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Research Article

Effects of Teacher Assessment and Cognitive Ability on Self-Concepts: Longitudinal Mechanisms for Children from Diverse Backgrounds

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Abstract: This study sought to determine whether the academic self-concepts of children come from teacher appraisal or their own cognitive abilities. Longitudinal data from the Millennium Cohort Study were used to answer this question by testing the internal/external frame of reference (I/E) model for English children aged 5, 7, and 11 years and of ethnic minority, disadvantaged, and advantaged backgrounds. The I/E model predicts that high verbal achievement leads to a high verbal self-concept but a low mathematical self-concept, and high mathematics achievement leads to a high mathematical self-concept but a low verbal self-concept. The results of structural equation modelling revealed that the I/E model was generally supported, but teacher assessment had greater effects on self-concept than did cognitive ability. Teacher assessment and cognitive ability measured in children at the age of 7 years predicted child self-concepts at 11 years old. Teacher assessment was less influenced by the type of measurement used but more influenced by the cultural backgrounds of the children than cognitive ability. The implications of these results are discussed herein.
Keywords: academic self-concept, cognitive ability, ethnic minority children, I/E model, teacher assessment.

INTRODUCTION

Achievement is the major source of academic self-concepts. Indicators of achievement exist on a continuum from teacher-perceived assessments of student achievement to the measurement of student cognitive ability through standardised tests [1]. Teacher assessment tends to be subjective and context-based, and assessments of cognitive ability tend to be based on context-free evaluations of intelligence starting from early childhood [2, 3]. The differences in the capacities of teacher assessment and cognitive ability tests to predict self-concepts may facilitate understanding how student self-concepts are acquired on the basis of subjective, human, and context-dependent teacher appraisal, compared with objective, measurable, and context-independent student cognitive ability.

Two methodological concerns are raised in this paper. First, the likely causal role of achievement (as indicated by teacher assessment and cognitive ability) in a self-concept should be properly investigated by analysing longitudinal data. Second, comparing children from ethnic minority, economically disadvantaged, and economically advantaged backgrounds may facilitate understanding how teacher assessment and cognitive ability are confounded by the context of student cultural and socioeconomic status because the context may influence the future educational, social, and economic success of students [4].

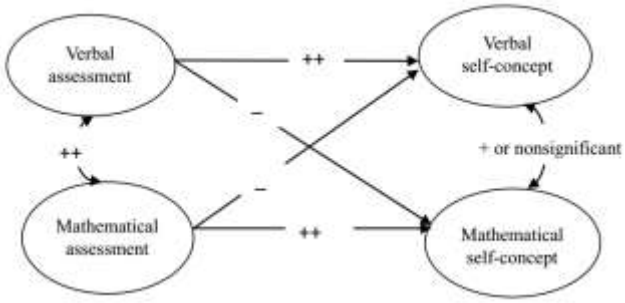
The internal/external frame of reference (I/E) model serves as a convenient theoretical and methodological basis for testing the causal effect of achievement on self-concepts in different academic domains. The Millennium Cohort Study (MCS) provided longitudinal data and the variables necessary for this study.

Teacher assessment and cognitive ability in I/E model research

The I/E model is one of the most well-researched models with a theoretical and methodological basis for addressing the causal effects of achievement on self-concepts. The I/E model predicts that verbal achievement leads to a high verbal self-concept but a low mathematical self-concept, and mathematics achievement leads to a high mathematical self-concept but a low verbal self-concept [5] (Model 1 in Figure 1). The same-domain positive effects of achievement on self-concepts are predicted on the basis of social comparison between individual achievements and those

of peers, whereas the cross-domain negative effects are based on intrapersonal comparisons of achievements among various domains of knowledge.

