The Relations Among Academic Motivation, Self-Concept, Aspirations and Choices: Integrating Expectancy-Value and Academic Self-Concept Theory

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List of Figures		viii
List of Tables		X
Table of Abbrev	viations	xi
Statement of A	uthorship and Sources	xii
Statement of Co	ontribution of others	xiii
Statement of Aj	ppreciation and Dedication	xviii
Copyright and I	Permissions	xix
Abstract		xxii
Chapter 1:	Introduction and Overview	1
Chapter 2:	Literature Review	4
Expectancy-V	/alue Theory of Achievement-Related Choices	4
The Expecta	ancy Component	5
The Value C	Components	6
Multiplicativ	e Relation between Expectancy and Task Value	8
Expectancy	-By-Value Interaction in Classical EVT	8
Reasons for	• the Omission of Expectancy-By-Value Interaction in Mo	odern EVT9
Empirical E	vidence for Expectancy-By-Value Interaction	
Integration o	of ASC Theory into EVT	
Self-concep	t	
Multidimen	sional and Domain Specific	
Reciprocal	Effect Model (REM)	
The Frame	of Reference Effects Based on ASC Theory	
Background	Factors (Gender and Socioeconomic Status) in Rela	tion to Modern
EVT		22
Gender		
Socioecono	mic Status	
Research Que	estions of the Thesis	23
Overarching	g Research Questions	
Specific Res	search Questions of the Five Empirical Studies	25
Chapter 3:	Methodology and Design	

Jiesi Guo	iii
Structural Equation Modelling	
Multiple Group Analyses	
Method Effects	
Complex Design	
Latent Interaction Modelling	
Unconstrained Approach	
Latent Moderated Structural (LMS) Equation Approach	
Estimator	
Missing Data	
Chapter 4: Study 1 - Expectancy-Value, Gender and Socio	peconomic
Background as Predictors of Achievement and Aspiration: A Mul	lti-cohort Study 35
Preface	
Abstract	
Expectancy-Value Theory	
Multiplicative Effect of Expectancy and Task Value	
Family Background and Gender	
The Hong Kong Context	
The Present Investigation	
Method	
Participants	
Measures	
Data Analysis	
Results	
Descriptive Statistics and Correlations	
The Hypothesised Model	
Expectancy by Task Value	
SES and Gender	
Discussion	
Chapter 5: Study 2 - Directionality of the Associations of	High School
Expectancy-Value, Aspirations and Attainment over Eight Years:	A Multiwave,
Longitudinal study	
Preface	
Abstract	
Expectancy-Value Theory	

Motivational Beliefs and Achievement	50
Motivational Beliefs and Educational and Occupational Aspiration	ons 51
Motivational Beliefs, Aspirations, and Educational Attainment	
The Present Investigation	52
Method	55
Participants	55
Measures	56
Analysis	
Results	60
Descriptive and correlations	60
Research Question 1: What roles do motivational beliefs play in sha	aping academic
achievement and subsequent educational attainment?	63
Research Question 2: What roles do motivational beliefs play in sha	aping educational
and occupational aspirations?	64
Research Question 3: Taking into account all cognitive and non-cog	nitive assets,
what roles do motivational beliefs play in shaping individual's edu	cational
attainment?	65
Discussion	66
Stability of Motivational Beliefs and Achievement	
The Interplay Among Motivational Beliefs, Achievement, Aspiration	ns, and
Attainment	
Indirect Link Between IQ, Motivational Beliefs, Achievement, Aspir	ations, and
Attainment	
Implication for Theory, Research, and Practice	69
Strengths, Limitations, and Directions for Future Studies	70
Conclusion	72
Chapter 6: Study 3 - Achievement, motivation, and educati	onal choices: A
ongitudinal study of expectancy and value using a multiplicative p	perspective 79
Preface	
Abstract	
Expectancy-Value Theory	
Relations Between Achievement, Motivational Beliefs and Choic	es 86
Multiplicative Relation Between Self-Concept and Task Values	
Gender Effects	

Jiesi Guo	v
The Present Investigation	
Method	
Participants	
Measures	
Data Analysis	96
Results	
Effects of Prior Achievement on Motivational Beliefs and Educational O	Outcomes.100
Effects of Motivational Beliefs on Educational Outcomes	
Multiplicative Effect of Math Self-Concept and Task Value	
Predictive Effects of Gender on motivational beliefs and educational ou	itcomes 103
Moderation Effect of Gender	
Discussion	
Predictive Effect of Self-Concept, Task Value and Their Interaction	105
Internal Comparison Process	
Gender Differences	
Limitations of This Study	
Conclusion	
Chapter 7: Study 4 - Extending Expectancy-Value Theory Pred	ictions of
Achievement and Aspirations in Physics, Chemistry, Earth Sciences an	d Biology:
Internal Comparison Processes and Expectancy-by-Value Interactions	129
Preface	
Abstract	
Internal Comparison Processes	
	100
Expectancy-value Framework	
Modern EV I	
Internal Comparison Processes: Integration of DC1 and EV1	
The Dressest lass stight and lask value	
The Present Investigation	
Method	140
Participants	
Measure	
Data Analysis	

Jiesi Guo		vi
Results		143
Tests of Pred	ictions Relating Achievement to Motivation Beliefs: Hypothesis	1 143
Tests of Pred	ictions Relating Motivational Beliefs to Aspirations: Hypothesis	2 144
Tests of Pred	ictive Relations Over Countries: Hypothesis 3	145
Discussion		146
The Relation	s between Achievement and Motivation Beliefs	146
The Relation	s between Motivation Beliefs and Aspirations	147
Generalizabil	lity of the Results	149
Implications	for Instructional Practices	150
Limitations a	nd Directions for Further Research	151
Chapter 8:	Study 5 - Probing Unique Contributions of Self-Concept	t, Task
Values and Th	eir Interactions Using Multiple Value Facets and Multiple Ad	cademic
Outcomes		162
Preface		163
Abstract		164
Expectancy-	value Theory	165
Association	among Self-Concept, Task Value and Achievement-Related	
Behaviors		165
Multiplicativ	ve Relation between Expectancy and Value	166
The Present	Study	167
Method		168
Participant	ts	168
Measures.		168
Statistical .	Analyses	169
Results		171
Second-or	der CFA	171
Second-Or	der Bi-Factor CFA	171
Predictive	Effects of Self-concept and Value Beliefs	176
Discussion		176
Unique Co	ntributions of the Four Value Components and Self-concept	176
The Nature	e of the Multiplicative Relation	176
Limitation	s, Strengths and Implications	178
Chapter 9:	General Discussion and Conclusion	184
Summary of	of Findings: Studies 1-5	

Jiesi Guo	vii
Discussion of General Findings	
Strengths of the Thesis	
Limitations and Directions for Future Research	
Implications for educational policy and practice	
References	207
Supplemental Materials – Study 1	234
Supplemental Materials – Study 2	250
Supplemental Materials – Study 3	
Supplemental Materials – Study 4	274
Supplemental Materials – Study 5	
Supplemental Materials – References	
Research Portfolio Appendix	
Publications:	

List of Figures

Figure 2.1 Eccles et al. model of achievement-related choices5
Figure 2.2 The Shavelson et al. academic self-concept model13
Figure 2.3 The Marsh/Shavelson model in relation to the verbal-mathematical
continuum of ASC13
Figure 2.4 The reciprocal effect model16
Figure 2.5 The Internal/External Frame of Reference (I/E) Model between verbal and
math domains
Figure 4.1 The hypothesised model 39
Figure 4.2 Path model depicted the hypothesised relations
Figure 4.3 Simple-slopes depicted the effects of the latent-interaction variables (self-
concept by utility value) on mathematics achievement and educational aspirations.
Figure 5.1 The hypothesised model54
Figure 5.2 Structural path model of the relations between motivational beliefs,
achievement and attainment (Model 1) 54
Figure 5.3 Structural path model of the relations between motivational beliefs and
educational and occupational aspirations55
Figure 5.4 Structural path model of the relations between motivational beliefs, IQ,
achievement, aspirations and attainment (Model 3)56
Figure 6.1 Conceptual model 123
Figure 6.2 Path model depicting the hypothesised relations, excluding latent interaction,
controlling for gender, Grade and SES124
Figure 6.3 Simple-slopes for the multiplicative effects of math self-concept and intrinsic
values on math course selection and Tertiary Entrance Rank [TER]

Figu	re 7.1 Structural path model of the relations	between	achievement,	self-concept,	and
	coursework aspirations across the four scien	ce domai	ns Model MG	6	157

- Figure 7.2 Structural path model of the relations between achievement, self-concept, and coursework aspirations across the four science domains Model MG6 158
- Figure 7.3 Structural path model of the relations between achievement, self-concept, and coursework aspirations across the four science domains Model MG6 159

Figure 7.4 Simple-slopes depicting the effects of latent interaction (self-concept by
intrinsic value and self-concept by utility value) on coursework aspirations 160
Figure 8.1 Second-order CFA models presenting the four value components 170
Figure 8.2 Response surface displays for the multiplicative effect of self-concept and task
value on the three outcomes175
Figure 8.3 Response surface display for synergistic and compensatory relations between
academic self-concept and task value based on the hypothetical results
Figure 9.1 Effect Sizes of path coefficients for self-concept and value beliefs in predicting
achievement-related outcomes across the five studies

List of Tables

Table 4.1 Sample size, distribution characteristics, means, and (standard deviation) of
variables by cohort and gender 40
Table 4.2 The direct, indirect and total effect of gender and ses on outcome variables 42
Table 5.1 Estimated correlation matrix for the latent variables across occasion
Table 5.2 Model fit statistics for the longitudinal cfa and sem models 63
Table 5.3 Indirect effects from the hypothesised model
Table 6.1 Standardised direct, indirect, and total effect for the path model without latent
interaction126
Table 6.2 Standardised direct, indirect, and total effect for the path model without latent
interaction 127
Table 6.3 The conditional indirect effect of self-concept on university entry and stem
major selection
Table 7.1 Model fit statistics for the cfa and sem models used in the present study 161
Table 8.1 Mean, standard deviation, distribution and intercorrelations among
motivational beliefs and outcome variables169
Table 8.2 Model fit statistics for the hypothesised models 172
Table 8.3 Intercorrelations among self-concept, value components and outcomes 172
Table 8.4 Standardised path coefficients of self-concept, value components and their
interactions on three outcomes based on second-order bi-factor model 173
Table 8.5 Standardised path coefficients of self-concept, value components and their
interactions on three outcomes based on second-order bi-factor model
Table 9.1 An overview of the five empirical studies conducted in this thesis

Table of Abbreviations

ASC	Academic Self-Concept	
BFLPE	Big-Fish-Little-Pond Effect	
CFA	Confirmatory Factor Analysis	
CFI	Comparative Fit Index	
DCT	Dimensional Comparison Theory	
EVT	Expectancy-Value Theory	
FIML	Full Information Maximum Likelihood	
I/E	Internal/External Frame of Reference	
LMS	Latent Moderated Structural Equation Approach	
OECD	Organisation for Economic Co-operation and Development	
PISA	Programme of International Student Assessment	
PME	Physics, Science, Mathematics, Engineering, and Computer	
	Technology	
STEM	Science, Technology, Engineering, and Mathematics	
TIMSS	International Trends in International Mathematics and Science Study	
RMSEA	Root Mean Square Error Approximation	
SEM	Structural Equation Modeling	
TLI	Tucker-Lewis Index	

Statement of Authorship and Sources

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma.

No parts of this thesis have been submitted towards the award of any other degree or diploma in any other tertiary institution.

No other person's work has been used without due acknowledgment in the main text of the thesis.

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Statement of Contribution of Others

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Statement of Contributions of Study 1

Study 1 - "Directionality of the Associations of High School Expectancy-Value, Aspirations, and Attainment: A Longitudinal Study" has been published in a peer-reviewed journal - *Learning and Individual Differences*.

I, Jiesi Guo, conducted this study and acknowledge that his contribution to the above paper is 70%

This study was supervised by Professor Herbert W. Marsh, Dr. Philip D. Parker, Professor Alexandre J.S. Morin, and Professor Alexander Seeshing Yeung. They contributed their expertise to this paper substantively and methodologically. Thus, the contribution of each of professor to the above paper is 5%-10%.

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Statement of Contributions of Study 2

Study 2 - "Directionality of the Associations of High School Expectancy-Value, Aspirations, and Attainment: A Longitudinal Study" has been published in a peer-reviewed journal - American Educational Research Journal.

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Statement of Contributions of Study 3

Study 3 - "Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective" has been published in a peer-reviewed journal - *Developmental Psychology*.

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Research Portfolio Appendix

Statement of Contributions of Study 4

Study 4 - "Extending Expectancy-Value Theory Predictions of Achievement and . Aspirations in Science: Internal Comparison Processes and Expectancy-by-Value Interactions" has been submitted to a peer-reviewed journal – *Learning and Instruction*.

I, Jiesi Guo, conducted this study and acknowledge that his contribution to the above paper is 75%

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293

xvi

Statement of Contributions of Study 5

Study 5 - "Probing the Unique Contributions of Self-Concept, Task Values and Their Interactions Utiog Multiple Value Facers and Maltiple Academic Outcomes" has been resubmitted to a peer-reviewed journal - AERA Open This study was conducted during my research stay in University of Tübingen in Germany in 2014, collaborating with the research team in Hector Research festitute of Education Sciences and Psychology. L Heat Guo, conducted this study and acknowledge that my contribution to the above paper is

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Professor Herbert W. Marsh	Aloramour

The data set used in this mady is part of the Motivation in Mathematics (MeMa) project, which is also managed (organized) by other research members: Dr. Huma Gaspard, Dr. Jenna Cambria, Dr. Barbera Finnger, Dr. Anna-Lank Dicke, Dr. Holger Brank, Mr. Isabelle Häfner, and Ma. Brights Reisson. They were involved in data collection and fath ergenization in the creation of the archive used in this study, and in some cases offered comments on early drafts of the raper. Thus, the contribution of each of them to the actual paper itself is estimated to bc 1-3%.

