.001**	**.342**	**.21**	**.06**	**.001**	**.466**
Utility value	[UO] .03	.06	.625	.065	[AO] .07	.05	.130	.150	[UO AO] **.25**	**.06**	**<.001**	**.509**
Personal value	.06	.04	.153	.166	−.01	.03	.737	−.029	−.05	.05	.303	−.124
Cost value (absence of)	.00	.03	.920	.008	**.05**	**.03**	**.041**	**.133**	.03	.04	.388	.079
Teacher perceptions	.01	.05	.826	.022	.04	.04	.284	.082	.05	.05	.308	.108
Gender (1 = male)	[UA UO] −.18	.09	.058	−.165	[UA] .13	.07	.072	.122	[UO] .08	.09	.400	.065
Explained variance	62.7%				60.4%				68.4%			
Unexplained variance, school level	.3%				3.5%				.0%			
Unexplained variance, residual	37.0%				36.2%				31.6%			

Notes: estimated coefficients (Est.), standard errors (SE), significance (*p*-values; Sig.), and effect sizes (Effect) are shown. Items/factors used 1–6 scales unless otherwise indicated. Significant predictors ($p < .05$ or below) have been highlighted in bold for clarity. Unexplained variance at the residual level can be assumed to reflect the student level. Significant differences ($p < .05$ or below) in coefficient magnitudes across groups (from separate interaction/moderation models for the various pairs of groups) have been highlighted in superscript.

Table 6
Science items/factors predicting students' science self-efficacy beliefs across confidence bias groups.

Item/factor	Under-confident (U) Est.	SE	Sig.	Effect	Accurate (A) Est.	SE	Sig.	Effect	Over-confident (O) Est.	SE	Sig.	Effect
Constant/intercept	**1.25**	**.37**	**.001**	**NA**	**1.82**	**.30**	**<.001**	**NA**	.76	.41	.064	NA
Mastery experiences (current grade)	**.23**	**.04**	**<.001**	**.607**	**.23**	**.03**	**<.001**	**.685**	**.19**	**.04**	**<.001**	**.534**
Mastery norms (what is a good grade)	UO .08	.05	.109	.137	AO .08	.04	.061	.131	UO AO **.21**	**.05**	**<.001**	**.402**
Subject-comparison	UA **.16**	**.05**	**<.001**	**.421**	UA .01	.03	.683	.037	.03	.05	.503	.087
Peer-comparison	**.10**	**.05**	**.033**	**.236**	**.08**	.04	.058	.175	.06	.06	.349	.125
Anxiety (absence of)	−.05	.06	.369	−.114	.03	.05	.452	.075	.07	.07	.318	.140
Social persuasions	.02	.06	.728	.039	**.12**	**.04**	**.002**	**.254**	.11	.06	.069	.233
Vicarious experiences	.07	.04	.138	.143	.04	.03	.190	.090	−.03	.05	.492	−.075
Interest value	.06	.08	.457	.135	.03	.05	.522	.073	**.17**	**.07**	**.023**	**.353**
Utility value	.11	.07	.111	.240	**.13**	**.05**	**.013**	**.265**	**.20**	**.08**	**.011**	**.392**
Personal value	UA UO **.11**	**.05**	**.038**	**.266**	UA −.03	.04	.451	−.071	UO −.09	.06	.132	−.213
Cost value (absence of)	.02	.04	.651	.039	.02	.03	.433	.055	.05	.05	.256	.121
Teacher perceptions	−.06	.07	.353	−.103	−.08	.05	.082	−.143	−.08	.07	.200	−.157
Gender (1 = male)	.10	.12	.393	.085	**.23**	**.08**	**.007**	**.194**	.17	.12	.144	.136
Explained variance	50.8%				47.3%				55.8%			
Unexplained variance, school level	2.2%				3.6%				1.9%			
Unexplained variance, residual	47.0%				49.0%				42.3%			

Notes: estimated coefficients (Est.), standard errors (SE), significance (*p*-values; Sig.), and effect sizes (Effect) are shown. Items/factors used 1–6 scales unless otherwise indicated. Significant predictors ($p < .05$ or below) have been highlighted in bold for clarity. Unexplained variance at the residual level can be assumed to reflect the student level. Significant differences ($p < .05$ or below) in coefficient magnitudes across groups (from separate interaction/moderation models for the various pairs of groups) have been highlighted in superscript.

comparisons and personal value were only positively predictive for under-confident students, while mastery norms were only positively predictive for over-confident students.