Model 1. The I/E model prediction with teacher assessment as the achievement indicator



Model 2. The I/E model prediction with cognitive ability as the achievement indicator

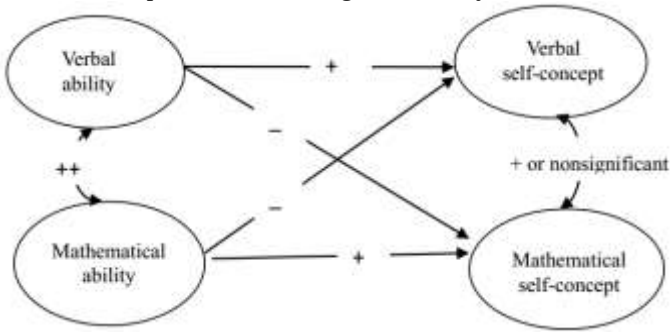


Fig-1: The I/E model predictions with teacher assessment (Model 1) and cognitive ability (Model 2) as the achievement indicator. '+' = weak positive; '++' = strong positive; '–' = weak negative

Teacher assessment is one of the major measures of achievement used in examining the I/E model. Research indicated that achievements measured according to school or class grades (at least partially on the basis of teacher assessment) tend to support the I/E model prediction more than those measured through standardised test results do [6]. Furthermore, standardised test results than cognitive ability tend to support the I/E model more in the strength of path parameters [7, 8]. This suggests that the I/E model is supported by school or class grades, standardised test results, and cognitive test results, in descending order.

According to the methodology of the I/E model, student achievements of different academic domains are often highly correlated with because of a higher-order, general intelligence factor (Figure 1) [9]. Cognitive ability is a more direct indicator of the general intelligence factor than teacher assessment. Thus, along the achievement indicator continuum, teacher assessment (teacher-perceived student achievement, not directly taken from school records) can be considered the most subjective, context-dependent achievement indicator, whereas cognitive ability (not based on school curriculum) is the most objective, context-independent one. The effects of teacher assessment on self-concepts may therefore be clearly understood if they are compared with those of cognitive test results.

Longitudinal effects of achievement or ability on self-concepts

Research on the I/E model and related studies has generally indicated that achievement has a longitudinal effect on self-concepts, but most of this research has focused on late primary school and middle school stages [10-12]. Previous studies have also found violations of the I/E model prediction in the cross-domain paths [13].

Early primary school curriculum design is less subject-based than later schooling and involves less differentiation between knowledge domains. The efficacy, validity, and reliability of longitudinal teacher assessment and child cognitive ability in predicting a self-concept over time have not been investigated.

Role of child cultural backgrounds

Teacher assessments of student achievement may be confounded by factors interacting with student characteristics such as their cultural and socioeconomic backgrounds. For example, teachers may underestimate test scores for children either in socioeconomically

advantaged secondary schools [1] or from socioeconomically disadvantaged backgrounds in early education [14].

Apparently, no studies have examined the applicability of the I/E model to students from ethnic minority, disadvantaged, and advantaged backgrounds. The I/E model, however, is generally supported by data from diverse countries [15-17] and from international databases [5, 18-20]. Möller, Streblow, and Pohlmann [21] found that students with learning difficulties also fit the I/E model predictions.

Research questions

A review of the literature suggests that teacher assessment and cognitive ability may play different roles in child self-concepts across domains, which may be understood in depth by considering the longitudinal development and cultural backgrounds involved. The I/E model provides a theoretical and methodological basis, and the MCS provides longitudinal data and required variables. In the results section, the teacher assessment models and cognitive ability models are quantitatively examined. In the discussion section, the results based on the two achievement indicators are compared and discussed alongside the related literature to obtain a complete picture of the findings [22]. This study therefore aims to answer the following three research questions.

1. What are the effects of teacher assessment of verbal and mathematics achievements of children at the ages of 5, 7, and 11 years on verbal and mathematical self-concepts of children at the age of 11 years for all children as a whole and for ethnic minority, disadvantaged, and advantaged children in England separately?

2. What are the effects of child verbal and nonverbal cognitive ability test results at the ages of 5, 7, and 11 years on child verbal and mathematical self-concepts at the age of 11 years for all children and for ethnic minority, disadvantaged, and advantaged children in England?

3. What are the qualitative differences between the results obtained by models based on teacher assessment (research question 1) and those based on cognitive ability (research question 2)?