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In this "thesis by publication" all the studies have been submitted for publication in peer-reviewed journals that are among the highest ranked journals in the educational and developmental psychology disciplines. Four of the five studies have been already published and are available in the public domain. However, in some cases, copyright restrictions preclude the presentation of the final published versions of the article. In such cases – as well as the case for the one study still in review—the final pre-publication version of the article is presented in the thesis. However, the reader is invited to download the final published article from the publisher's website.

Studies	Publications	Publishers	Permission	Version of papers in this thesis
1	Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S., & Yeung, A. S. (2015). Expectancy-value in mathematics, gender and socioeconomic background as predictors of achievement and aspirations: A multi-cohort study. <i>Learning and</i> <i>Individual Differences</i> , <i>37</i> , 161– 168. doi:10.1016/j.lindif.2015.01.008	Elsevier	Yes. Author retains the right to include the article in a thesis or dissertation (provided that this is not to be published commercially) (https://www.elsevier.com/about/company- information/policies/copyright/personal- use)	The final published version
2	Guo, J., Marsh, H. W., Morin, A. J. S., Parker, P. D., & Kaur, G. (2015). Directionality of the Associations of High School Expectancy-Value, Aspirations, and Attainment: A Longitudinal Study. <i>American</i> <i>Educational Research Journal</i> , <i>52</i> (2), 371–402. doi:10.3102/0002831214565786	Sage	Yes. Author retains the right to republish your article in a book that you are writing or editing (including a thesis or dissertation) (https://au.sagepub.com/en- gb/oce/journals-permissions)	The final published version
3	Guo, J., Parker, P. D., Marsh, H. W., &	APA	Waiting for permission from the publisher	The final pre-

	Morin, A. J. S. (2015). Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective. <i>Developmental Psychology</i> , <i>51</i> (8), 1163–1176. doi:10.1037/a0039440		to use the final published version of the article	published version
4	Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S. (in review). Extending Expectancy-Value Theory Predictions of Achievement and Aspirations in Physics, Chemistry, Earth Sciences and Biology: Internal Comparison Processes and Expectancy-by-Value Interactions.			The final submitted version
5	Guo, J., Nagengast, B., Marsh, H. W., Kelava, A., Gaspard, H., Brandt, H., Trautwein, U. (2016). Probing the Unique Contributions of Self-Concept, Task Values, and Their Interactions Using Multiple Value Facets and Multiple Academic Outcomes. <i>AERA Open</i> , 2(1), 1–20. <u>http://doi.org/10.1177/23328584156</u> 26884	Sage	Open access Journal	The final published version

Abstract

The fact that many talented and capable students opt out of the STEM (science, technology, engineering, and mathematics) pipeline and that women remain underrepresented in STEM fields are international phenomena and a matter of considerable concern amongst policymakers. Expectancy-value theory (EVT) (Eccles, 2009) is one of the major frameworks for studying achievement motivation, and has been widely used to tackle this issue. Previous EVT research has demonstrated that students' expectancy and value beliefs for specific academic subjects are important precursors of achievement-related behaviours (Eccles, 2009; Wigfield, Tonks, & Klauda, 2009). Despite the fact that research on task values has increased, it still lags far behind research on expectancy-related beliefs (e.g., academic self-concept [ASC]) (Wigfield et al., 2009), which is known to represent an important determinant of diverse educational outcomes (Marsh, 2007). This thesis integrated EVT and ASC and extended prior work by closely investigating: (a) the unique contributions of ASC and multiple value components in predicting diverse achievement-related outcomes, particularly during post-high school transition; (b) the multiplicative relation between ASC and value beliefs (i.e., ASC-by-value interaction) that was a core assumption of the original EVT but seems to have disappeared from modern EVT (Nagengast et al., 2011); (c) how well the theoretical models posited in ASC theory (e.g., multidimensional and domain specific selfconcept model, reciprocal effect model [REM], internal/external frame-of-reference [I/E] model with its extension to dimensional comparison theory [DCT]) generalise to different value beliefs; and (d) how the social and cultural factors (e.g., gendered socialisation, socioeconomic status [SES]) shape individual and gender differences in educational and career pathways.

This thesis explored new perspectives on EVT and ASC theory through five empirical studies relying on advanced methodologies and using data from large and representative national/international samples. Studies 1 and 4 respectively drew on Grade 8 students from Hong Kong (N = 13,621) and four OECD countries (N = 18,047), based on the International Trends in International Mathematics and Science Study. Studies 2 and 3 respectively drew on longitudinal data from representative samples of U.S. (N = 2,213) and Australian (N = 10,370) students during post-secondary school transition. Finally, study 5 was based on a sample of German 9th-grade students (N = 1,978).

First, this thesis provided strong support for modern EVT's proposition of different value components, which had differential predictive effects on achievement-related outcomes. Intrinsic value was more directly associated with academic effort, engagement and coursework aspirations, whereas utility value was more directly associated with educational

Jiesi Guo

aspirations and postsecondary academic choices, such as university entry and STEM major selection. Particularly, study 5 incorporated four major value components and found that attainment value and cost played salient roles in predicting students' academic achievement, engagement, and effort. Controlling for value beliefs, ASC, particularly general ASC, played an important role in influencing not only educational achievement and long-term attainment but also choice behaviours.

Second, there was support for a priori predictions that domain-specific ASC and task value interacted with each other to predict a wide range of achievement-related outcomes. However, the results indicated relatively weak support for ASC-by-value interactions based on general academic motivational beliefs.

Third, this thesis integrated ASC and EVT and provided strong support for domain specificity, REM, the I/E model, and DCT in relation to ASC and intrinsic value, but also in relation to utility value to a lesser extent. Specifically, high domain specificity of motivational beliefs and their distinctive relationship with achievement-related outcomes were evident across math, reading, and science, as well as across subject domains within science. Internal (dimensional) comparison processes posited in the I/E model and DCT not only help students form their motivational beliefs, but also subsequently influence their choice behaviour across domains. The thesis also found the significant reciprocal effects of motivational beliefs and achievement over critical development periods.

Finally, ASC and value beliefs played important mediating roles between gender and SES, and achievement-related outcomes. Despite gender differences in the mean level of motivational beliefs and educational outcomes, gendered processes underlying the choice of educational pathway were similar for both genders.

The findings of the five studies were discussed in light of the broader research context. Both theoretical and policy implications for educators, parents and students were derived.

Chapter 1: Introduction and Overview

Highly-skilled professions often require university training, particularly in the science, technology, engineering, and mathematics (STEM) related fields. Such professionals are critical for industrialised countries seeking to recover from the global financial crisis and to maintain their global competitiveness (International Monetary Fund, 2010; Organisation for Economic Co-operation and Development [OECD], 2010). Unfortunately, in industrialised countries, many talented and capable students opt out of STEM courses (e.g., advanced maths course) at high school and subsequently turn away from careers in STEM (Bøe, Henriksen, Lyons, & Schreiner, 2011; National Science Board, 2014; National Science Foundation, 2011, 2014). Although females are better represented than males in undergraduate degrees and have made large inroads into the medical and life science workforce, women continue to be underrepresented in other STEM fields (Alon & Gelbgiser, 2011; National Science Foundation, 2014; OECD, 2010; Parker, Nagy, Trautwein, & Lüdtke, 2014; Schoon & Polek, 2011).

Expectancy-value theory (EVT) (Eccles, et al., 1983; Eccles, 2009; Wigfield & Eccles, 2002) is one of the major frameworks for studying achievement motivation, and has been widely used to tackle these issues (Guo, Parker, Marsh, & Alex, 2015; Parker et al., 2012, Parker, Nagy et al., 2014; Perez, Cromley, & Kaplan, 2014; also see Wang & Degol, 2013 for a review). Considerable research based on EVT has demonstrated that competence beliefs and value beliefs represent critical determinants of academic choices, engagement and aspirations (e.g., Eccles, 2009; Watt et al., 2012; Wang & Eccles, 2013). Although modern EVT (Eccles, 2009) emphasises that different value components should play differential roles in influencing achievement-related outcomes, relatively little prior work has considered multiple task values together with ASC to examine their unique contributions in predicting educational outcomes, particularly during the post-high school transition.

Furthermore, according to early iterations of the EVT framework (see Atkinson, 1957; Atkinson & Feather, 1966; Feather, 1982; Vroom, 1964), competence beliefs and value beliefs were assumed to interact with each other in influencing achievement-related behaviours in addition to the first-order (main) effects. In other words, classic EVT proposes that the effects of expectancies of success on the outcome should depend on the extent to which an individual values a given domain, and vice versa. However, until recently, empirical research examining the interaction effect among motivational beliefs on achievement-related behaviours in non-experimental settings has been surprisingly sparse.

On the other hand, it has been well documented that academic self-concept (ASC) is an important determinant of diverse educational outcomes. Considerable research has been

Chapter 1: Introduction and Overview

conducted in relation to its formation as well as into the factors that influence it (Marsh, 2007). Given that the expectancy component of EVT is typically operationalised by ASC in educational research (Eccles & Wigfield, 2002; Eccles, 2009), processes posited in ASC theoretical models play important roles in EVT processes. However, theoretical considerations typical of research on ASC have not been well integrated into EVT (Nagy, Trautwein, Baumert, Köller, & Garrett, 2006; Nagy et al., 2008; Parker et al., 2012, Parker, Nagy et al., 2014). Thus, an integration of EVT and ASC theory is likely to provide novel theoretical insights to each theory and a better understanding of the dynamics leading students to make different academic choices.

Therefore, the aim of this thesis was to provide a comprehensive test of EVT and its integration with ASC theory, particularly testing the effects of expectancy, value and expectancy-by-value interactions on diverse achievement-related outcomes (e.g., achievement, aspirations, academic choices, and engagement). Five empirical studies focusing on maths and science motivational beliefs were conducted based on multiple large and representative national/international databases and advanced methodology. This thesis thus examined the generalisability of the results across countries and student cohorts, aiming to provide a full picture of the student decision-making process leading to STEM-related educational and career pathway during the post-high school transition.

Based on the integration of EVT and ASC theory, this thesis dealt with the central question of how student expectancy, value beliefs and, in particular, their interaction (expectancy-by-value interaction), influenced various student achievement-related behaviours in maths and science (e.g., high school maths coursework selection and aspirations, academic engagement and effort, university major selection, and educational aspirations and attainment), which were important precursors of STEM-related careers. To this end, this thesis addressed a number of questions. First, it examined the unique effects of ASC and multiple value components as well as their combined effects (i.e., ASC-by-value interactions) on diverse achievement-related outcomes. Second, it explored how well the theoretical models posited in ASC theory (e.g., multidimensional and domain specific self-concept model, reciprocal effect model [REM], internal/external frame-of-reference model [I/E] model with its extension to dimensional comparison theory [DCT]) generalise to different value beliefs. Finally, it examined how the social and cultural factors (e.g., gendered socialisation, socioeconomic status [SES]) shape individual and gender differences in STEM-related educational and career pathways.

This thesis is structured as follows: the literature review (Chapter 2) presents the theoretical background for the five empirical studies and aims at situating these studies within

Chapter 1: Introduction and Overview

their broader research context. This chapter also introduces the research questions and hypotheses guiding the five empirical studies. The design and methodology chapter (Chapter 3) presents the overarching research methods used in the five studies. Chapters 4 to 8 present the five empirical studies realised within this thesis. Chapter 9 concludes this thesis with a general discussion of implications for future research and educational practice.

The purpose of this chapter is to provide a review of the literature on expectancy-value theory (EVT) and academic self-concept (ASC) theory, and to demonstrate the research gap of the integration of EVT and ASC. Specifically, first, the expectancy-value model of achievement-related choices is explained further; second, the disappearance of the expectancy-by-value interaction that had been the cornerstone of the classic EVT is also discussed. Third, the ASC theories — including domain specificity, REM, I/E model and DCT, and their integration with EVT — are elaborated in-depth. Finally, the influence of gender and SES on motivational beliefs and achievement-related outcomes is addressed.

Expectancy-Value Theory of Achievement-Related Choices

The expectancy-value framework has been particularly generative in achievement motivational research. Starting with Atkinson's seminal work (1957, 1964), expectancy-value models focus on two categories of motivational factors: individual's expectancies (expectations of success) and the value they have for succeeding at a task. However, most early EVT research focused on arbitrary tasks in laboratory settings (see reviews by Wigfield, 1994; Wigfield & Eccles, 2002). It was in the early 1980s that Eccles and her colleagues proposed a modern version of the expectancy-value model on achievement-related choices within an education context (Eccles et al., 1983). Compared to the traditional EVT (e.g., Atkinson, 1957, 1964; Atkinson & Feather, 1966), modern EVT elaborates multiple components of task values and articulates the relationships between expectancies and values to a variety of psychological, social, and cultural determinants and processes (Eccles, 2009; Eccles et al., 1983).

Eccles et al.'s EVT model of achievement-related choices is depicted in Figure 2.1 (Eccles, 2009, 2011). Viewing the model from right to left, achievement-related choices and performance are most directly influenced by expectancies and values. In turn, these achievement-related beliefs are affected by one's goals and self-schemas, such as self-concept of one's ability. These social cognitive constructs, in turn, are influenced by individuals' perceptions of socialisers' (e.g., parents, teachers, peers) attitudes and expectations for them, and by their own interpretation of previous achievement-related experiences. Finally, individuals' task perceptions and interpretation of past social and personal experiences are linked to the socialisation processes in various cultural and social settings (e.g., cultural norms, gender role, family socioeconomic status [SES]) as well as one's aptitudes, talents, personalities and temperamental characteristics. In particular, modern EVT proposed the causal links from achievement-related choices to the experiences an individual passes through. Thus, modern EVT takes a developmental and integrative perspective to explain how

expectancies and values are shaped over time by individual and contextual factors in influencing students' academic choices and performance.



Figure 2.1 Eccles et al. model of achievement-related choices (Eccles et al., 1983). Adapted from "Gendered educational and occupational choices: Applying the Eccles et al. model of achievement-related choices," by J. Eccles, *International Journal of Behavioral Development*, 35, 196. Copyright 2011 by International Society for the Study of Behavioural Development.