Numerous other differences in significance occurred across the confidence bias groups (e.g. the influence of peer-comparisons being non-significant for over-confident students but significantly predictive for under-confident students), but the magnitudes of the associated coefficients were not highlighted to be significantly different (at $p < .05$ or below) across the various pairs of groups. Further research with higher numbers of students may be necessary to statistically confirm such differences (i.e. considering differences across paired groups reduces the number of considered students, likely reducing the power of the process to confirm smaller differences).

Nevertheless, the results clearly highlighted that those with different confidence biases appeared to be influenced in different ways (i.e. different influences were significant and/or with different magnitudes). Such differences can be inferred to associate with the biases themselves. For example, subject-comparisons predicted self-concept when under-confident, but not when students were accurate; subject-comparisons may then be a plausible cause of under-confidence. However, given the methodology, direct causality cannot be established and inferences are limited to what may be plausible. Nevertheless, the results beneficially provide clear hypotheses for future research with different methods.

3.4. Predicting self-concept with self-efficacy and predicting self-efficacy with self-concept

The expectancy-value model assumes that mastery experiences are interpreted into self-concept beliefs which are then interpreted into self-efficacy beliefs, together with the influence of further factors (Eccles, 2009). It was outside the scope of the presented research to explore whether self-concept was conceptually antecedent to self-efficacy or vice versa: it was simply and intuitively assumed that both were different contextualised expressions of someone's self-confidence. It is still plausible to assume that self-concept and self-efficacy beliefs may influence each other, although their close relation may ensure that any predictive models using both factors are harder to interpret (e.g. high proportions of variance are likely to be explained, regardless of any other predictors).

Nevertheless, the predictive models as above were repeated to model self-concept (appended for brevity: Appendix C in the Supplementary material) and self-efficacy (Appendix D in the Supplementary material), and self-concept/self-efficacy per confidence bias group (Appendix E and Appendix F in the Supplementary material), but also including self-efficacy/self-concept within the opposite model. Perhaps unsurprisingly, self-concept was then the strongest predictor of self-efficacy, and self-efficacy was then the strongest predictor of self-concept.

The fundamental results from the earlier models were still observed, however, and other insights also became apparent: mastery norms negatively predicting self-concept and positively predicting self-efficacy became more clearly apparent; over-confident students were influenced more, and under-confident students were influenced less, by their other expression of self-confidence (i.e. self-concept strongly predicted self-efficacy for over-confident students but far less so for under-confident students; self-efficacy strongly predicted self-concept for over-confident students but again less so for under-confident students).

4. Discussion

The presented research makes a number of new contributions to knowledge. Firstly, under-confident students were shown to report lower interest in science, utility of science, and various other beliefs when compared to accurately-evaluating and over-confident students, affirming that under-confidence can be detrimental or limiting within science education.

Secondly, the students' self-confidence beliefs (whether expressed as self-concept or as self-efficacy), on average, could be predicted by their interest and utility for science together with various other predictors, over and above the effect of their reported grades, which extends traditional assumptions about sources of or influences on students' self-confidence beliefs. Limiting research to only consider the four theorised antecedents to self-efficacy (Bandura, 1997; Usher & Pajares, 2008b) or to only consider the subject-comparisons and peer-comparisons assumed to influence self-concept (Marsh et al., 2015a, 2015b) may ultimately only provide a partial understanding of the area and may give misleading effect sizes.

Thirdly, students with different confidence biases can be inferred to form their beliefs in different ways: different factors with different magnitudes predicted self-confidence (whether self-concept or self-efficacy) when the students were under-confident compared to when they were over-confident. For example, the self-confidence beliefs (both self-concept and self-efficacy) of under-confident students were predicted by their subject-comparisons, together with other factors, and not by their perceived utility of science; conversely, the self-confidence beliefs of over-confident students were predicted by their perceived utility of science, together with other factors, but not by their subject-comparisons. These were only associations, however, but provide a plausible starting point for more detailed and extensive research into the potential causes of confidence biases.

Accordingly, the research provides new insights into understanding students' experiences within science education, where the implications of confidence biases have not been explored, and provides new insights for motivational theories and wider educational psychology, where research has not previously explored what might predict under-confident, accurate, and over-confident beliefs in educational contexts.