METHODS

Participants

Longitudinal data were obtained from the MCS compiled by the U.K. Data Service. Eight data sets were used: teacher assessment of students at the ages of 5, 7, and 11 years; student cognitive ability test results at the ages of 5, 7, and 11 years; student self-concepts at the age of 11; and student backgrounds. The eight data sets were combined with a common identifier ('mcsid'), resulting in a total of 18,593 students with 1,461 ethnic minority, 8,348 disadvantaged, and 8,784 advantaged students. The sample sizes of the teacher participants were 14,806 for the age 5 wave, 5,595 for the age 7 wave, and 6,224 for the age 11 wave.

Measures

Four types of data set contents were used in this study. The reverse-coded variables were recorded for higher scores to represent higher degrees before data analysis.

Teacher assessment

The teachers rated student verbal achievements, including listening, speaking, reading, and writing or English competences, at the ages of 5, 7, and 11 years, respectively, on a 5-point scale from 1 (*well above average*) to 5 (*well below average*). Detailed information about the observed variables for teacher assessment is presented in Figure 2.

Cognitive ability

Child cognitive ability was represented by raw or ability scores obtained through cognitive tests on numbers, calculations, shapes, picture similarity, pattern construction, number skills, or working memory at the ages of 5, 7, and 11 years, respectively. Detailed information about the observed variables for cognitive ability is presented in Figure 3.

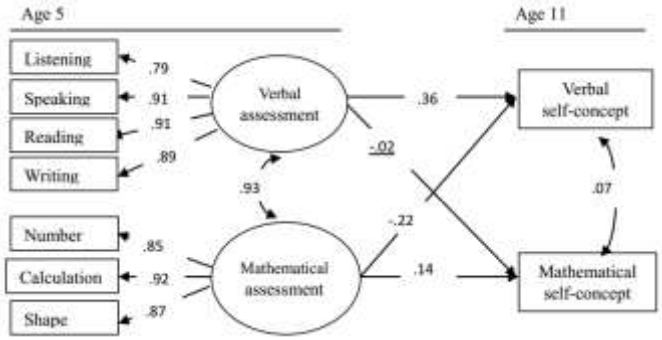
Self-concept

English and mathematical self-concepts were obtained on the basis of child responses to the items 'I am good at English' and 'I am good at maths' on a 4-point Likert scale from 1 (*strongly agree*) to 4 (*strongly disagree*) at the age of 11 years.

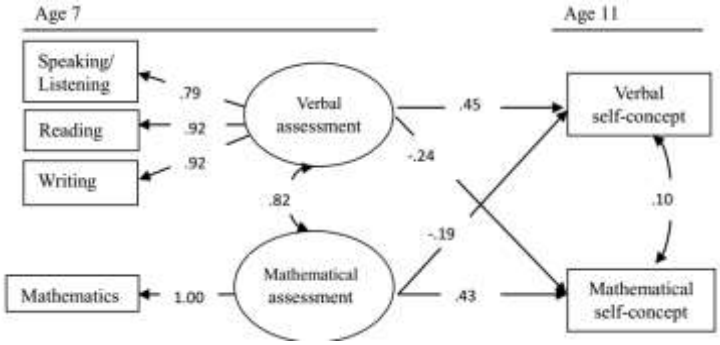
Cultural backgrounds

The MCS oversampled children from ethnic minority and socioeconomically disadvantaged (the poorest 25% of society) backgrounds and then sampled children who were not in the aforementioned two categories as children from advantaged backgrounds.

Model A.



Model B.



Model C.