The Expectancy Component

Theories focusing on expectancy-related constructs attempt to address the critical motivational question "Can I do this task?" (Eccles, Wigfield, & Schiefele, 1998). The expectancy component has been captured in various theories (e.g., EVT, self-concept theory, self-efficacy theory, attribution theory, and control theory) and specific constructs (e.g., expectations of success, ASC, self-efficacy beliefs, perceptions of task difficulty, and perceived control). Eccles and her colleagues (Eccles et al., 1983) define *expectations of success* as a task-specific self-belief about success in a future task. As noted above, in their expectancy-value model, expectations of success are directly linked to another type of expectancy: *ability self-concept* (Eccles, 2009; Eccles & Wigfield, 2002). Ability self-concept, such as ASC refers to individuals' current sense of their competence in a given domain (Harter, 1990; Marsh, 1989, 2007), whereas expectations of success refer to self-beliefs regarding one's ability to successfully complete a specific upcoming task. Although these two types of expectancies are theoretically distinguishable, there is abundant empirical evidence that expectations of success are highly correlated with ASC and usually collapsed into a

single construct in real-life settings (Eccles, 2009; Eccles & Wigfield, 2002; Wigfield & Eccles, 2002). This leads to a number of EVT studies relying on ASC as a measure of expectations of success (e.g., Musu-Gillette, Wigfield, Harring, & Eccles, 2015; Simpkins, Fredricks, & Eccles, 2012; Trautwein et al., 2012; Wang & Eccles, 2013; Wang, Eccles, & Kenny, 2013). For this reason, this thesis relies on ASC as a measure of expectancy, and uses these terms synonymously.

The Value Components

To optimally motivate students' achievement behaviours, theories addressed another fundamental motivational question "Do I want to do the task?", which reflects individuals' beliefs in having a value or reason to do a given task (Eccles et al., 1998). When an individual values a specific task, he/she is more likely to engage in that behaviour. Building the seminal work of early researchers on broad human values (e.g., Battle, 1965; Crandall, 1969; Deci, 1975; Feather, 1982; Rokeach, 1979), modern EVT elaborates four subjective task values (Eccles et al., 1983; Wigfield & Eccles, 1992, 2002).

Intrinsic value. Intrinsic value refers to the enjoyment a person gains from performing an activity. This component is similar to the concept of intrinsic motivation (Ryan & Deci, 2000) and interest (Schiefele, 1999). Students who intrinsically value an activity are more likely to persist and deeply engage in it, leading to increased learning outcomes (Wigfield & Cambria, 2010; Renninger & Hidi, 2011).

Attainment value. Attainment value refers to the personal importance of doing well on a specific task and is linked to the relevance of engaging in a task for the affirmation of one's personal and social identities (Eccles, 2009; Eccles &Wigfield, 2002). The primary distinction between intrinsic value and attainment value is that tasks done for enjoyment are considered intrinsically motivated, whereas attainment value refers to tasks done to affirm individuals' self-image and both personal and social identities (Hulleman, Barron, Kosovich, & Lazowski, 2015). For example, a student may have a high attainment value for physics class because competence in physics allows him/her to confirm important aspects of self. Attainment value becomes more salient, particularly in the secondary school settings with students having more well-articulated identities (Eccles & Wang, 2012).

Utility value. Utility value refers to how a specific task fits within an individual's various short- and long-term plans and objectives. This component is similar to the concept of extrinsic value, and more specifically, to identified regulation defined in self-determination theory as engaging in a given task as a means to an end rather than an end in itself (Ryan & Deci, 2000). An academic task can have high utility value as it facilitates personal benefits, even though it lacks intrinsic value (Eccles & Wigfield, 2002). For instance, an individual

majoring in biology in high school may not feel interested in maths (i.e., intrinsic value), however, taking maths courses may be beneficial as it allows him/her to pursue a medical degree.

Cost. Cost refers to the perceived negative aspects of engaging a specific task in terms of emotional costs, such as performance anxiety and fear of failure, the anticipated effort needed to succeed, and potential loss of opportunities given that making one choice usually results in forfeiting other options (Eccles, 2009; Eccles &Wigfield, 2002). Eccles et al. (1983) noted that the first type of cost was linked to the costs of failure, whereas the other two types of cost reflect the cost of success (e.g., giving up time and energy for valued alternatives). Cost has been the least studied component of task value.

It has been well documented that task value and expectancy are domain-specific, from preadolescence to early adulthood (see Wigfield, Tonks, & Klauda, 2009 for a review, also see subsequent discussion). More recently, research has shown that the four value components can be empirically differentiated in the maths domain (Conley, 2012; Luttrell et al., 2010; Trautwein et al., 2012), with all studies revealing a similar correlation pattern among the value components. More specifically, cost is negatively correlated with intrinsic, utility and attainment values, whereas these three components are positively correlated with each other. Typically, the highest correlations are found between intrinsic and attainment values. Intrinsic value tends to be more highly correlated with expectancy than do the other value components. Indeed, individuals are likely to gain enjoyment for tasks at which they feel competent, and individuals are also likely to develop competence at tasks that they find enjoyable. Substantial relations between competence beliefs and intrinsic value have also been widely proposed in other motivation theories, for example, Harter's (1978) effectance model and Ryan and Deci's (2000) self-determination theory (Wigfield & Eccles, 2002). In relation to achievementrelated outcomes, it has been well documented that expectancy is a stronger predictor of academic achievement than value beliefs, whereas value beliefs are more closely associated with choices behaviours, such as course-taking decision, academic engagement and effort, and educational and career aspirations (e.g., Cole, Bergin, & Whittaker, 2008; Denissen, Zarrett, & Eccles, 2007; Eccles, Barber, & Jozefowicz, 1999; Marsh, Abduljabbar et al., 2013; Nagengast et al., 2011; Perez et al., 2014; Trautwein & Lüdtke, 2009; Wang, 2012; Wang & Eccles, 2013; Watt, Eccles, & Durik, 2006; Watt et al., 2012).

In Studies 1 to 4 of this thesis, intrinsic value and utility value are used, which is in line with typical applications of EVT in research that has seldom incorporated more than two or three of the expected components of value (e.g., Musu-Gillette et al., 2015, Simpkins et al.,

2012; Wang & Eccles, 2013). However, the four value components were included in study 5 to examine the unique contribution of each to the prediction of achievement-related outcomes.

Multiplicative Relation Between Expectancy and Task Value Expectancy-By-Value Interaction in Classical EVT

As noted earlier, EVT had its origin in the early cognitive models in the 1940s and 1950s, superseding earlier behaviourist models (Atkinson, 1957). A core assumption of classical EVT (Atkinson, 1957) was the multiplicative combination of expectancy and task value (i.e., expectancy-by-value interaction). The multiplicative relation between expectancy and value suggests that the relation between expectancy and outcomes depends on the extent to which an individual values a given domain and vice versa.

Typically, the interaction between two independent predictors (i.e., expectancy and task value) has been described as being *compensatory* or *synergistic* in relation to the outcome. The nature of the interactions in relation to the two taxonomies is considerably different, which has theoretical and substantive implications for motivation researchers. Specifically, a compensatory relation suggests that as long as individuals have high expectancy or attach high value to a given academic task, they will be motivated to engage in it. In other words, high expectancy can compensate for low value and vice versa. In contrast, a synergistic relation suggests that both expectancy of success and task value are seen as essential to high task engagement. For example, if a student does not expect to succeed at a task, low outcomes are likely, even in the presence of high value. Likewise, low value should also result in lower outcomes, even when combined with high expectancy. However, expectancy-by-value interactions have invariably occurred in combination with substantial first-order ("main") effects of expectancy and value, complicating the interpretation of the respective effects. For this reason, perhaps, prior EVT research has not fully developed the nature of interactions in relation to *a prior* EVT predictions.

In a review of articles based on the original EVT models, Feather (1982) found a synergistic relation between expectancy and value in predicting a given task. Most early EVT research was conducted in laboratory settings (e.g., Atkinson, 1957; Atkinson & Feather, 1966; Feather, 1959). In many studies, expectancy (ability self-concept) or value was experimentally manipulated to be "zero" through random assignment to conditions (see Feather, 1982 for more discussion).

In modern EVT, Eccles (2009, p. 84) has noted that "the motivational power of ability self-concepts to influence task choice is, at least partially, determined by the value individuals attach to engaging in the domain". However, the relationship between expectancy and value is often implicitly assumed to be purely additive in nature, which implies that ASC and value

would predict achievement-related outcomes uniquely and independently. This may be because over time a greater emphasis on non-experimental studies in modern EVT research and the subsequent methodological complications this entails. The lack of modern research including an interaction term led Nagengast et al. (2011) to ask: "Who took the "x" out of expectancy-value theory?". One major focus of this thesis is to utilise modern statistical approaches to re-introduce the ExV interaction back into EVT.

Reasons for the Omission of Expectancy-By-Value Interaction in Modern EVT

There are several reasons for the omission of the expectancy-by-value interaction in modern EVT research. First, the omission of the expectancy-by-value interaction may be partly due to the shift from experimental designs focusing on within-person (intraindividual) differences to real-world settings focusing on between-persons (interindividual) differences (Nagengast et al., 2011; Trautwein et al., 2012). In experimental research, expectancy, value and task difficulties were operationally defined and directly manipulated. The stronger the manipulation is, the larger the differences between the experimental factors are likely to be. However, modern EVT (Eccles, 2009; Eccles et al., 1983) places the relationship of expectancy and value in real-world contexts by linking them to achievement-related outcomes in typical school settings. In the real-world environment, expectancy and value are assessed by surveys and questionnaires, which lead to the focus shifting from experimentally manipulated differences (which were necessarily uncorrelated by design) in different tasks to naturally occurring differences in the various components of value (Busemeyer & Jones, 1983; Nagengast et al., 2011; Trautwein et al., 2012). Thus, examination of interaction effect was based on those naturally occurring between-persons differences in expectancy and value (Trautwein et al., 2012).

Even when empirically evaluated in survey research, interaction effects have typically been small to moderate in size in observational studies (Aiken & West, 1991; Marsh, Hau, Wen, Nagengast, & Morin, 2013; McClelland & Judd, 1993; Trautwein et al., 2012). In experimental studies, expectancy and value can be manipulated by research to more extreme levels in order to amplify interaction effects (Nagengast et al., 2011; Trautwein et al., 2012, 2013). However, in non-experimental, empirical settings, cases with extreme conditions (e.g., very high expectancy coupled with extremely low task value) are sparse, which results in more difficulties in detecting interaction effects. In particular, when expectancy and value are highly correlated the empirical studies seeking to locate expectancy-by-value interaction effects might be underpowered (Aiken & West, 1991).

Second, the paucity of empirical research on expectancy-by-value interaction could be due to the lack of advanced statistical techniques suited to assess expectancy-by-value

interactions. Although interaction effects can be detected in multiple regression analysis using manifest variables, the interaction effects are likely to be underestimated (Carroll, Ruppert, Stefanski, & Crainiceanu, 2006; Marsh, Hau et al., 2013). The reason is that the predictors are measured with error and this measurement error combines multiplicatively in forming the product terms (Marsh, Hau et al., 2013). This leads to product terms being more unreliable and more difficult to detect (MacCallum & Mar, 1995; Marsh, Hau et al., 2013). Thus, estimation of true interaction effects requires large sample sizes and reliable predictors to avoid Type 2 errors (i.e., failure to detect a statistically significant interaction, even though one exists) (Trautwein et al., 2012).

Structural equation modeling (SEM) (Bollen, 1989) techniques that control for measurement error by assessing latent variables with multiple indicators provide a solution to tackle interaction effects in non-experimental designs. Although there has been increasing attention paid to models with latent interaction since the 1980s (Kenny & Judd, 1984; Jöreskog & Yang, 1996; Ping, 1995, 1996), it has only recently become easily accessible for applied researchers, such as the latent moderated structural equation approach (LMS) (Klein & Moosbrugger, 2000) and the unconstrained product indicator approach (Marsh, Wen, & Hau, 2004) (see further discussion in the next chapter).

Empirical Evidence for Expectancy-By-Value Interaction

Based on these approaches, there is some recent empirical support for latent expectancy-by-value interactions. For example, Trautwein et al. (2012), in a study based on German secondary school data, examined the latent interactions between ASC and each of the four value components in predicting academic achievement separately. The findings showed that the four multiplicative terms (i.e., ASC-by-value) had statistically significant and positive effects on English and maths achievement, suggesting a synergistic relationship. In addition, Nagengast et al. (2011) similarly tested latent interactions of science ASC and intrinsic value on extracurricular activities and career aspirations in science, and found a similar synergistic relationship across 57 countries based on the Programme for International Student Assessment (PISA) 2006 data. Finally, Nagengast et al. (2013), drawing on a within-person perspective (i.e., studying homework across six domains: German, English, history, maths, physics, and biology), and using multilevel SEM with latent interactions, also showed that ASC and value (combination of utility value and cost) synergistically interacted in predicting within-person homework effort.

Although these empirical studies successfully reintroduced the multiplicative relation between expectancy and value in motivation research, three important limitations need to be addressed. First, existing studies have only considered one value component and its interaction with ASC in one SEM model when testing latent interactions, although modern EVT proposed that expectancy and each value component simultaneously influence achievementrelated choices and performance. This makes is difficult to evaluate the relative and unique effects of different value components, particularly as they tend to be at least moderately correlated.

Second, these studies are all based on expectancy and value measures from a single wave of data. Longitudinal studies with other critical behavioural choices, such as coursework taking-decision, aspirations and school engagement, would allow us to examine how well expectancy-by-value interaction generalise to diverse outcomes to draw stronger conclusions for the importance of expectancy-by-value interaction in modern EVT.