4.1. Under-confidence and over-confidence within science education

Under-confident students reported consistently lower than accurately-evaluating and over-confident students, affirming that under-confidence may indeed be detrimental as previously assumed (Bouffard & Narciss, 2011), and as seen in younger mathematics students in England (Sheldrake et al., 2014). Notably, under-confident students reported lower interest and utility for science while reporting the same current grades as accurately-evaluating students. Under-confident students do not therefore lack ability: indeed, within the research design, they scored the highest on the questionnaire tasks. Since self-confidence, interest, and utility are closely associated with students' subject choices (e.g. Mujtaba & Reiss, 2014; Regan & DeWitt, 2015; Sheldrake, Mujtaba, & Reiss, 2015), under-confident students may perhaps perceive their science options to be limited: low confidence in their expected grades at GCSE/A-Level may perhaps mean that science is not considered as a potential option, for example, regardless of their current grades. Nevertheless, further research needs to explore the implications of under-confidence on wider educational outcomes such as examination results and subject choices.

The self-concept and self-efficacy beliefs of under-confident students were not predicted by their interest in science or by their perceived utility of science. Under-confident students may then be disadvantaged in two ways: firstly, they are likely to hold lower interest in science and perceived utility of science (which are relevant to wider educational choices); and secondly, in contrast to other students, interest or utility do not motivationally help inspire their self-confidence, over and above their own attainment.

Over-confident and accurately-evaluating students reported similar self-concept, interest, and utility associated with science, yet over-confident students reported significantly lower current grades. Such results somewhat cohere with prior research, for example where over-confident students in mathematics reported higher interest in mathematics compared to those who were under-confident (Gonida & Leondari, 2011). Differences may perhaps occur across subjects, suggesting the benefit of further research to consider biology, chemistry, and physics separately.

Higher utility predicted higher self-concept for over-confident students, over and above their reported grades and other influences, but utility was non-significant for accurately-evaluating and under-confident students. The perceived utility of science has been found to associate with students' intentions to study science in England (Mujtaba & Reiss, 2014); educators may then need to help ensure that all students who are focused on science careers or other extrinsic benefits have the necessary skills and attainment, otherwise, over-confident students may find that they are potentially unable to accomplish their goals, given admissions criteria for some courses or university study.

Curiously, accurately-evaluating students reported the highest self-efficacy (their expected attainment at GCSE and A-Level), perhaps suggesting that holding accurate beliefs may be beneficial; however, the students' actual GCSE and A-Level attainment was unknown and longitudinal research would be necessary to explore such implications.

4.2. Self-confidence within wider educational research

On a wider level, the results also have implications to general educational research. On average for all students, science self-confidence, expressed as self-concept and as self-efficacy, was strongly predicted by the students' interest and perceived utility of science, over and above their reported grades and other influences.

The influences of interest and utility on students' self-concept and self-efficacy have been assumed within the expectancy-value model (Eccles, 2009), but appear to have been infrequently explored in practice. For example, earlier research has found that higher self-concept has led to higher subsequent attainment, over and above prior attainment, which in turn has led to higher self-concept (Huang, 2011), but no further factors were considered. Such results can perhaps be explained given that an expression of higher self-concept also appears to be an expression of higher interest (as presented here), over and above someone's attainment, and given that higher interest has been found to predict higher subsequent attainment (Köller, Baumert, & Schnabel, 2001). Higher interest may ensure that more time and effort is applied in studying, for example, which may then lead to higher attainment. Future research may need to explicitly consider whether interest, self-confidence, and other factors reflect tendencies to apply effort, studying strategies, and/or other practices (as considered for some areas, e.g. Multon et al., 1991), and so provide a more comprehensive explanation of any motivational associations.

With the exception of received praise (i.e. positive 'social persuasions'), which was strongly predictive, theorised influences on self-confidence such as peer-comparisons, subject-comparisons, and anxiety, had lower predictive magnitudes compared to interest and utility but were still nevertheless relevant. Theorised influences on self-efficacy (Bandura, 1997; Usher & Pajares, 2008b) predicted self-concept, and vice versa, highlighting that earlier models have only provided a partial understanding of what influences students' self-efficacy or self-concept. Future research may need to balance replication with considering what other contextually-relevant factors may also need to be modelled. Additionally, the sequential inclusion of predictors highlighted that effect sizes (or even significance) could easily be misleading if influences were considered in relative isolation.