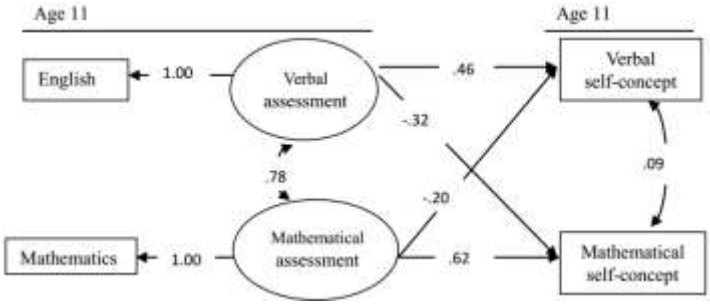
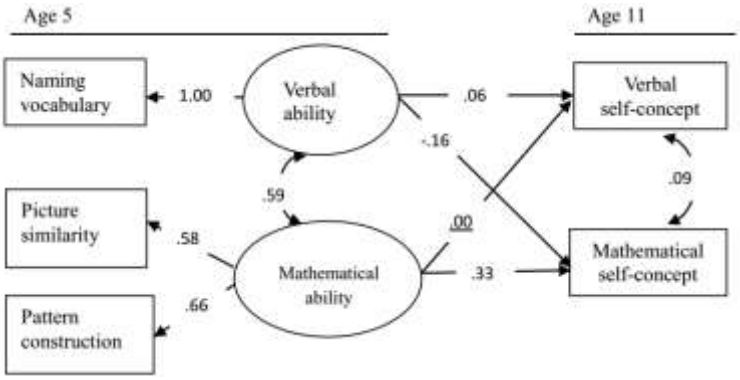
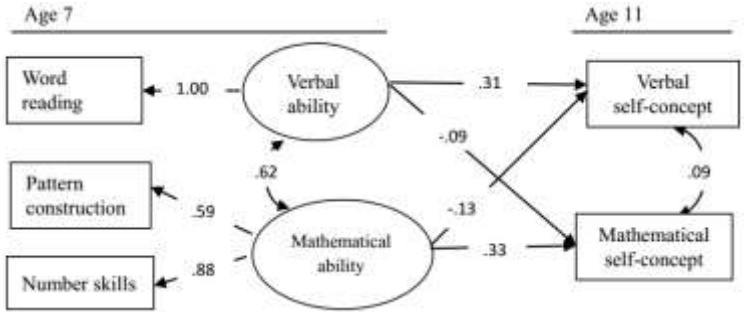


Fig-2: The I/E model with verbal and mathematical self-concepts at the age of 11 years regressed on verbal and mathematical teacher assessment at the ages of 5 years (Model A), 7 years (Model B), and 11 years (Model C). The parameters are SEM results for all children as a single group. The parameters underlined are not significant at p = .05

Model D.



Model E.



Model F.

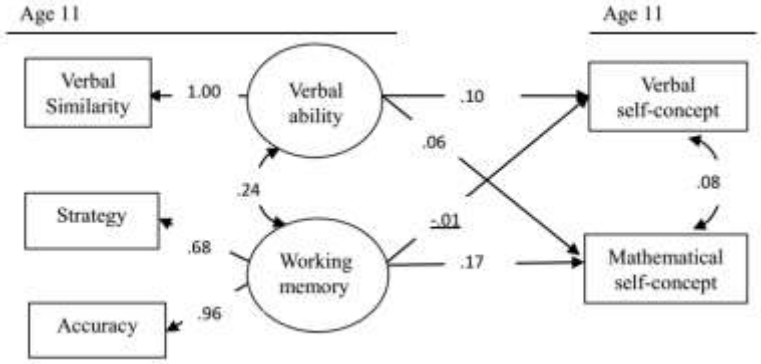


Fig-3: The I/E model with verbal and mathematical self-concepts at the age of 11 years regressed on verbal and non-verbal cognitive abilities at the ages of 5 years (Model D), 7 years (Model E), and 11 years (Model F). The parameters are SEM results for all children as a single group. The parameters underlined are not significant at p = .05

Data analysis

The research questions were examined using structural equation modelling (SEM) and R software (Version 3.1.3; R Core Team) and the R lavaan package [23]. The problem of missing data was resolved using full information maximum likelihood (FIML) estimation because FIML is recommend to accompany SEM [24]. The raw or ability scores were standardised before SEM analysis to facilitate data processing.

Four fit indices or criteria were used to determine the goodness-of-fit of a model (i.e., the degree of similarity between the variance–covariance matrix of the obtained data and that predicted by a model). A nonsignificant chi-square value (χ^2) was the basic criterion and is thus presented in the results section, but it was not used as the major criterion because it tends to become significant when there are large sample sizes [25], as in this study. The major criteria used to determine an acceptable model in this study were a lower than .10 root mean square error of approximation, a higher than .90 comparative fit index, and a higher than .90 Tucker–Lewis index [26].