Third, recent studies of expectancy-by-value interactions (Nagengast et al., 2011; Trautwein et al., 2012) have argued that support for EVT implies a synergistic expectancy-byvalue interaction, suggesting that a compensatory interaction might not support EVT. However, there has been insufficient attention given to the nature of first-order effects ("main" effects of ASC and value) and interaction (ASC-by-value) effects as providing support for EVT predictions. Although it is essentially true that positive interaction effects tend to indicate synergistic relations and negative interaction effects tend to indicate compensatory relations, the interpretation of the results in relation to EVT fundamentally depends on the simultaneous consideration of both first-order and interactions effects, particularly in the case in which expectancy and value beliefs are not orthogonal. Superficial interpretations of interaction effects without also taking into account the size and nature of the first-order effects can be misleading. Instead, interpretation of interaction effects should always be based on a graph of the results in relation to a priori predictions.

To fill the gaps in the literature, this thesis includes multiple value components and ASC in one SEM model and examines their interactions in predicting a wide range of achievement-related choices and performance (e.g., high school maths coursework selection and aspirations, university major selection, educational attainment) based on both cross-sectional and longitudinal data. Also, it provides a more complete evaluation of the nature of multiplicative relation in support for EVT by juxtaposing the recent literature and the results of the five studies in this thesis.

To summarise, very recent but limited EVT research has "rediscovered" the expectancy-by-value interaction that was a cornerstone of classical EVT research but seemed to have disappeared until very recently. The proposition of expectancy-by-value interaction has important theoretical and practical implications for motivation researchers. For example,

tackling either expectancy or value in isolation in one subject domain is unlikely to be an effective way to promote students' engagement in that domain. Of particular importance in this thesis is the examination of prediction of expectancy-by-value interaction in relation to modern EVT.

Integration of ASC Theory into EVT

As noted earlier, the expectancy component of EVT is typically operationalised by ASC in educational research (Eccles & Wigfield, 2002; Eccles, 2009), and therefore processes associated with ASC described here play important roles in EVT processes. Following Shavelson, Hubner, and Stanton's (1976) seminal article, ASC research in education has been dominated by several theoretical models (i.e., the multidimensional and domain-specific self-concept model, the REM model, the I/E model with its extension to DCT) based on Marsh's research programme (Marsh, 2007). However, these theoretical considerations have not been well integrated into EVT (Marsh, 2007). We begin by briefly reviewing each theoretical model used in this thesis and then propose a novel implication for EVT and an innovative integration of EVT and ASC research.

Self-concept

In the literature, self-concept is broadly defined as a construct related to an individual's perception of themselves, and is posited to be a multifaceted, hierarchical construct including academic and non-academic self-concept (Shavelson et al., 1976; Marsh & Shavelson, 1985; also see subsequent discussion). Self-concept is formed through experience with interpretations of an individual's environment, particularly of evaluations by significant others. A positive self-concept is valued as an important variable in many disciplines of psychology, such as educational, developmental and social psychology, and has been shown to be a critical mediator facilitating attainment of other desirable outcomes (e.g., Seligman & Csikszentmihalyi, 2000; Marsh & Craven, 2006). In educational settings, a positive ASC is positively associated with academic achievement (Marsh & Craven, 2006) and choice behaviours (e.g., coursework selection) (Parker et al., 2012, Parker, Marsh et al., 2014). Furthermore, ASC has been found to be an important predictor of other desirable educational outcomes, such as academic engagement and effort (Skaalvik & Rankin, 1995; Skinner, Wellborn, & Connell, 1990), persistence (Skaalvik & Rankin, 1996), educational and career aspirations (Marsh, Abduljabbar et al., 2013; Nagengast & Marsh, 2012), and longterm educational attainment (Marsh & O'Mara, 2008, 2010; Guay, Larose, & Boivin, 2004).

Multidimensional and Domain Specific

Shavelson et al. (1976) initially posited that ASC is a multidimensional, hierarchical construct in which different school subjects (i.e., maths, English, history, science) of ASC are

highly correlated; forming a single higher-order construct (see Figure 2.2). However, based on subsequent empirical studies, Marsh and Shavelson (1985; also see Marsh, Byrne, & Shavelson, 1988) found that maths ASC was nearly uncorrelated with verbal ASC, whereas students' achievements in the subjects were highly correlated. They posited a revised model of ASC, known as the Marsh/Shavelson model, that comprised two higher-order ASC factors (maths and verbal) and a continuum of ASC factors in various school subjects ranging from maths ASC at one end to verbal ASC at the other end (Marsh, 2007) (see Figure 2.3). More specifically, physics and chemistry are assumed to be located closer to the maths domain, whereas biology is assumed to be located close to the middle of the continuum. In addition, more verbal subjects (i.e., foreign languages and history) are assumed to be located closer to the verbal half of the verbal-maths continuum.



Figure 2.2 The Shavelson et al. academic self-concept model (Shavelson et al., 1976). Adapted from "Self-Concept: Validation of Construct Interpretations," by R. J. Shavelson, J. J. Hubner, and G. C. Stanton, 1976, *Review of Educational Research*, 46, 413. Copyright 1976 by Sage.



Figure 2.3 The Marsh/Shavelson model in relation to the verbal-mathematical continuum of ASC (Marsh & Shavelson, 1985)

Note. English refers to the native language verbal domain.

The validity of the revised model of ASC (Marsh & Shavelson, 1985) has been well supported by considerable empirical studies, which consistently show the distinction of maths and verbal ASC (e.g. Marsh, 1990; Marsh & Hau, 2004; Marsh et al., 1988, 2014). In addition, a wide variety of research has demonstrated this domain specificity of maths and verbal ASC in relation to external criteria (e.g., academic achievement, grades and course selection) (Arens, Yeung, Craven, & Hasselhorn, 2011; Marsh, Lüdtke et al., 2015; Marsh & Yeung, 1997; Parker et al., 2012). In general, verbal ASC is more strongly related to verbal outcomes, whereas maths ASC is more strongly related to maths outcomes.

Furthermore, the distinction of maths and verbal components were systematically observed for task value across preadolescence into early adulthood of task value (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Watt, 2004; Chow et al., 2012; Simpkins et al., 2012; Wigfield & Eccles, 2002; also see Wigfield et al., 2009 for a review). However, most of this EVT research treated task value as a single, value scale (e.g., Jacobs et al., 2002; Watt, 2004) or only focused on intrinsic value (Denissen et al., 2007; Wang et al., 2013; Wigfield, Eccles, Mac Iver, Reuman, & Midgley, 1991), seldom including other value components. An exception is that Xu (2010) who juxtaposed ASC, intrinsic value, and utility value and found that utility value was less distinctive (higher correlation between mathematic and verbal utility value) than intrinsic value and ASC between maths and verbal domains.

Domain specificity of motivational beliefs in science. Marsh (1990) successfully separated physics responses from general science and found that the correlation between the two factors was moderate for students attending Grades 7 to 10 (r = .553) and somewhat smaller for their younger counterparts attending Grades 5 and 6 (r = .241) based on a confirmatory factor analysis (CFA) approach. However, subsequent motivation studies in the literature that have taken ASC in multiple science domains into account are sparse. Rather, these studies considered ASC in science either as a relatively unidimensional construct or focused on one science subdiscipline (e.g., Chow et al., 2012; Chiu, 2008; 2012; Goetz, Cronjaeger, Frenzal, Lüdtke, & Hall, 2010; Marsh, Abduljabbar et al., 2013; Nagy et al., 2006, 2008). For example, a recent cross-cultural study based on the Trends in International Mathematics and Science Study (TIMSS) 2007 dataset found that mathematic ASC was modestly correlated with general science ASC and both ASC responses were highly correlated with matching academic achievement and coursework aspirations (Marsh, Abduljabbar et al., 2013; also see Chiu, 2008; 2012). Interestingly, Marsh et al. (2013) also incorporated intrinsic value and utility value and revealed that the pattern of results for
intrinsic value was similar to that for ASC, but utility value appeared to be less domainspecific than ASC and intrinsic value. In relation to external criteria, ASC was more strongly related to matching achievement, whereas intrinsic value was more strongly related to matching coursework aspiration (Marsh, Abduljabbar et al., 2013, also see Nagy et al., 2006).

More recently, research has begun to examine domain-specific motivational beliefs among science domains (e.g., Jansen, Schroeders, & Lüdtke, 2014; Jansen, Schroeders, Lüdtke, & Marsh, 2015; Marsh, Lüdtke et al., 2015; Parker, Nagy et al., 2014). For instance, using a large nationally representative sample of German high school students (N = 44,584), Jasen et al. (2015) found that correlations among ASC factors in physics, chemistry and biology were moderate and each of the three ASC factors was highly correlated with corresponding achievement scores and grades. More specifically, consistent with the verbalmathematical continuum posited in the Marsh/Shavelson model (see Figure 2.3), the correlation between physics and chemistry ASC factors. Similar patterns of results were also evident in recent empirical studies (Jansen et al., 2014; Marsh, Lüdtke et al., 2015). However, there has been much less empirical research on the factor structure of value beliefs among multiple science domains (Wang & Degol, 2013).

To summarise, both ASC and value beliefs are both theorised as multidimensional, hierarchically ordered constructs that are the main drivers of student achievement performance and choices. However, in comparison to ASC, the factor structure of task value has not been fully evaluated in relation to multiple value dimensions and different subject domains, particularly within science subdisciplines. Given that motivationally and behaviourally opting out of school subjects makes it very difficult to re-join them in later years (Watt, 2010; Sells, 1980), the distinctiveness of ASC and value beliefs in secondary school provides insight into how students initiate educational and career trajectories in various disciplines. This thesis provides a more thorough evaluation of domain specificity of the four value components in relation to reading, maths and multiple science domains.

Reciprocal Effect Model (REM)

ASC and academic achievement are substantially correlated, but this finding leaves unanswered the critically important question of their temporal ordering. Historically, theoretical models contrasted one-directional predictions but researchers did not have appropriate statistical models to contrast these predictions. By the integration of the skill development model, which proposed that academic achievement affects ASC, and the selfenhancement model, which proposed that ASC affects academic achievement, Marsh and his colleagues (Marsh, 2007; Marsh & Craven, 2006) postulated a reciprocal effects model (REM)

in which prior ASC influences subsequent achievement and prior achievement influences subsequent ASC.

More specifically, as depicted in Figure 2.4, the REM posits: (a) strong positive paths from prior measure of ASC and achievement to subsequent measure of the corresponding constructs (solid grey lines); (b) positive paths from prior ASC to subsequent achievement (solid black lines); (c) positive paths from prior achievement to subsequent ASC (dashed line). The generalisability of the REM has been widely supported in numerous empirical studies across diverse samples of adolescents and subject domains in different ASC instruments (e.g., Huang, 2011; Marsh & O'Mara, 2008; Möller, Retelsdorf, Köller, & Marsh, 2011; see metaanalysis by Valentine & DuBois, 2005; Valentine, DuBios, & Cooper, 2004).





Note. ASC = academic self-concept; ACH = academic achievement; solid black lines indicate the effects of prior ASC on subsequent achievement, whereas dashed lines indicate the effects of prior achievement on subsequent ASC; horizon lines (solid grey) link the same variable across multiple waves indicates stability. Within-time associations between constructs were specified by the inclusion of time-specific covariance relationships (i.e., ASC is correlated to motivation factors at T4). In ASC, the residual variances among the corresponding indicators are allowed to correlate over time.

Consistent with the REM, modern EVT postulates that students' motivational beliefs as a function of achievement-related activities (e.g., prior academic achievement) influence subsequent academic performance and behaviours (Eccles et al., 1983). However, in contrast to ASC studies, researchers have not fully addressed the temporal ordering of EVT constructs in relation to achievement or other educational outcomes. For example, research focusing on the interest component of value (e.g., intrinsic value) suggests that ASC is causally predominant over intrinsic value and that the effects of intrinsic value are substantially attenuated when controlling for ASC (Köller, Baumert, & Schnabel, 2001; Marsh, Trautwein et al., 2005). More recently, Pinxten, Marsh, De Fraine, Van Den Noortgate, and Van Damme (2014) incorporated ASC and intrinsic value with academic achievement and found strong

support for REM in relation to ASC but somewhat weaker support in relation to intrinsic value from Grades 3 to 7. However, few studies have considered other value components (e.g., utility value) to explore the reciprocal relationship with academic achievement.

In summary, the reciprocal temporal ordering of ASC and achievement is well established in the literature. However, studies examining REM in relation to value beliefs or different achievement-related outcomes are sparse. The temporal ordering between motivational beliefs and educational outcomes has fundamental implications for their application. For instance, the reciprocal relationships of ASC and intrinsic value with academic achievement suggest that educators should strive to improve both ASC and intrinsic value along with achievement in order to produce positive changes in each of these constructs. In order to bridge these gaps in empirical evidence, this thesis integrates REM into EVT and tests ASC, value beliefs, and various educational outcomes (e.g., academic achievement, educational and career aspirations), particularly during the transition from late adolescence to adulthood.

The Frame of Reference Effects Based on ASC Theory

Dating back to James (1890–1963), psychologists have long understood that selfbeliefs are partially dependent on evaluations of objective achievements relating to frames of reference (Marsh, 2007). Thus, different frames of reference or standards of comparison can result in individuals' disparate ASCs even if they have identical objective ability (Möller & Marsh, 2013). The two most generally posited frames of reference used to explain selfevaluations are social comparisons (Biernat & Eidelman, 2007; Dijkstra, Kuyper, van der Werf, Buunk, & van der Zee, 2008) and temporal comparisons (Albert, 1977; Möller, Pohlmann, Köller, & Marsh, 2009; Wilson & Ross, 2000;). Self-perceptions partially depend on how individuals compare their current abilities and performances not only with their own prior abilities and performances (i.e., temporal comparisons) but also with those of peers (i.e., social comparisons) (Marsh, 2007). Recently, drawing on a variety of theoretical approaches, researchers in educational psychology suggest that self-perceptions may also be influenced by internal comparisons (Marsh, 1986, 2007; Möller & Marsh, 2013). However, Möller and Marsh (2013) highlight that dimensional comparison theory (DCT) that draws on an internal frame of reference (Marsh, 1986) are presented as "a largely neglected but influential processes in self-evaluation" (p. 544). Particularly, a growing number of studies based on the internal/external frame of reference (I/E) model (Marsh, 1986) have shown that selfperceptions may also be formed as a function of internal comparisons, in which accomplishments in one particular subject domain can serve as a frame of reference for other subject domains—sometimes referred to as "dimensional comparisons" (e.g. Möller & Marsh;

2013; Marsh et al., 2014; Marsh, Lüdtke et al., 2015). Although there is theoretical and empirical support for the I/E model and DCT in ASC research, this thesis extends this research in order to integrate it with EVT.