Higher perceived standards for attainment (mastery norms; 'What grade do you think people need to get in order to be "good" at science?') negatively predicted self-concept but positively predicted self-efficacy when considered with the students' current grades but no other influences. However, the mastery norms indicator was not predictive of self-concept beliefs, on average, once further influences were also included, such as the students' perceived peer-comparisons (science perceived to be easier or harder for the student than for their classmates). Believing that science was easier for the student than for their peers predicted higher self-confidence, over and above their current grades and other influences (there was no 'unintuitive' peer-comparison effect). Nevertheless, peer-comparisons had a lower effect on students' self-concept when compared to other influences, such as received praise, interest, utility, and anxiety for science.

This provides a new perspective onto the proposed universal detriments of peer-comparisons and high attainment contexts on students' self-concept beliefs (e.g. Nagengast & Marsh, 2011; Marsh et al., 2015a). Higher mastery norms (perhaps implicit or explicit in higher-attaining schools) may not necessarily be detrimental to self-concept, when considered together with contextually-relevant factors rather than in abstract isolation; high norms may even be beneficial for self-efficacy beliefs (perhaps through providing higher standards to motivationally aim towards). The differential associations of mastery norms with confidence biases also highlighted that any potential detriments or benefits may not necessarily be applicable to all students, and that detriments may be occurring via the presence or absence (or through the generation) of confidence biases.

Essentially, the 'missing link' of confidence biases has perhaps now been revealed, which is a substantive new insight. Believing that higher grades were necessary to be 'good' at science, on average, predicted higher self-efficacy, but may associate with over-confidence for some students; conversely, such beliefs did not predict students' self-concept beliefs, on average, but may predict lower self-concept for some students through associating with under-confidence.

4.3. Self-confidence within wider educational research: self-confidence as motivation

Students' science self-confidence (their various beliefs of their abilities and capabilities, expressed here as self-concept and as self-efficacy) was predicted by their interest and utility, together with other influences, over and above their attainment. Interest and utility are also motivational factors predicting wider outcomes such as students' subject choices (Regan & DeWitt, 2015). Motivation appears to an inherent aspect of self-confidence, so that expressions of self-confidence appear to be, partially, also expressions of motivation. This helps explain why higher self-confidence, when considered alone, may associate with higher subsequent attainment, over and above prior attainment.

Self-confidence as reflecting motivation is perhaps more clearly seen when considering self-efficacy in more detail. Self-efficacy was originally applied to help understand behaviour such as fears, defences, and phobias; accordingly, it was contextually-relevant to consider negative physiological states such as anxiety as (limiting) influences on someone's self-efficacy (Bandura, 1977). Someone may dislike spiders, for example, and become anxious when thinking about them: their confidence in their future capability to open a box containing numerous spiders would then presumably be rather low; nevertheless, they do not lack the capability to open boxes, and may be motivated to do so if a box holds something of interest. Within education, it is contextually-relevant to consider interest and other areas rather than focus only on negative states.

Answering 'How confident are you in being able to gain a Grade A in science?' may depend on someone's attainment, but also on whether they find science interesting or useful enough to motivate themselves to gain a Grade A, together with various other influences. Similarly, agreeing with 'I do well in science' or 'I am good at science' may again depend on someone's attainment, but also on whether they value science enough to interpret their attainment as 'good' or only as 'average'.

Different students may also be influenced in different ways. Expressions of motivation as self-confidence may potentially lead to over-confidence in some, but not all, students. Nevertheless, further research into causes of confidence biases, and students' motivational expressions, appears to be necessary: many other factors may be relevant or provide a more comprehensive understanding of the area.

4.4. Limitations and implications to subsequent research

In contrast to measuring someone's attainment or interest, it is somewhat unfeasible to ask someone whether they are under-confident, accurate, or over-confident; instead, a confidence bias is generally revealed through researchers comparing some form of expressed belief (e.g. task-confidence) against some other standard (e.g. task-score), which unavoidably depends on the selected indicators, the research design, and/or other areas. Accordingly, confidence biases and groups can be explored and defined in various ways; while some research has applied paired tasks and confidence ratings (e.g. Chen, 2003), as applied here, other research has explored students' relative beliefs or attainment compared to others (e.g. Kruger & Dunning, 1999).