RESULTS

Effects of teacher assessment

The results of SEM revealed that the I/E model generally supported teacher assessment as an indicator of achievement (Table 1; Model 1 in Figure 1; Figure 2). The models that completely fitted the prediction of the I/E model included:

(a) The ages of 7 and 11 years for all children, using the statistical method of signal group SEM (testing all specified variables in all children) and that of multigroup SEM (testing whether the three age groups of children had similar patterns of path parameter estimates while freely estimating the other parameters),
(b) The ages of 7 and 11 years for both ethnic minority and disadvantaged children, and
(c) All three age models for advantaged children.

Table 1: Path parameter estimates and fit index values for models A–C with teacher assessment as the achievement indicator

	Vsc		Msc		χ^2	*df*	RMSEA	CFI	TLI
Regressed on	Vas	Mas	Vas	Mas					
All children (single group analysis)									
Model A: age 5 -> age 11	.36	-.22	**-.02**	.14	1671.97	23	.075	.98	.97
Model B: age 7 -> age 11	.45	-.24	-.19	.43	45.04	6	.036	1.00	.99
Model C: age 11 -> age 11	.46	-.20	-.32	.62	.00	0	.000	1.00	1.00
All children (multigroup analysis)									
Model A: age 5 -> age 11	.34	-.19	**-.05**	.18	85555.05	108	.073	.98	.97
Model B: age 7 -> age 11	.45	-.23	-.18	.43	67.05	26	.030	1.00	1.00
Model C: age 11 -> age 11	.47	-.20	-.32	.63	22.99	8	.030	1.00	1.00
Ethnic minority children									
Model A: age 5 -> age 11	**.11**	**-.04**	**.26**	**-.20**	468.96	23	.096	.97	.95
Model B: age 7 -> age 11	.42	-.27	-.20	.43	6.72	6	.013	1.00	1.00
Model C: age 11 -> age 11	.40	-.23	-.36	.59	.00	0	.000	1.00	1.00
Disadvantaged children									
Model A: age 5 -> age 11	.54	-.39	**-.01**	.14	748.00	23	.079	.98	.97
Model B: age 7 -> age 11	.47	-.26	-.16	.37	21.42	6	.036	1.00	.99
Model C: age 11 -> age 11	.44	-.16	-.31	.61	.00	0	.000	1.00	1.00
Advantaged children									
Model A: age 5 -> age 11	.27	-.09	-.13	.29	560.55	23	.064	.99	.98
Model B: age 7 -> age 11	.45	-.19	-.20	.47	27.13	6	.038	1.00	.99
Model C: age 11 -> age 11	.50	-.23	-.30	.65	.00	0	.000	1.00	1.00

Note. The path parameters and χ^2 values underlined are not significant at $p = .05$. The path parameter in **bold** violates the prediction of the I/E model (Figure 1). The path parameters are standardised solutions. Vsc = verbal self-concept; Vas = teacher assessment on student verbal competence; Msc = mathematical self-concept; Mas = teacher assessment on student mathematical competence; χ^2 = chi-square (or minimum function test) statistic; *df* = degree of freedom; RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI = Tucker–Lewis Index.

The model for ethnic minority children aged 5 years completely failed to fit the predictions of the I/E model in the four parameter estimates. A minor violation of the I/E model was the nonsignificant negative path from verbal assessment to mathematical self-concepts for all samples in this group.

The major findings were that teacher assessment at the ages of 7 and 11 years had a desirable capacity to predict child self-concepts at the age of 11 years for all children according to the I/E model prediction. Teacher assessment at the ages of 5, 7, and 11 years all had a desirable predictive capacity for advantaged children; however, it lost its predictive capacity completely for ethnic minority children aged 5 years.

Effects of cognitive ability

The second set of SEM analysis examined the models with cognitive ability as the achievement indicator (Table 2; Model 2 in Figure 1; Figure 3). The results revealed that the I/E model was completely supported by the age 7 models for all children and for ethnic minority, disadvantaged, and advantaged children. All violations in the age 5 and 11 models occurred in the cross-domain paths, except for the additional path from verbal ability to the verbal self-concept for the ethnic minority children, with cognitive ability at the age of 5 years as the achievement indicator.