Internal/external frame-of-reference (I/E) model. The I/E model posited what at the time seemed to be paradoxical relations among subject-specific ASCs and achievement to explain near zero-correlation between maths and verbal ASC even though achievement in these two domains were highly correlated (Marsh, 1986, 2007). According to the I/E model (Figure 2.5), students form both verbal and maths ASCs as a function of two underlying comparison processes or frames of reference: a) externally comparing their self-perceived performance in a subject domain with that of their peers in the same school or classroom (i.e., an external frame of reference); and b) by internally comparing their performances in one particular subject domain against their performances in other subject domains (i.e., an internal frame of reference). This internal comparison is an ipsative process, such that an increase in ASC for one subject domain (i.e., verbal or maths) corresponds to a decrease in ASC in another domain (Marsh, 2007). Hence, this ipsative ranking process leads to achievement in one domain being negatively associated with ASC in another domain.



Figure 2.5 The internal/external frame of reference (I/E) model between verbal and maths domains (Marsh, 2007).

Note. The horizontal paths (solid grey lines) leading from achievement to ASC in the same domain are predicted to substantial and positive (++), whereas the cross paths (solid black lines) leading from achievement in one domain to ASC in a non-matching domain are predicted smaller and negative (-).

The I/E model for ASC and achievement based on verbal and maths constructs has been supported by longitudinal, cross-cultural and experimental studies (e.g., Marsh, 2007; Marsh & Hau, 2004; Möller et al., 2011; Parker, Marsh, Lüdtke, & Trautwein, 2013; Pohlman & Möller, 2009). A recent meta-analysis based on 69 datasets (N = 125,308) provided strong support for the I/E model by simultaneously evaluating the effects of maths and verbal

achievements on ASCs (Möller et al., 2009). More specifically, maths and verbal achievements were highly correlated (.67), whereas correlations between maths and verbal ASCs were substantially weaker (.10). The external comparison processes lead to substantively positive predictions of achievement to ASC in the matching domain (.49 for verbal, .61 for math). However, the internal comparison processes led to a significantly negative prediction of verbal achievement in maths ASC (-.27) as well as that of maths achievement in verbal ASC (-.21). The results generalised across different measures of achievement ASC as well as age, gender and country groups, supporting the robustness of I/E predictions in relation to a classic I/E model.

As discussed earlier, modern EVT (Eccles, 2009, 2011) posits that expectancy and task value are multidimensional and hierarchical constructs; previous achievement-related activities and accomplishments (e.g., prior domain-specific achievement) affect students' expectancies and how they prioritise or rank task value across various subject domains. In turn, the *relative* intraindividual hierarchies of expectancy and value influence subsequent behavioural choices in a particular domain. When students select the activities they want to pursue, domain comparisons within individuals are triggered as they tend to select those activities that they think they can master and that have the highest value for them (Eccles, 2009, 2011). All such behavioural choices are considered to be associated with costs, given that (following an ipsative-like process) selecting one option often results in forfeiting other options (Eccles, 2009; Chow et al., 2012; Schwartz, 2004). Also, Eccles (2009, p. 84, 2011) further suggests that in the formation of ASC, "both external and internal comparison processes are key—people assess their own skills by comparing their performances with those of other people and with their own performances across domains".

The internal comparison process described in the I/E model posits that students use their accomplishments in one domain (e.g., maths vs. verbal) to evaluate their accomplishment in the other, leading to the extreme domain specificity of ASCs. Xu (2011) found I/E-like patterns for ASC and intrinsic value, but they were much weaker for attainment value and utility value. One explanation, based on modern EVT (Eccles, 2009), might be that the formation of utility value and attainment value is more related to an individual's personal and collective identities, whereas intrinsic value is more related to performance-based experiences (also see Marsh, Martin, & Debus, 2001). However, there is insufficient research on the generalisability of the internal comparison process to different motivational constructs and particularly the EVT value components in EVT.

Dimensional comparison theory (DCT). More recently, the I/E model has been extended into DCT by incorporating a wider variety of domains in addition to maths and

verbal domains. Theoretically, the extension of the I/E model into DCT is based on a prior continuum of academic domains that vary between the maths and verbal endpoints The ordering of subject domains along the verbal-to-maths continuum is based on the theoretical and empirical research that led to the Marsh/Shavelson model (Marsh, 1990; Marsh et al., 1988) (see Figure 2.3, also see earlier discussion). DCT postulates that ASCs are formed not only by contrasting but also by assimilating dimensional comparisons. Contrasting dimensional comparison processes predict that good performance in one domain leads to lower ASC in other domains (like contrast effects posited in the traditional I/E model based on maths and verbal domains). On the other hand, assimilating dimensional comparison processes are characterised by good performance in one domain leading to higher ASC in other domains (i.e., assimilation effects). The critical feature of DCT is the cross-paths involving "near" and "far" comparisons, which relates to how students determine similarity of different subject domains (Marsh et al., 2014; Marsh, Lüdtke et al., 2015). According to the maths-verbal continuum of school subjects, DCT posits that cross-paths involving "near" comparisons are substantively less negative and may even be positive (i.e., assimilation effect: Marsh, Lüdtke et al., 2015). For example, near domains (i.e., physics vs. chemistry, native language vs. foreign language) may be seen as similar or complementary domains, which results in positive cross-paths leading from one domain to ASC in the other domain. However, significantly negative cross paths leading from achievement occur between far domains (physics vs. verbal, maths vs. foreign language), in particular between the maths and verbal domains that are at opposite ends of the maths-verbal continuum of ASCs.

There is more recent empirical support for DCT predictions across multiple subject domains (i.e., maths, physics, chemistry, biology, foreign language, native language) (Marsh et al., 2014; Marsh, Lüdtke et al., 2015; Jansen et al., 2014, 2015). For instance, drawing on large samples of German high school students, Jansen et al. (2015) extended a classic I/E model (in relation to maths and verbal) with three science domains (physics, chemistry, and biology) and found a substantially positive effect of achievement on the matching measure of ASC (i.e., the horizontal path) across the five domains. More importantly, in relation to crosspaths, physics, chemistry and, in particular maths had contrast effects on German, whereas small assimilation effects were found between maths, physics, and chemistry. Nevertheless, apparently very little research has examined the internal comparison process posited in DCT for value beliefs.

Internal comparisons process for the prediction of achievement-related behaviours. The internal comparison process that is such a critical process in the I/E model and dimensional comparison theory was subsequently integrated into EVT (Marsh & Yeung,

1997). However, it is only recently that studies have begun to integrate both models in the study of behaviour choices, such as coursework selection in high school (Nagy et al., 2006; 2008) and university major selection and career aspirations (Parker et al., 2012; Parker, Nagy et al., 2014).

Recent research has integrated the notions of EVT and the I/E model with its extension to DCT and found that internal comparison between maths and verbal domains are useful for predicting both achievement-related coursework choices and aspirations. (Nagy et al., 2008; Parker et al., 2012). For example, high ASC and ability in the verbal domain led to low coursework aspirations in maths, after controlling maths ASC and ability (Nagy et al., 2008; Parker et al., 2012). More recently, Parker, Nagy et al. (2014) extended this research and tested the role of internal comparison processes in predicting students' career aspirations in multiple major domains. Specifically, Parker, Nagy et al. (2014) found that high maths ASC was associated with a greater likelihood of aspiring to a career in maths, physics, and engineering, rather than biological/medical sciences, whereas high English ASC was associated with a greater likelihood of having career aspirations in biological/medical sciences rather than in maths, physics, and engineering. These ASCs were positively predicted by achievement in the same domain but negatively predicted by achievement in another domain. However, Parker, Nagy et al. (2014) only compared ASCs between maths and verbal domains, which are perceived as maximally dissimilar dimensions (Möller & Marsh, 2013) and are placed at the end points of the academic continuum (Marsh, 1990). This leaves open the question as to whether students engage in assimilating dimension comparisons between similar domains that are close to each other on the continuum (e.g., physics and chemistry) during the decision-making process. To fill this gap, this thesis integrates the comparison process posited in DCT into EVT to explore how the comparison process is associated with the formations of ASC and value beliefs, as well as behavioural choices (e.g., coursework selection and aspirations), across multiple subject domains in addition to maths and verbal domains.

To summarise, it is important to evaluate the integration of EVT and the internal comparison processes posited in the I/E model and DCT, in which outcomes in any one domain depend not only on accomplishments, on ASC beliefs, and on value perceptions in that domain, but also on how these constructs compare to those in other, contrasting domains. In the literature, such internal comparison processes were found to play an important role in forming students' ASC and subsequently shaping achievement-related performance and choices. However, there is insufficient research of the generalisability of the internal

comparison process to different components of task value, particularly among multiple science domains.

Background Factors (Gender and Socioeconomic Status) in Relation to Modern EVT

According to modern EVT (Eccles, 2009; Eccles et al., 1983), a set of social and cultural factors (e.g., gender role socialisation and SES) are assumed to influence individuals' achievement-related choices and performance through the relationship with expectancy and task value.

Gender

Historical stereotypes about male superiority in maths and science are in direct contrast to growing evidence of gender similarities in maths achievement (Else-Quest, et al., 2010; Hyde et al., 1990; Lindberg, Hyde, Petersen, & Linn, 2010). However, it has been well documented that boys tend to have higher maths ASCs than girls (Marsh et al., 2013; Marsh & Hau, 2007; Parker et al., 2012, 2014; Wigfield et al., 1997). Gender differences in value beliefs depend on the operationalisation of value beliefs and differences in the value dimensions incorporated (Gaspard et al., 2015). For example, there was no gender difference in maths task value when treated as a single, general value scale (Jacobs et al., 2002; Wang, 2012; Wang & Eccles, 2013). Research that differentiated value components found that boys had a higher intrinsic value in maths (Nagy et al., 2006, 2008; Watt et al., 2012) and perceived maths as more useful than girls (Eccles et al., 1999; Marsh, Abduljabbar, et al., 2013; Updegraff, Eccles, Barber, & O'Brien, 1996). Importantly, these differences in motivational beliefs predict disproportionate gendered course-taking in maths (Eccles et al., 1999; Nagy et al., 2006, 2008; Wang, 2012; Watt et al., 2012) and subsequent maths-intensive major selection in university (Parker et al., 2012; Parker, Nagy et al., 2014).

Furthermore, to understand better the gendered processes underlying the choice of educational pathways, Eccles (2009) suggests that research should focus on gender differences, not only in the mean level of motivational beliefs and educational choices but also in the relationships between these constructs. However, on the basis of EVT, the extant research investigating gender as a moderator has been limited and has yielded mixed evidence (e.g., Simpkins et al., 2012; Wang, 2012; Watt et al., 2012). For example, based on a multicohort study using data from Australia, Canada, and the United States, maths utility value was found to be a stronger unique predictor of female adolescents' maths-related career choices compared to maths ASC and intrinsic value (Watt et al., 2012). In contrast, Wang (2012) found that the relations between maths ASC and task value and maths-related career

aspirations and maths course enrolment are invariant across gender based on U.S. high school students.

Socioeconomic Status

Family background also plays an important role in achievement-related choices. Children growing up in families where parents have high educational levels and occupational status, and provide more cultural capital (i.e., cultural possessions such as books, tutors and computers) are more likely to have higher academic achievement (Chiu & Xihua, 2008), enter universities (Bowen et al., 2009; Bourdieu & Passeron, 1977; Eccles, Vida, & Barber, 2004; Hillmert & Jacob, 2010) and take STEM-related subjects or majors in colleges and universities (Gorard & See, 2009; Sciarra, 2010; Trusty & Ng, 2000). In addition, consistent with modern EVT (Eccles, 2009), multiple studies have demonstrated that SES influences entry into university and pursuing a science-related career through its association with children's ASC (Parker et al., 2012; Parker, Marsh et al., 2014; Schoon, Ross, & Martin, 2007) and task value (e.g., utility value; Wood, Kurtz-Costes, & Copping, 2011).

To summarise, although research found that motivation factors are important mediators of the relations between background factors (gender and SES) and educational outcomes, very few studies have considered both ASC and multiple value beliefs simultaneously when investigating the mediating role of motivation factors. This thesis included ASC and multiple value beliefs as potential mediators, and further explored the nature of the relations between gender and SES, and achievement related outcomes. Whether such relations are moderated by gender is also examined. furthermore, from a cross-cultural perspective, the modern EVT was originally designed to explain a sociocultural phenomenon, in which cultural differences not only shape the way education is valued but also the way in which self-beliefs are constructed and encouraged (Wigfield & Eccles, 2002; Wigfield et al., 2009). However, in extant EVT research, the role of culture in students' motivational dynamics has often been neglected. Drawing on multiple large datsets, whether the effects of gender and SES vary by different cultural groups is also addressed.

Research Questions of this Thesis

Drawing on the EVT framework and its integration with ASC theory, this thesis provided a comprehensive test of the roles of students' ASC and value beliefs in the process leading to different educational and career pathways, with a focus on STEM pathways. First, this thesis examined the differential effects of ASC and multiple value components on achievement-related outcomes (e.g., high school maths course selection and science course aspirations, university STEM major enrolment), which was proposed in modern EVT but has not been well studied. In addition, this thesis tested the multiplicative relation between ASC

and value beliefs in predicting educational outcomes, which was the historical cornerstone of classic EVT (Atkinson, 1957) but it seemed to have mysteriously disappeared from the modern EVT model (Nagengast et al., 2011; Trautwein et al., 2012). Furthermore, this thesis integrated three of the main theoretical models in ASC research (domain specificity, REM, and I/E model) into EVT, and examined how these models generalise to different components of task value with various achievement-related outcomes.