The presented results highlighted that task-level confidence biases helped reveal and consider subject-level confidence biases, but further benefit or confirmation may be gained from explicitly calculating biases in subject-level beliefs, potentially through relative comparisons or other approaches.

Influences on students' self-confidence may also vary by age and across subject domains, and also across areas within science (biology, chemistry, and physics). As the presented results highlighted, the inclusion of different factors may change the significance or effect sizes associated with any modelled factors, and ideal predictors may not necessarily have been discovered yet. Some factors, such as self-confidence expressed via self-efficacy, can also be operationalised in various ways (more so than self-concept), which in turn may be (predictively) influenced in different ways.

The data were not longitudinally collected from the same students over time, and the predictive models therefore only considered associations between students' concurrently-reported expressions. It cannot necessarily be concluded that any particular influence is indeed temporally or causally antecedent to students' self-concept or self-efficacy beliefs. This limitation is not unique to the presented research, however, and cross-sectional designs are often the only feasible approaches within educational research.

A number of areas were unavoidably covered through single items to ensure feasible implementation of the questionnaire and for direct comparability and contextualisation against other international research (e.g. single-item measures of perceived peer-comparisons and subject-comparisons were used as in TIMSS). Reassuringly, prior research has validated the use of single-item measurement when compared to more extensive scales (Gogol et al., 2014). Such approaches may improve efficiency, assuming that items can be formulated to measure clear, distinct, and/or theoretically-based concepts, but it is likely beneficial for further research to also explore the area with more extensive item sets.

Fundamentally, as in any quantitative research, the results must be considered cautiously: questionnaire items are not necessarily ideal in reflecting students' beliefs; statistical models are not necessarily ideal in representing a wider context. Accordingly, the results are not necessarily definitive, but instead present plausible findings and highlight clear areas for development through more extensive future research.

As a final note, current terminology within theoretical perspectives and associated with students' self-confidence is not necessarily intuitive (e.g. 'self-concept', 'attainment value') and may perhaps benefit from refinement.

4.5. Conclusions and wider implications for science education and practice

Increasing the numbers of students studying science remains a priority for England and for other countries (The Royal Society, 2014). Considering students' self-confidence offers a productive way to help ensure that students' future choices are not unnecessarily constrained; in contrast to other potential influences on subject choices, such as school type, home resources, and students' backgrounds (Regan & DeWitt, 2015), under-confidence or over-confidence (once recognised) can more feasibly be amended via interventions, teachers, or the students themselves.

On average, students' science self-confidence was predicted by various factors: current self-confidence (self-concept, expressed as subjective beliefs of 'doing well' or 'being good' at science) was most strongly predicted by received praise, current grades, and interest in science; self-confidence for future attainment (self-efficacy, expressed as expected future grades) was most strongly predicted by current grades and perceived utility of science.

Students with different confidence biases were influenced in different ways. The self-confidence beliefs (both self-concept and self-efficacy) of under-confident students were predicted by their subject-comparisons (finding science easier or harder than other subjects), together with other factors, and not by their interest in science or their perceived utility of science; conversely, the self-confidence beliefs of over-confident students were predicted by their interest and utility of science, together with other factors, but not by their subject-comparisons. Similarly, lower personal value of science to the students' identity predicted lower self-efficacy only for under-confident students.

Addressing under-confidence (or considering the area further) may be necessary before assuming that increasing interest in science can promote higher self-confidence for all students. Additionally, educators may also need to ensure that focusing on the utility associated with science does not lead to over-confidence, otherwise some students may potentially lack the attainment needed to pursue their wider goals or careers.

It may be beneficial to combine some classroom assessment with also asking students' about their confidence in their answers, and so potentially increase students' self-reflection and/or reveal under-confidence or over-confidence. Feedback could perhaps then be tailored so that students can reflect on their successful experiences, rather than on any other negative feelings. Reminders may also be useful regarding science as inclusive: attainment can be gained by all, regardless of whether someone considers themselves to be a 'science person' or not.