Table 2: Path parameter estimates and fit index values for models D–F with cognitive ability as the achievement indicator

	Vsc		Msc		χ^2	*df*	RMSEA	CFI	TLI
Regressed on	Vab	Mab	Vab	Mab					
All children (single group analysis)									
Model D: age 5 -> age 11	.06	**.00**	-.16	.33	7.23	2	.018	1.00	.99
Model E: age 7 -> age 11	.31	-.13	-.09	.33	21.19	2	.035	1.00	.99
Model F: age 11 -> age 11	.10	**-.01**	**.06**	.17	1.14	2	.000	1.00	1.00
All children (multigroup analysis)									
Model D: age 5 -> age 11	.11	**-.01**	-.13	.32	45.32	14	.028	.99	.98
Model E: age 7 -> age 11	.30	-.12	-.11	.36	40.81	14	.027	1.00	.99
Model F: age 11 -> age 11	.12	**.00**	**.07**	.17	20.14	14	.012	1.00	1.00
Ethnic children									
Model D: age 5 -> age 11	**.07**	**-.07**	-.10	.19	.62	2	.000	1.00	1.01
Model E: age 7 -> age 11	.21	-.09	-.15	.37	1.06	2	.000	1.00	1.00
Model F: age 11 -> age 11	.12	-.07	**.07**	.14	1.96	2	.000	1.00	1.00
Disadvantaged children									
Model D: age 5 -> age 11	.12	**-.01**	-.18	.38	.16	2	.000	1.00	1.01
Model E: age 7 -> age 11	.32	-.10	-.07	.32	8.47	2	.032	1.00	.99
Model F: age 11 -> age 11	.10	**.02**	**.06**	.17	3.46	2	.015	1.00	1.00
Advantaged children									
Model D: age 5 -> age 11	.11	**.01**	-.11	.34	18.15	2	.047	.99	.94
Model E: age 7 -> age 11	.32	-.13	-.12	.41	12.42	2	.038	1.00	.98
Model F: age 11 -> age 11	.13	**.00**	**.09**	.20	1.16	2	.000	1.00	1.00

Note. The path parameters and χ^2 values underlined are not significant at $p = .05$. The path parameter in **bold** violates the prediction of the I/E model (Figure 1). The path parameters are standardised solutions. Vsc = verbal self-concept; Vab = verbal ability; Msc = mathematical self-concept; Mab = mathematical ability; χ^2 = chi-square (or minimum function test) statistic; df = degree of freedom; RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI = Tucker–Lewis Index.

The three cultural backgrounds of children had similar patterns in supporting the I/E model, except for the models for ethnic minority children aged 5 and 11 years. Working memory test results (at the age of 11 years) had a lower predictive capacity than that of mathematics-related cognitive test results (at the ages of 5 and 7 years). All models for cognitive ability at the age of 7 years perfectly fitted the I/E model prediction. The results of similar patterns, which fitted the I/E model across the three backgrounds and demonstrated the models for the age of 7 years to be superior to those for the age of 11 years (compared with the perfect fit by teacher assessment models for the age of 11 years), suggested that the predictive capacity of cognitive test results relies on the type of measurement used.

DISCUSSION

The discussion section focuses on a qualitative comparison of the results obtained for answering research question 3. Three major findings are as follows: (a) Teacher assessment has a greater effect on self-concepts than does cognitive ability. (b) Both teacher assessment and cognitive ability beginning at the age of 7 years can predict child self-concepts at the age of 11 years, and teacher assessment is less influenced than cognitive ability by the type of measurement used. (c) Teacher assessment is more strongly influenced than cognitive ability by the cultural backgrounds of children.

Teacher assessment is a more accurate predictor of a self-concept than cognitive ability

The models examined in this study generally support the predictions of the I/E model (Figures 1–3) [5]. An overall comparison reveals that the results obtained from the models with teacher assessment as the main achievement indicator (53 parameters among the total 60 parameters in Table 1, consistent with the I/E model prediction) tend to support the I/E model more than those with cognitive ability as the main achievement indicator do (45 of 60 in Table 2). These results have two implications. First, teacher assessment is revealed to play a more substantial role in student self-concept compared with student cognitive ability. This suggests that teacher assessment is a more accurate reflection of student achievement, which in turn influences student self-concepts. This result is consistent with past research findings, in that models that use school grades as achievement indicators fit the I/E model more closely than do those that use standardised test results [6]. Furthermore, models that use standardised test results as achievement indicators fit the I/E model predictions more closely than do those that use cognitive test results as achievement indicators [7].