In this thesis, four representative national/international databases were used. Specifically, studies 1 and 4 drew on the TIMSS datasets (i.e., TIMSS1999, 2003, and 2007). TIMSS is the fourth in a cycle of internationally comparative assessments designed to provide researchers, educators and practitioners with information about educational achievement and learning contexts in maths and science around the world. The data used in study 2 came from a five-wave longitudinal follow-up study — the US Youth in Transition study (YIT) (Bachman & O'Malley, 1977; also see Bachman, 2001, 2002). The data used in study 3 came from the 2003 cohort of the Longitudinal Study of Australian Youth (LSAY03) extension of the PISA 2003 (OECD, 2005a). Like TIMSS, the PISA database is designed to provide internationally comparable evidence of student performance and related competencies. However, it mainly focuses on the Organisation for Economic Co-operation and Development (OECD) countries and one school subject domain in one wave. Finally, the dataset used in study 5 (see Gaspard et al., 2015) was part of the larger *Motivation in Mathematics* (MoMa) project drawing from 9th grade high school students from 82 classes in 25 academic track schools (*Gymnasium schools*) in Germany.

This thesis was based on secondary data analyses which have provided great benefits for research in social science (Elder, 1998; Elder, Pavalko, & Clipp, 1993). The secondary data analysis can be defined as the re-use of the initial data in creative, innovative, and novel ways for offering new insights into theory and addressing substantively issues that benefit policymakers and broader community (Kum & Ahalt, 2013). The databases covering reliable and valid measures of multiple value components positive in EVT with ASC based on large samples are sparse, which is particularly important for detecting latent interaction (see above discussion). However, this thesis utilised multiple datasets based on nationally representative samples, which allowed exploring the unique and combined contributions of ASC and different value components to predict a wide range of achievement-related outcomes. Thus, the generalisability of the results across countries and student cohorts was examined in this thesis, aiming to provide a more comprehensive picture of the student decision-making process leading to STEM-related educational and career pathways.

Overarching Research Questions

One of the central contributions of this thesis was to probe the predictive contributions of ASC, task values, and their interactions on achievement-related outcomes. More precisely, this thesis examined the unique effects of ASC and multiple value components, as well as their combined effects (i.e., ASC-by-value interactions), on a wide range of achievement-related outcomes. Importantly, it evaluated whether the interaction effect along with the first-order effect of ASC and value beliefs are consistent with modern EVT. Recent studies on ASC-by-value interaction (e.g., Nagengast et al., 2011; Trautwein et al., 2012) have not considered the first-order and interaction effects of more than one value component with self-concept in the same model. This research gap was addressed in this thesis. Thus, this thesis provides strong tests on how the interactive roles of ASC and value play in predicting diverse achievement-related outcomes.

Specific Research Questions of the Five Empirical Studies

In the education domain, based on modern EVT (Eccles, 2009; Eccles et al., 1983), expectancies of future success in the various subject domains and the subjective value students attach to these various domains have been well documented as two key components to explain students' achievement-related choices and performance (Wigfield et al., 2009; Wang & Degol, 2013). On the other hand, based on the hierarchical and multidimensional factor structure of ASC, a large body of ASC research has demonstrated how internal processes are associated with the formation of ASC, which in turn influences achievement-related outcomes (coursework selection, engagement, subsequent achievement, educational aspirations, and subsequent university attendance) (Marsh, 2007, Marsh & O'Mara, 2010; Nagengast et al., 2012; Parker et al., 2012; Parker, Nagy et al., 2014). Although the expectancy component of EVT is typically represented by ASC, the theoretical models posited in ASC theory have not been well integrated into modern EVT.

More specifically, although value beliefs are theorised as a multidimensional, multidomain, and hierarchically ordered construct, the extant EVT research has not fully tested this structure, the relative importance of the lower-order and the higher-order (global) component, and the content domain specificity of the specific components (studies 4 and 5). Furthermore, modern EVT assumes that components of value as a function of previous achievement-related experience lead to enhanced subsequent achievement-related outcomes. However, in contrast to ASC studies, researchers have not fully addressed the temporal ordering of value beliefs in relation to achievement or other educational outcomes (study 2). Finally, the internal (i.e., ipsative) comparison process posited in the I/E model has been wellarticulated in modern EVT (Eccles, 2009, 2011). However, little EVT research investigates

how internal comparison processes influences the formation of value beliefs and subsequent behavioural choices (studies 3 and 4).

Furthermore, two background variables (gender and SES) were incorporated to examine the mediating roles of ASC and value beliefs as well as gendered processes underlying students' behavioural choices (studies 1 and 3). Thus, the present investigation advances our understanding of women's underrepresentation in some STEM pathways and of how SES influences the process underlying choice of these pathways.

In addition to the examination of ASC-by-value interaction, the specific research questions of the five empirical studies as now elaborated:

Study 1 (*Expectancy-value in mathematics, gender and socioeconomic background as predictors of achievement and aspirations: A multi-cohort study* [published in *Learning and Individual Differences*]) examined the relations between maths ASC and value beliefs (intrinsic and utility values) and student background variables (gender and SES) in predicting maths achievement and educational aspirations. In addition to ASC-by-value interactions, this study examined how ASC and value beliefs mediated the relations between background variables and educational outcomes. In addition, study 1 explored whether the relations among SES, motivational beliefs and educational outcomes, including the latent interaction, varied by gender. Participants were from three cohorts (1999, 2003, and 2007, N = 13,621) of Hong Kong's TIMSS dataset covering a period of considerable change in the Hong Kong education system providing a strong test of the robustness of these findings.

Study 2 (*Directionality of the associations of high school expectancy-value, aspirations, and attainment: a longitudinal study* [published in *American Educational Research Journal*]) examined the directionality of the associations among cognitive assets (IQ, academic achievement), motivational beliefs (ASC and task values), and educational and occupational aspirations over time from late adolescence (Grade 10) into early adulthood (five years post-high school). Participants were from a nationally representative sample of U.S. boys N = 2,213). Specifically, we explored how ASC and value interplayed with academic achievement and educational and occupational aspirations (i.e., REM of ASC and value with achievement and aspirations) in predicting long-term educational attainment.

Study 3 (*Achievement, motivation, and educational choices: a longitudinal study of expectancy and value using a multiplicative perspective* [published in *Developmental Psychology*]) examined individual and gender differences in ASC and value beliefs (intrinsic and utility values), university entry and selection of educational pathway (e.g., science, technology, engineering, and mathematics [STEM] major selection). Participants were from a nationally representative longitudinal sample of 15-year-old Australian youths (N = 10,370).

In particular, we explored how the internal comparison process posited in the I/E model and DCT influenced long-term educational outcomes. The mediating role of ASC and value beliefs and gendered patterns was also tested.

Study 4 (*Extending expectancy-value theory predictions of achievement and aspirations in physics, chemistry, earth sciences and biology: internal comparison processes and expectancy-by-value interactions* [under review in *Learning and Instruction*]) tested the predictions about how ASC and task value are related to students' achievement and their coursework aspirations in four science domains (physics, chemistry, earth sciences and biology), integrating EVT and the internal comparison process posited in DCT. Participants are 18,047 Grade 8 students from four OECD countries (Czech Republic, Hungary, Slovenia and Sweden) based on the TIMSS2007 dataset. These four countries were the *only* OECD countries in which students completed surveys in relation to all four science domain-specific subjects. Other OECD countries were excluded from this analysis as survey data was not available for all science domains

This study evaluated domain specificity of ASC and value beliefs (intrinsic and utility values) across the four science domains. It also examined how the internal comparison process generalised across ASC and different components of task value, particularly among multiple science domains, and how this comparison process was associated with coursework aspirations.

Study 5 (*Probing unique contributions of self-concept, task values and their interactions using multiple value facets and multiple academic outcomes* [published in *AREA Open*]) examined the unique contributions of the four major value beliefs (intrinsic, attainment, and utility values and cost) and ASC on achievement, self-reported effort, and teacher-rated behavioural engagement in maths. Participants were 1,868 German 9th-grade students. The present study captured the multidimensional nature of task values and explored each value component and its interaction with ASC in predicting achievement-related outcomes. Importantly, it also provided a more complete evaluation of the nature of multiplicative relation in support for EVT, by juxtaposing the recent literature and the results of the present investigation.

In this chapter, the major research methods are presented. Specifically, issues in structural equation modeling (SEM) (e.g., multiple group analysis, method effects, and complex design) are firstly discussed in relation to why these methods are important to the analyses performed in this thesis. Second, two modern approaches employed to test the latent interaction between ASC and value beliefs are presented. Finally, the methods used to handle missing data are discussed.

Structural Equation Modeling

The structural equation modeling (SEM) framework allows analyses of relations between latent variables in which measurement error, non-linear effects and complex sampling designs (e.g., clustering) are accounted for (Bollen, 1989). Latent variable SEM starts with a confirmatory factor analysis (CFA) model. The CFA model (i.e., the measurement model) is a crucial first step as it tests the adequacy of the expected relations and constraints between the measured indicators and the underlying latent variables (Bollen, 1989; Little, 2013). In this thesis all data analyses, CFAs and SEMs, were conducted with Mplus 7.11 (Muthén & Muthén, 1998–2013). To evaluate the adequacy of the measurement properties of each construct in CFA models, as well as the extent to which the SEM model represents the proposed theory by fitting the data well, a set of indices are utilised. In applied CFA and SEM research, there is a predominant focus on traditional indices that are relatively independent of sample size (Hu & Bentler, 1999; Marsh et al., 2004) such as the comparative fit index (CFI), the root-mean-square error of approximation (RMSEA) and the Tucker-Lewis Index (TLI). For consistency with prior works, these three indices as well as the χ^2 statistics and parameter estimates are reported in each study. Values greater than .95 and .90 for CFI and TLI typically indicate excellent and acceptable levels of fit to the data. RMSEA values of less than .06 and .08 are considered to reflect good and acceptable levels of fit to the data. However, these cut-off values constitute only rough guidelines rather than golden rules (Marsh, Nagengast, & Morin, 2012; Marsh, Hau, Balla, & Grayson, 1998).

Multiple Group Analyses

The evaluation of model invariance across different groups (e.g., gender or cohort) or over different occasions for the same groups has been widely applied in SEM studies (Meredith, 1993; Marsh et al., 2009; Millsap & Meredith, 2007). A series of increasingly stringent invariance constraints on the parameters of measurement and structural parts of the model can be tested by evaluating fit indices. Indeed, it is typically more useful to compare the relative fit of different models in a nested taxonomy of measurement invariance models than to compare the relative fit of single models (Marsh et al., 2009, 2012). Cheung and

Rensvold (2002) and Chen (2007) have suggested that if the decrease in CFI is not more than .01 and the RMSEA increase is less than .015 for the more parsimonious model, then invariance assumptions are tenable. Again, all these proposals should be considered as rough guidelines or rules of thumb.

Factor loading invariance is the precondition for meaningful comparisons of the variance-covariance matrices of the latent variables across groups (Millsap, 2011). Thus, to compare differences in patterns of relations among groups, it is only necessary to have factor loadings invariant for latent variable models. However, invariance of factor loadings and item intercepts is a prerequisite for the comparability of factor means across groups (e.g., gender). Although researchers can pursue further restrictive invariance testing (e.g., uniquennesses invariances, factor variance-covariances invariances, etc.) that may prove fruitful in understanding measurement or structural differences across groups, this thesis mainly focuses on testing factor loadings and item intercepts invariances which are the only key pre-requisite to the key comparisons conducted in this thesis.

Method Effects

Method effects are non-trait effects associated with idiosyncratic aspects of particular items (Marsh, Abduljabbar et al., 2013). Failing to take into account these effects would result in unsatisfactory model fit, biased parameter estimates of path coefficient between the corresponding latent constructs, and substantive misinterpretations (Marsh & Hau, 2004; Marsh, Abduljabbar et al., 2013). Method effects associated with negative item wording have been reported for many scales since the construct irrelevant variance of negatively worded items tends to detract from the construct validity of interpretations (Marsh, 1986; DiStefano & Motl, 2006; Marsh, Abduljabbar et al., 2013). Correlated uniquenesses between negatively worded items are generally used to test for negative-item method effects (Marsh, 1986; Marsh, Scalas, & Nagengast, 2010). For example, in studies 1 and 4 based on the TIMSS data, analyses involve survey items with negative wording for ASC ("Mathematics/Physics is more difficult for me than for other" and "Mathematics/Physics is not one of my strengths") and for intrinsic value ("Mathematics/Physics is boring). The correlated uniquenesses between the three items are thus included to control for method effects (Marsh, Abduljabbar et al., 2013, 2015). In addition, following recommendations by Marsh and Hau (1996), in study 4 we included correlated uniquenesses for each matched pair of domain-specific science motivational items that are parallel worded, such as "I usually do well in physics" and "I usually do well in biology". The exclusion of these correlated uniquenesses would bias parameter estimates so that correlations between matching latent constructs across different domains are systematically inflated (Marsh et al., 2010; Marsh, Abduljabbar et al., 2015).

Hence, in this thesis, correlated uniquenesses are posited as a priori between negatively worded items and between those with parallel wording to obtain unbiased parameter estimates.

Complex Design

The datasets used in this thesis have a hierarchical, nested data structure in which students are nested within schools and classes. For a true multilevel SEM, variance on the within and between school/class levels need to be decomposed in order to model relation at the different levels simultaneously. Of particular interest in this thesis is the individual-level relationship among latent variables, and analyses that do not involve any school/class-level variables. Thus, a single-level SEM appears sufficient and appropriate (Muthén & Satorra, 1995; Stapleton, 2006). However, ignoring the sampling design effects of the clustered sample data would lead to biased estimates of standard errors (Stapleton, 2006). Hence, complex design modeling is used in this thesis. This method results in the same parameter estimates are corrected for nesting of students at the school/classroom level. This method is implemented in Mplus 7.11 through the TYPE = COMPLEX function (Muthén & Muthén, 1998–2013). The complex function provides the corrected standard errors of the estimates and a scaled chi-square statistics robust to non-independence of clustered observations within the same cluster (Muthén & Satorra, 1995; Stapleton, 2006).