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Supplementary material

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References

Ackerman, P., & Wolman, S. (2007). Determinants and validity of self-estimates of abilities and self-concept measures. *Journal of Experimental Psychology: Applied*, *13*(2), 57–78. http://dx.doi.org/10.1037/1076-898X.13.2.57.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). Doing science versus being a scientist: examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617–639. http://dx.doi.org/10.1002/sce.20399.

Arens, A. K., Seeshing Yeung, A., Craven, R., & Hasselhorn, M. (2011). The twofold multidimensionality of academic self-concept: domain specificity and separation between competence and affect components. *Journal of Educational Psychology*, *103*(4), 970–981. http://dx.doi.org/10.1037/a0025047.

Bøe, M. V., & Henriksen, E. K. (2015). Expectancy-value perspectives on choice of science and technology education in late-modern societies. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education* (pp. 17–29).Dordrecht: Springer. http://dx.doi.org/10.1007/978-94-007-7793-4_2.

Bøe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: young people's achievement-related choices in late-modern societies. *Studies in Science Education*, *47*(1), 37–72. http://dx.doi.org/10.1080/03057267.2011.549621.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. http://dx.doi.org/10.1037/0033-295X.84.2.191.

Bandura, A. (1997). *Self-efficacy: the exercise of control.* New York: Freeman.

Baron, R., & Kenny, D. (1986). The moderator—mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51*(6), 1173–1182. http://dx.doi.org/10.1037/0022-3514.51.6.1173.

Bol, L., Hacker, D., O'Shea, P., & Allen, D. (2005). The influence of overt practice, achievement level, and explanatory style on calibration accuracy and performance. *The Journal of Experimental Education*, *73*(4), 269–290. http://dx.doi.org/10.3200/JEXE.73.4.269-290.

Bong, M., & Clark, R. (1999). Comparison between self-concept and self-efficacy in academic motivation research. *Educational Psychologist*, *34*(3), 139–153. http://dx.doi.org/10.1207/s15326985ep3403_1.

Bong, M., & Skaalvik, E. (2003). Academic self-concept and self-efficacy: how different are they really? *Educational Psychology Review*, *15*(1), 1–40. http://dx.doi.org/10.1023/A:1021302408382.

Bong, M. (2001). Role of self-efficacy and task-value in predicting college students' course performance and future enrollment intentions. *Contemporary Educational Psychology*, *26*(4), 553–570. http://dx.doi.org/10.1006/ceps.2000.1048.

Bouffard, T., & Narciss, S. (2011). Benefits and risks of positive biases in self-evaluation of academic competence: introduction. *International Journal of Educational Research*, *50*(4), 205–208. http://dx.doi.org/10.1016/j.ijer.2011.08.001.

Britner, S., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499. http://dx.doi.org/10.1002/tea.20131.

Chen, P., & Zimmerman, B. (2007). A cross-national comparison study on the accuracy of self-efficacy beliefs of middle-school mathematics students. *The Journal of Experimental Education*, *75*(3), 221–244. http://dx.doi.org/10.3200/JEXE.75.3.221-244.

Chen, P. (2003). Exploring the accuracy and predictability of the self-efficacy beliefs of seventh-grade mathematics students. *Learning and Individual Differences*, *14*(1), 79–92. http://dx.doi.org/10.1016/j.lindif.2003.08.003.

Chiu, M. M., & Klassen, R. (2010). Relations of mathematics self-concept and its calibration with mathematics achievement: cultural differences among fifteen-year-olds in 34 countries. *Learning and Instruction*, *20*(1), 2–17. http://dx.doi.org/10.1016/j.learninstruc.2008.11.002.

Deci, E., & Ryan, R. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Department for Education. (2013). *National curriculum in England: science programmes of study*. London: Department for Education. Retrieved August 10, 2015, from Department for Education: https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study.

Department of Education. (2015, March 31). *School performance tables*. Retrieved August 31, 2015, from Department of Education: http://www.education.gov.uk/schools/performance/download_data.html.

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist*, *44*(2), 78–89. http://dx.doi.org/10.1080/00461520902832368.

Gogol, K., Brunner, M., Goetz, T., Martin, R., Ugen, S., Keller, U., & Preckel, F. (2014). "My Questionnaire is Too Long!" The assessments of motivational-affective constructs with three-item and single-item measures. *Contemporary Educational Psychology*, *39*(3), 188–205. http://dx.doi.org/10.1016/j.cedpsych.2014.04.002.