The second implication is that teacher assessment predicts self-concepts more reliably, but not validly, than cognitive ability does. This implication suggests that teacher assessment is not a true representation of child achievement, but may be confounded by other irrelevant factors such as child self-concepts and cultural backgrounds. The confounding factor intervening in the effects of teacher assessments on self-concepts can be further understood by considering child ages and cultural backgrounds, as the following discussion shows.

Achievement indicators at age 7 and measurement methods for cognitive ability

The teacher assessment models that most closely fit the I/E model prediction are those for the ages of 7 and 11; for cognitive ability, the closest models are those for the age of 7 years. The cognitive ability models for the age of 7 years perform as predictably as those for the ages of 7 and 11 years in the teacher assessment models. The findings suggest that both teacher assessment and cognitive ability, at least starting from the age of 7 years, can predict self-concepts at the age of 11 years among all children. The result that cognitive ability retains its capacity for predicting self-concepts is consistent with previous findings that cognitive test results were significant predictors of both achievement and behavioural outcomes later in life [27].

Using different types of measurements appears to reduce the predictive capacity of cognitive ability but does not reduce that of teacher assessment. The occurrence of greatest predictive capacity in the teacher assessment model for children aged 11 years (Model C in Figure2) suggests that teacher assessment is relatively uninfluenced by the type of measurement used, even if only one observed variable is employed as the achievement indicator. The lowest predictive capacity occurred in the cognitive ability model for children aged 11 years (Model F in Figure 3) with violations of the I/E model observable in cross-domain paths and in the same pattern across all three backgrounds of the children. This finding suggests the positive view that working memory (the cognitive ability measured at the age of 11 years, linked with executive functioning and indicators of general intelligence) can be a desirable indicator of achievement in mathematics [28-30], which in turn can positively predict the mathematical self-concepts among children from diverse backgrounds. From a negative standpoint, working memory might gradually lose its desirability for measuring mathematics achievement, because children require abilities that are more complex when their schooling progresses from the age of 11 years onwards. Future research could investigate this speculation on the basis of longitudinal data, but self-concepts may be difficult to perceive accurately and thus measure in young children such as the 5- and 7-year-olds in this study.

Teacher assessment is influenced more than cognitive ability by cultural backgrounds of children

The patterns of the results based on cognitive ability models tended to be stable across the three cultural backgrounds of children, whereas those based on teacher assessment models tended to be unstable. A significant example is that teacher assessment at the age of 5 years completely failed to predict self-concepts at the age of 11 years in the I/E model for ethnic minority children (which was the least accurate model among all those in Tables 1 and 2) but provided highly accurate results for advantaged children.

These results suggest that teacher assessment of young ethnic minority children is unreliable. Previous research indicated that children of ethnic minority backgrounds tended to have low problem-solving skills rather than low achievement [31]. Classes with large portions of ethnic minority children were shown to be vulnerable to reduced achievement because of emotional exhaustion in teachers [32]. The reason for these findings might therefore be that teachers often do not sufficiently understand or accurately assess ethnic minority children's procedural knowledge and behaviours, which differ from those of the ethnic majority. Policy makers should support additional

efforts among teachers to clearly understand the cognitive, social, and emotional behaviours of ethnic minority children [33], and use this understanding to design proper measures and activities for assessing the achievement of ethnic minority children.

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NOTES ON CONTRIBUTOR

Mei-Shiu Chiu received a B. A. and an M. A. Degree in Education from National Taiwan Normal University and completed her doctoral study at the Faculty of Education, Cambridge University, UK. She has been a teacher in secondary education. Her research interests focus on interactions between emotion/affect, cognition, and culture for diverse knowledge domains (e.g., mathematics, science and energy) in relation to teaching, assessment, and large-scale surveys.

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