For studies 1 and 4, the HOUWGT weighting variable provided in the TIMSS data is also used in data analyses in order to correct the computation of standard errors and tests of statistical significance. Consistent with its two-stage stratified sampling design, TIMSS provides the HOUWGT weighting variable that has six components, one each for school, class and student level, and one each for adjustment factor associated with non-participation at these three levels (Olson, Martin, & Mullis, 2008). HOUWGT is based on the actual number of students in each participating country that is appropriate for correct computation of standard errors and tests of statistical significance (Marsh, Abduljabbar et al., 2013). Thus, HOUWGT weighting variable and clustering variables (i.e., class and school) were taken into account in the data analyses in studies 1 and 4. Likewise, the international PISA database used a complex sampling design (see OECD, 2005b, for details). Consequently, selection probabilities differ between student and schools and all analyses of the PISA data have to use the appropriate weights, which additionally correct for school and student non-response, to obtain representative results (see OECD, 2005b). Therefore, the weighting variable provided in the PISA2006 was utilised in study 3.

Latent Interaction Modeling

As discussed earlier, empirical research examining the interaction effect between expectancy (ASC) and value beliefs on achievement-related behaviours in non-experimental settings has been surprisingly scarce in the literature. One of the reasons for this sparsity is the error-prone specification of non-linear interaction effects when implemented outside of the latent variable framework due to the lack of control for measurement error (e.g., Bollen, 1996; Kenny & Judd, 1984; Jöreskog & Yang, 1996; Ping, 1995, 1996). However, recently researchers have been able to examine interaction effects between latent variables using structural equation modeling (SEM) (Bollen, 1989) techniques such as the latent moderated structural equation approach (LMS) (Klein & Moosbrugger, 2000) and the unconstrained product indicator approach (Marsh et al., 2004). For the purpose of this thesis, these two approaches are employed. Each approach is discussed below in detail.

Unconstrained Approach

Kenny and Judd (1984) initially developed the basic product-indicator approach to estimate latent interaction effect. In their approach, multiple product-indicators were used for the specification of the interaction term in the measurement model. Based on Kenny and Judd's (1984) seminal work, the product-indicator approach has received subsequent development (Algina & Moulder, 2011; Hayduk, 1987; Jöreskog & Yang, 1996; Ping, 1995, 1996; Wall & Amemiya, 2001). However, these approaches were cumbersome to implement and required overly restrictive assumptions on which it was based, leading to the development of new approaches (Marsh et al., 2004; Marsh, Hau et al., 2013).

In comparison to the traditional constrained approach (e.g., Jöreskog & Yang, 1996; Algina & Moulder, 2011) and the partially constrained approach (Wall & Amemiya, 2001), the unconstrained approach is relatively simple to implement in that most of the complicated constraints required in the original Kenny and Judd (1984) approach are relaxed (Marsh et al., 2004). The unconstrained approach has shown performance as good as the constrained approach when the underlying assumptions of the constrained approach are met in the simulation study, and much better performance when these assumptions are not met — which is generally the case (Marsh et al., 2004).

The SEM with two latent predictors and their interacting latent variable is typically specified as:

$$\eta = \gamma_1 \xi_1 + \gamma_2 \xi_2 + \gamma_3 \xi_1 \xi_2 + \zeta. \tag{1}$$

where γ_1, γ_2 and γ_3 are the partial regression coefficients of the latent predictor variables and their cross-product and ζ is the structural model residual. The latent predictors

)

 ξ_1 and ξ_2 as well as the latent outcome variable η are each inferred from at least two indicators as specified in the corresponding measurement models. ξ_1, ξ_2 and ξ_3 are allowed to be correlated with each other, but each is uncorrelated with measurement errors and the residual term ζ .

$$x_{ij} = \lambda_{xi}\xi_i + \delta_{ij}, y_k = \lambda_{yk}\eta + \varepsilon_k,$$
⁽²⁾

where x_{ij} is the *j*th indicator of the *i*th latent predictor variable ξ_i , λ_{xi} is the corresponding factor loading and δ_{ij} is the corresponding residual, y_k is the *k*th indicator of the latent outcome variable η , λ_{yk} is the corresponding factor loading, and ε_k is the corresponding residual.

Product-indicator approaches, such as the unconstrained approach, identify the latent cross-product $\xi_1 \xi_2$ by products of indicators of the latent predictor variables, according to the following measurement model

$$x_{1i}x_{2l} = \lambda_{1i2l}\xi_{1}\xi_{2} + \delta_{1i2l}, \tag{3}$$

where x_{1i} is the *i* th indictor of ξ_i and x_{2i} is the *l* th indicator of ξ_2 , λ_{1i2l} is the corresponding factor loading on the latent product variable and δ_{1i2l} is the corresponding residual. The critical problem with the indicator approach is how to form the product indicator. All indicators of the latent variables are centred before the product indicators are computed (Marsh et al., 2004). According to the guiding principles proposed in Marsh et al. (2004): (a) all the multiple indicators of both latent predictors need to be used, and (b) the same indicator should not be re-used in forming the indicator for the latent product variable (also see Marsh, Hau et al., 2013). Hence, each indicator in ξ_1 and ξ_2 should be used only once in the formation of the product indicators. In this thesis, product indicators are formed based on the reliabilities of the indicators of ξ_1 and ξ_2 (i.e., the best item in ξ_1 with the best item in ξ_2) for detailed discussion about construction of product indicators see Marsh et al., 2004, 2007; Marsh, Hau et al., 2013.

Latent Moderated Structural (LMS) Equation Approach

In contrast to the product-indicator approach, by specifying a separate latent interaction variable the LMS approach uses conditional distributions to present the non-linear effects (Klein & Moosbrugger, 2000; Kelava et al., 2011). Specifically, a likelihood function for a non-normal distribution is derived, which is approximated by numerical methods, and maximised through the use of the expectation maximisation (EM) algorithm (Dempster, Laird, & Rubin, 1977; Klein & Moosbrugger, 2000). Thus, the LMS directly estimates the

parameters of the latent interaction model given in Equation 1 without having separate indicators of the product term.

The LMS approach makes the same standard assumptions of latent variable models as the unconstrained approach (except for normally distributed *y* variables of the latent outcome variable η). In general, assumption of normality for the measured *y* of the latent η is violated in models with interaction. The LMS approach maximises special fitting likelihood function that takes the non-normality of the indicators of the dependent latent variable into account, but it still relies on normality assumptions about the indicators of the latent predictor variables. Thus, although both the unconstrained approach and the LMS approach provide unbiased results under normality assumptions, the LMS approach is more precise (efficient), in particular when the sample is small (Marsh et al., 2004, Kelava et al., 2011). However, these advantages are offset by the need to use specialised software to estimate the interaction model and no information of fit indices based on the χ^2 statistics as well as of modification indices. In particular, a crucial advantage of the unconstrained approach over the LMS approach is the high computational demands of the LMS approach, which substantially limits its applicability (Marsh et al., 2004; Marsh, Hau et al., 2011).

In this thesis, the LMS approach is applied to test interaction effect in studies 1 and 3, in which only two latent variable interactions are included simultaneously. However, given the problem of high computational burden of the LMS approach (as discussed earlier), the unconstrained approached is employed in studies 2, 4 and 5, in which more than four latent variable interactions are tested in a single SEM model.

Estimator

Consistent with the assumptions of the unconstrained approach and the LMS approach, the models are estimated using the Mplus robust maximum likelihood (MLR) estimator (Klein & Moosbrugger, 2000; Marsh et al., 2004). MLR estimation is also robust in relation to the non-normality and non-independence of observations when used in conjunction with a design-based correction that controls for controlling for the hierarchical, nested nature of the data (Muthén & Muthén, 2008–2013) (see earlier discussion).

Missing Data

It is rare that a dataset is without missing values, particularly in longitudinal studies. According to Rubin's theory (1987), there are three mechanisms for missing data: missing completely at random (MACR), missing at random (MAR), and missing not at random (MNAR). Historically, statistical analyses were conducted using the traditional approaches (i.e., listwise deletion and mean substitution) to missing data under the assumption that all the missing data is due to a MACR process. However, in most practical applications this

assumption is violated. The reason is that MACR mechanism refers to the missingness that is unrelated to any characteristics of the participants and can thus be considered to occur in a purely random manner, that is to represent a random sample of the complete data.

MAR refers to missingness that is associated with other variables present in the analysis model, whereas MNAR indicates that the missingness on a given variable is associated with the value of that variable itself. Under both assumptions, the traditional approaches can seriously undermine the estimates and have therefore received heavy criticism (Enders, 2010; Little, Jorgensen, Lang, & Moore, 2013). However, there has been substantial development in the methodologies to deal with missing data issues, such as full information maximum likelihood (FIML) and multiple imputation (MI). Under MAR assumptions, these two state-of-the art methods have been shown to be robust to departures from normality assumptions and to provide unbiased results, even for low sample sizes and/or high rates of missing data (Graham, 2009; Graham, Olchowski, & Gilreath, 2007; Enders, 2010). In particular, these approaches makes it possible to use auxiliary variables (i.e., a variable not directly included in the model, but allowed to predict the missing values) related to the missing data mechanism present in the data in order to transform data from MNAR to MAR (Little et al., 2013; Enders, 2010).

In this thesis, the missing data in the two longitudinal studies (1 and 3) focusing on the post-high school transition appeared to be mainly related to attrition, particularly for post-school outcomes that typically were estimated several years after the initial time wave. In such cases, MAR is the most likely missing data mechanism. Studies 1 and 4 utilised the TIMSS datasets, which are based on the matrix sampling design through which each participants only received a random subset of items. Consequently, there were substantial numbers of missing values of maths and science test scores. However, these missing data were MACR due to the nature of the randomised matrix design. In study 5, the percentage of missing data was relatively low (2.9% at maximum). Thus, in this thesis both FIML and MI are used to handle missing data.

Chapter 4: Study 1 - Expectancy-Value, Gender and Socioeconomic Background as Predictors of Achievement and Aspiration: A Multi-cohort Study

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Preface

The overarching goal of this thesis was to examine the unique and combined contributions of ASC and value beliefs in the prediction of achievement-related outcomes. In pursuing this overarching aim, study 1 examined how 8th Grade Hong Kong studensts' self-concept and intrinsic and utility values related to their educational outcomes (achievement and educational aspirations) in the maths domain. Although the ASC-by-value interaction has been reintroduced in recent empirical studies (e.g., Nagengast, et al., 2011), study 1 was among the first to consider both ASC and multiple task values and their interactions (i.e., ASC-by-intrinsic value and ASC-by-utility value) together in order to examine the relative and unique effects of each in their predictions on educational outcomes. This provided a strong test for the theoretical assumption of EVT that multiple task values simultaneously and differentially influenced achievement-related outcomes.

Another major goal of the thesis was to explore how gender role socialisation and family socioeconomic status (SES) shaped students' academic and motivational pathways. Study 1 examined the direct effects of gender and SES as well as the extent with which these direct effects are mediated by motivational beliefs. For a more complete understanding of gendered processes underlying academic pathways, study 1 also tested whether the relations among SES, motivational beliefs and the educational outcomes differed as a function of gender. However, research on moderation effects of gender so far has been very limited and has yielded mixed evidence across different cultures (Watt et al., 2012). Study 1 is one of the first to examine gendered motivational processes affecting academic achievement and aspirations in an Asian context.

Learning and Individual Differences 37 (2015) 161-168



Expectancy-value in mathematics, gender and socioeconomic background as predictors of achievement and aspirations: A multi-cohort study $\stackrel{\scriptstyle\smile}{\sim}$

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ABSTRACT

This study drew on expectancy-value theory (EVT) to examine the relations between mathematics motivation (academic self-concept and task values) and student background variables in predicting educational outcomes. Using latent-variable models with latent interactions, we investigated the multiplicative effect of self-concept and value, which is central to classic EVT. The mediating role of motivation and gendered patterns was also explored. Hong Kong's TIMSS dataset for three cohorts (1999, 2003, and 2007) was used over a period where the education system had experienced considerable changes, providing a strong test of the robustness of these findings. The results suggested: (a) self-concept is more important for students with lower utility values in predicting their educational outcomes; (b) while boys and girls had similar levels of math self-concept and values, girls tended to have higher mathematics achievement and educational aspirations; (c) family socioeconomic status is more strongly linked to educational aspirations for boys.

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Expectancy-value theory (EVT), beginning with the seminal work of Atkinson (1957), continues to be one of the most dominant theories of achievement motivation (Eccles, 1994, 2009). EVT proposes that expectancy of success in a given task and the degree to which this task is valued are determinants of achievement-related performance and choices (Eccles, 1994, 2009). Although Eccles and her colleagues (Eccles, 1994, 2009; Eccles & Wigfield, 2002; Eccles (Parsons) et al., 1983) elaborated multiple components of subjective task values and linked motivational beliefs to other psychological, social, and cultural factors, the multiplicative relation between expectancy and value, which was the cornerstone of classic EVT (Atkinson, 1957), has been less researched. This gap could be due to the lack of advanced statistical techniques suited to measuring expectancy by value interactions. With recent developments of latent variable approaches to interaction effects, researchers are now able to more accurately analyze the latent interactions inherent in classic EVT (Marsh, Wen, & Hau, 2004; Nagengast et al., 2011; Trautwein et al., 2012). However, these empirical studies only considered one component of task values with expectancy when testing the interactive relation, which is inconsistent with the assumption of EVT that multiple task values simultaneously influence achievementrelated outcomes.

In addition, in the EVT model, the association of children's backgrounds, including gender role socialization and family socioeconomic status (SES), with educational outcomes is believed to be mediated through expectancy and task values. Even though recent studies have demonstrated that motivational beliefs play a significant role in mediating the relation of gender and SES with educational outcomes (e.g., De la Fuente, Sander, & Putwain, 2013; Nagy, Trautwein, Baumert, Köller, & Garrett, 2006; Nagy et al., 2008; Parker et al., 2012), few studies have considered both expectancy and multiple task values together and compared direct and indirect effects when investigating the mediating role of motivational beliefs.