Gonida, E., & Leondari, A. (2011). Patterns of motivation among adolescents with biased and accurate self-efficacy beliefs. *International Journal of Educational Research*, *50*(4), 209–220. http://dx.doi.org/10.1016/j.ijer.2011.08.002.

Hacker, D., Bol, L., Horgan, D., & Rakow, E. (2000). Test prediction and performance in a classroom context. *Journal of Educational Psychology*, *92*(1), 160–170. http://dx.doi.org/10.1037/0022-0663.92.1.160.

Hansford, B., & Hattie, J. (1982). The relationship between self and achievement/performance measures. *Review of Educational Research*, *52*(1), 123–142. http://dx.doi.org/10.3102/00346543052001123.

Huang, C. (2011). Self-concept and academic achievement: a meta-analysis of longitudinal relations. *Journal of School Psychology*, *49*(5), 505–528. http://dx.doi.org/10.1016/j.jsp.2011.07.001.
Jiang, Y., Song, J., Lee, M., & Bong, M. (2014). Self-efficacy and achievement goals as motivational links between perceived contexts and achievement. *Educational Psychology*, *34*(1), 92–117. http://dx.doi.org/10.1080/01443410.2013.863831.
Köller, O., Baumert, J., & Schnabel, K. (2001). Does interest matter: the relationship between academic interest and achievement in mathematics. *Journal for Research in Mathematics Education*, *32*(5), 448–470. http://dx.doi.org/10.2307/749801.
Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology*, *77*(6), 1121–1134. http://dx.doi.org/10.1037/0022-3514.77.6.1121.
Kuncel, N., Credé, M., & Thomas, L. (2005). The validity of self-reported grade point averages, class ranks, and test scores: a meta-analysis and review of the literature. *Review of Educational Research*, *75*(1), 63–82. http://dx.doi.org/10.3102/00346543075001063.
Möller, J., & Pohlmann, B. (2010). Achievement differences and self-concept differences: stronger associations for above or below average students? *British Journal of Educational Psychology*, *80*(3), 435–450. http://dx.doi.org/10.1348/000709909X485234.
Marsh, H., & Martin, A. (2011). Academic self-concept and academic achievement: relations and causal ordering. *British Journal of Educational Psychology*, *81*(1), 59–77. http://dx.doi.org/10.1348/000709910X503501.
Marsh, H., & Parker, J. (1984). Determinants of student self-concept: is it better to be a relatively large fish in a small pond even if you do not learn to swim as well? *Journal of Personality and Social Psychology*, *47*(1), 213–231. http://dx.doi.org/10.1037/0022-3514.47.1.213.
Marsh, H., Craven, R., & Debus, R. (1999). Separation of competency and affect components of multiple dimensions of academic self-concept: a developmental perspective. *Merrill-Palmer Quarterly*, *45*(4), 567–601.
Marsh, H., Abduljabbar, A. S., Morin, A., Parker, P., Abdelfattah, F., Nagengast, B., & Abu-Hilal, M. (2015a). The big-fish-little-pond effect: generalizability of social comparison processes over two age cohorts from Western, Asian, and Middle Eastern Islamic countries. *Journal of Educational Psychology*, *107*(1), 258–271. http://dx.doi.org/10.1037/a0037485.
Marsh, H., Lüdtke, O., Nagengast, B., Trautwein, U., Abduljabbar, A. S., Abdelfattah, F., & Jansen, M. (2015b). Dimensional comparison theory: paradoxical relations between self-beliefs and achievements in multiple domains. *Learning and Instruction*, *35*, 16–32. http://dx.doi.org/10.1016/j.learninstruc.2014.08.005.
Marsh, H. (1986). Verbal and Math self-concepts: an internal/external frame of reference model. *American Educational Research Journal*, *23*(1), 129–149. http://dx.doi.org/10.3102/00028312023001129.
Mujtaba, T., & Reiss, M. J. (2014). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15-year-old students' aspirations to study physics in post-compulsory English schools. *International Journal of Science and Mathematics Education*, *12*(2), 371–393. http://dx.doi.org/10.1007/s10763-013-9404-1.
Mullis, I., Martin, M., Ruddock, G., O'Sullivan, C., & Preuschoff, C. (2009). *TIMSS assessment fameworks*. Chestnut Hill, Massachusetts: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.
Multon, K., Brown, S., & Lent, R. (1991). Relation of self-efficacy beliefs to academic outcomes: a meta-analytic investigation. *Journal of Counseling Psychology*, *38*(1), 30–38. http://dx.doi.org/10.1037/0022-0167.38.1.30.
Nagengast, B., & Marsh, H. (2011). The negative effect of school-average ability on science self-concept in the UK, the UK countries and the world: the Big-Fish-Little-Pond-Effect for PISA 2006. *Educational Psychology*, *31*(5), 629–659. http://dx.doi.org/10.1080/01443410.2011.586416.
Pajares, F., & Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. *Contemporary Educational Psychology*, *24*(2), 124–139. http://dx.doi.org/10.1006/ceps.1998.0991.
Parker, P., Marsh, H., Ciarrochi, J., Marshall, S., & Abduljabbar, A. S. (2014). Juxtaposing math self-efficacy and self-concept as predictors of long-term achievement outcomes. *Educational Psychology*, *34*(1), 29–48. http://dx.doi.org/10.1080/01443410.2013.797339.
Phillips, J., & Gully, S. (1997). Role of goal orientation, ability, need for achievement, and locus of control in the self-efficacy and goal-setting process. *Journal of Applied Psychology*, *82*(5), 792–802. http://dx.doi.org/10.1037/0021-9010.82.5.792.
Regan, E., & DeWitt, J. (2015). Attitudes, interest and factors influencing stem enrolment behaviour: an overview of relevant literature. In E. K. Henriksen, J. Dillon, & J. Ryder (Eds.), *Understanding student participation and choice in science and technology education* (pp. 63–88).Dordrecht: Springer. http://dx.doi.org/10.1007/978-94-007-7793-4_5.
Shavelson, R., Hubner, J., & Stanton, G. (1976). Self-concept: validation of construct interpretations. *Review of Educational Research*, *46*(3), 407–441. http://dx.doi.org/10.2307/1170010.
Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2014). Calibration of self-evaluations of mathematical ability for students in England aged 13 and 15, and their intentions to study non-compulsory mathematics after age 16. *International Journal of Educational Research*, *64*, 49–61. http://dx.doi.org/10.1016/j.ijer.2013.10.008.
Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2015). Students' intentions to study non-compulsory mathematics: the importance of how good you think you are. *British Educational Research Journal*, *41*(3), 462–488. http://dx.doi.org/10.1002/berj.3150.
Snijders, T., & Bosker, R. (2012). *Multilevel analysis: an introduction to basic and advanced multilevel modeling*, 2nd ed. London: SAGE Publications.
The Royal Society (2014). *Vision for science and mathematics education*. London: The Royal Society.
Tymms, P. (2004). Effect sizes in multilevel models. In I. Schagen, & K. Elliot (Eds.), *But what does it mean? the use of effect sizes in educational research* (pp. 55–66).Slough: National Foundation for Educational Research.
Usher, E., & Pajares, F. (2008a). Self-efficacy for self-regulated learning: a validation study. *Educational and Psychological Measurement*, *68*(2), 443–463. http://dx.doi.org/10.1177/0013164407308475.
Usher, E., & Pajares, F. (2008b). Sources of self-efficacy in school: critical review of the literature and future directions. *Review of Educational Research*, *78*(4), 751–796. http://dx.doi.org/10.3102/0034654308321456.
Viljaranta, J., Tolvanen, A., Aunola, K., & Nurmi, J.-E. (2014). The developmental dynamics between interest, self-concept of ability, and academic performance. *Scandinavian Journal of Educational Research*, *58*(6), 734–756. http://dx.doi.org/10.1080/00313831.2014.904419.
Wang, M.-T., & Degol, J. (2013). Motivational pathways to STEM career choices: using expectancy-value perspective to understand individual and gender differences in STEM fields. *Developmental Review*, *33*(4), 304–340. http://dx.doi.org/10.1016/j.dr.2013.08.001.
Wigfield, A., & Eccles, J. (2000). Expectancy—value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68–81. http://dx.doi.org/10.1006/ceps.1999.1015.
Zell, E., & Krizan, Z. (2014). Do People Have Insight Into Their Abilities? A Metasynthesis. *Perspectives on Psychological Science*, *9*(2), 111–125. http://dx.doi.org/10.1177/1745691613518075.