Therefore, our aim is to provide a comprehensive test of EVT, including the multiplicative relation and mediating role of math expectancy and task values on math academic achievement and educational aspirations. Given that social and cultural processes are achievement-related behaviors (Eccles, 2009), we also explore gender differences in the relations of SES and motivational beliefs with educational outcomes, particularly in the multiplicative relation between expectancy and task values. For robustness of the analysis, we include data from multiple cohorts (1999, 2003, 2007) of Hong Kong students who participated in the Trends in International Mathematics and Science Study (TIMSS). The substantial changes in the Hong Kong education system resulting from major educational reforms from the year 2000

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162

(Education Commission, 2000) together with the handover of sovereignty from the UK to China in 1997 (Dimmock & Walker, 1997) provide us with an interesting context for testing the salience of EVT predictions. Specifically, consistency of results across this historically important period would provide a strong test of the robustness of predictions based on EVT.

1. Expectancy-value theory

The modern EVT model posits that achievement-related performance is most directly influenced by the individual's expectancies of academic success and a subjective assessment of the inherent value of the academic task. However, socialization processes linked to various cultural and social settings (e.g., school and family) introduce individual differences in motivational beliefs, leading to differential performance. Modern EVT (Eccles (Parsons) et al., 1983) defines expectancy of success as a task-specific belief about the possibility of experiencing future success in that task that is directly related to one's evaluation of one's competency within a specific academic domain (e.g., academic selfconcept, Marsh, 1986). Following Eccles and colleagues (Eccles, 2009; Eccles & Wigfield, 2002; also see Nagengast et al., 2011; Nagy et al., 2008), here we use academic self-concept as a measure of expectancy of success.

Modern EVT distinguishes between multiple components of value (Eccles & Wigfield, 2002). In the current study, we focus on two value components: intrinsic value that refers to the enjoyment a person gains from performing an activity; and utility value, relating to how a specific task fits within individual future plans and objectives. Expectancy and value are both known to be domain specific (Eccles & Wigfield, 2002; Wigfield & Eccles, 2002). Research has shown that competence beliefs are related positively to several different dimensions of value within a specific domain, but that the relations involving intrinsic value seem to be the strongest (Wigfield & Eccles, 2002). In crosssectional and longitudinal studies, there is growing evidence of expectancy beliefs having a strong influence on achievement, while value beliefs have stronger influence on choice, effort, and persistence in achievement-related activities (Gasco & Villarroel, 2014; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Nagengast et al., 2011; Trautwein et al., 2012).

2. Multiplicative effect of expectancy and task value

The classic EVT conceptualization emphasizes the presence of the multiplicative combination of expectancy and value (Atkinson, 1957). More precisely, both high expectancy beliefs and task values were seen as essential for attaining high academic achievement and guiding educational aspirations. That is, expectations and subjective values were proposed to combine multiplicatively to determine the outcomes (Feather, 1982). Nevertheless, tests of EVT models are primarily additive in nature (where two or more predictors uniquely and independently predict the outcome variable) rather than multiplicative. Over time, this has led to the disappearance of possible multiplicative interaction effects from EVT research (see Nagengast et al., 2011). A possible reason for the omission of the interaction term was the lack of appropriate methods for testing multiplicative relations (see Appendix A in Supplemental material for more discussion). However, applied researchers now have access to new methods for testing latent interactions. Nagengast et al. (2011) found significant multiplicative relations between self-concept and intrinsic value on extracurricular activities and aspirations across 57 countries based on the Programme for International Student Assessment (PISA) 2006 data. In a study with a German sample, Trautwein et al. (2012) also found evidence of the significant multiplicative effects of expectancy and four subcomponents of value (attainment, intrinsic value, utility value, and cost), each considered separately, on English and math achievements. These findings have yet to be replicated with a stronger analytic approach to examine multiple predictions of multiple outcomes across multiple data points within the same study.

3. Family background and gender

According to the EVT framework (Eccles, 2007, 2009), parents provide social-emotional influences on children's motivation beliefs which in turn influence children's educational performance and aspirations (Eccles, 2007, 2009). Because parents' beliefs and behaviors are associated with their socio-economic status (SES), families with higher SES are likely to produce more positive outcomes for children (Eccles, 2009). However, the majority of the literature on family SES has focused on direct, positive effects of SES on children's academic achievement (see Sirin, 2005 for a review), perceived competence and task beliefs (Eccles, 2007) and children's expectations of how far they will go in school (Halle, Kurtz-Costes, & Mahoney, 1997). More recent research has started to investigate the mediation effects of motivational beliefs, suggesting that the relations of SES to academic achievement and educational aspirations are partially mediated by motivation variables (Grolnick, Friendly, & Bellas, 2009).

Likewise, based on EVT (Eccles, 2009), gender exerts influences on achievement-related behaviors through its associations with motivational beliefs. In other words, gender differences in achievementrelated behaviors are mediated by gender differences in motivational beliefs (Eccles, Barber, & Jozefowicz, 1999; Nagy et al., 2006, 2008; Simpkins, Davis-Kean, & Eccles, 2006). Multiple studies have reported more positive math self-concepts, attitudes and affect for males (Eccles & Wigfield, 2002; Marsh & Yeung, 1998; Marsh et al., 2013). However, in recent decades, growing evidence in cross-national metaanalyses (Else-Quest, Hyde, & Linn, 2010; Lindberg, Hyde, Petersen, & Linn, 2010) shows gender similarities in math achievement. Furthermore, there has been a dramatic increase in females' educational aspirations, and particularly in secondary school, females tend to report higher educational aspirations than their male counterparts (Schoon & Polek, 2011). Although the mediating role of motivation factors has been widely addressed in the literature (e.g., Parker et al., 2012), apparently no previous studies have considered both self-concept and multiple task values and their multiplicative effects simultaneously and examined the direct, indirect and total effects of gender and SES to educational outcomes

In addition to mediation effects, gender also exerts moderation effects (Eccles, 2009; Nagy et al., 2006; Simpkins et al., 2006; Watt et al., 2012). However, research so far has yielded mixed evidence regarding gender differences when examining the relations among SES, motivational beliefs, and academic outcomes across different cultures. For example, math utility value was found to play a more important role for educational aspirations in Australian high school female samples, whereas the relation between math motivation beliefs and educational aspirations did not vary by gender in samples from the USA and Canada (Watt et al., 2012). In addition, the relation between SES and educational aspirations did not vary by gender in the UK sample (Schoon & Polek, 2011), whereas the relation was stronger for African-American males (Trusty, 2002). However, very little research has examined whether the relationships among SES. motivational beliefs, and educational outcomes, vary as a function of gender in an Asian context.

4. The Hong Kong context

In 1997, Hong Kong experienced its largest social change—the handover of sovereignty from the UK to China. Among the many effects of this change of government, there have been profound changes in the Hong Kong educational system. Since the changeover, a number of new initiatives have been implemented with the attempt to enhance the quality of school education. They include a Medium of Instruction Guidance for Secondary Schools to reinforce the 'biliterate and

J. Guo et al. / Learning and Individual Differences 37 (2015) 161-168

trilingual' policy (1998); support for information technology in education (1998); a series of new curriculum reforms (2001); and systemic and structural changes including basic competency assessments, changed structures in secondary and higher education, and the implementation of Liberal Studies as a new curriculum domain (2004; see Chong, 2012). These policies and initiatives at various levels (system, school, class, and student levels) have led to substantial changes in the Hong Kong educational system after the handover. In particular, the numbers of English-medium schools have significantly decreased from around ninety percent to only a quarter of secondary schools after Instruction Guidance was implemented (Zhu & Leune, 2011).

Within what they called a 'non-intervention period', Marsh, Hau, and Kong (2000) showed that the second-language medium (i.e., English in the Hong Kong Chinese context) had substantially negative effects on math achievement and academic self-concepts in other school subjects (see Appendix B in Supplemental material). Further to the change of medium of instruction for many students, education and curriculum reforms in math education have been successively implemented in Hong Kong since 1999 (Leung, 2006). These reforms have placed an increased emphasis on the enhancement of students' learning motivation (e.g., establishing confidence in and positive attitudes to math) (Education Commission, 2000). Nevertheless, influenced by the Confucian heritage culture that has a strong academic achievement orientation of the Chinese culture, Hong Kong students' intrinsic motivation is often dominated by extrinsic values (Luo, Hogan, Yeung, Sheng, & Aye, 2013; also see Appendix B in Supplemental material).

5. The present investigation

The purpose of this study was to investigate the multiplicative relations of expectancy and value on outcome variables, which seems to have disappeared from the modern EVT model (Nagengast et al., 2011; Trautwein et al., 2012). Further, we examine how students' background variables (gender and SES) predict self-concept and task values, which in turn influence math achievement and educational aspirations. Also, we explore whether the relationships among SES, motivational beliefs and outcomes, including the latent interaction, vary by gender. The hypothesized model (see Fig. 1) was built on the basis of the EVT framework (Eccles, 1994, 2009). First, we hypothesized math self-concept to be a stronger predictor of mathematics achievement, and value to be a stronger predictor of educational aspiration, when both expectancy and value are considered simultaneously (e.g., Eccles & Wigfield, 2002; Marsh et al., 2013). More importantly, we anticipated the multiplicative effect of self-concept and value on outcome variables to be significant, indicating that students with both high self-concept and value would be likely to have higher achievement and aspirations. Second, we expected that self-concept and task values would significantly mediate the relationships between SES and gender and educational outcomes. Third, given the absence of a strong empirical basis for making predictions about whether the associations among SES, motivational beliefs and academic outcomes will function differently for boys and girls, we treat the gender moderation analysis as a research question. Finally, despite the huge societal changes in Hong Kong with the change in government, we expected robust effects predicted by EVT outlined above to remain relatively unaffected.

6. Method

6.1. Participants

The target population was Hong Kong Grade 8 students who participated in the TIMSS 1999, 2003 and 2007 waves. TIMSS employed a very efficient method to attain accurate and representative samples through a two-stage sampling procedure (e.g., Mullis et al., 2000). The first stage comprised a sample of schools; the second comprised a single classroom selected randomly from the different grades in the sampled schools (Martin, Mullis, Foy, & Olson, 2008). As a result of this selection process in Hong Kong, the 5179 students (49.3% girls, 50.7% boys), 4972 (50.4% girls, 49.6% boys), and 3470 (50.4% girls, 49.6% boys) formed the three samples in the present study. The average age of these students was 14.4 at the time of TIMSS testing in 1999 (Mullis et al., 2000), 2003 (Mullis, Martin, Gonzalez, & Chrostowski, 2004), and 2007 (Martin et al., 2008).

6.2. Measures

The measures of the student background variables (gender and SES), expectancy-value constructs and achievement-related and aspiration outcomes were selected from the student-background questionnaire. All motivation items were answered on a 4-point Likert scale (from 1 "disagree a lot" to 4 "agree a lot"). Higher values represented more favorable responses (see Appendix C in Supplemental material).

Expectancy. The math self-concept scale was used to assess students' expectancy of success. The scale consisted of four items in TIMSS 2003 and 2007, but five items in TIMSS 1999 (e.g., "I usually do well in mathematics"). Reliability of this scale was good (Cronbach's alpha $\alpha = .772$ to .808).

Task value. TIMSS (see Olson, Martin, & Mullis, 2008) created a scale of Students' Positive Affect Toward Mathematics (PATM) to assess the affect experienced when participating in math-related activities (e.g., "I enjoy learning mathematics"), in line with the notion of *intrinsic value* (MIV) in the modern EVT (Eccles (Parsons) et al., 1983). Likewise, the TIMSS Students Valuing Mathematics (SVU) scale is similar to *utility value* (MUV) in the modern EVT (Eccles (Parsons) et al., 1983), which assesses how well math achievement relates to current and future goals (e.g., "I need to do well in mathematics to get the job I want"). These two constructs demonstrated very good reliability across three cohorts ($\alpha = .763$ to 863).

Academic achievement. Students' math achievement used in the present study was derived from the TIMSS math test. TIMSS relied on Item Response Theory (IRT) scaling to assess achievement and obtain accurate



Fig. 1. The hypothesized model.

164

J. Guo et al. / Learning and Individual Differences 37 (2015) 161-168

measures of trends from previous assessments. TIMSS IRT scaling approach uses multiple imputations to provide proficiency scores in math for each student, even if each student responds only to a part of the item pool (Martin et al., 2008). Five plausible values were estimated for each student for attaining comparable achievement scores in order to obtain unbiased estimates.

Educational aspirations. A single item was used in the three waves of data to assess students' education aspirations ("How far in school do you expect to go?"). The response scale ranged from finishing upper secondary school to beyond bachelor program.

Background variables. SES was assessed with a scale including three items including the highest educational level of father and mother and the number of books at home. Reliability of this scale was good ($\alpha = .707$ to 740). Gender was self-reported and coded 0 for girls and 1 for boys, so that positive coefficients indicate higher scores for boys.

6.3. Data analysis

Within a structural equation modeling (SEM) framework, we used the latent moderated structural (LMS) equation approach (Klein & Moosbrugger, 2000) to model the latent interactions between expectancy and value beliefs in predicting the outcome variables with Mplus 7.11 (Muthén & Muthén, 1998–2013). LMS directly models the implied non-normal distribution of the latent outcome variables and its indicators (Kelava et al., 2011). Consistent with the assumptions of LMS, all Confirmatory Factor Analysis (CFAs) and SEMs were estimated using robust maximum likelihood (MLR) estimation (Klein & Moosbrugger, 2000).

In addition, all analyses were based on TIMSS' HOUWGT weighting variable that incorporates three components related to sampling of the school, class and student respectively, and three associated with non-participation at the levels of school, class and student (for more details on the incorporation of weights in analyses, see Marsh et al., 2013). All models were estimated while taking into account individuals' nesting within classes and schools using the design-based correction of standard errors available in Mplus 7.11 (using the TYPE = COMPLEX option, see Muthén & Muthén, 1998–2013).

6.3.1. Missing data

Multiple imputations were used to account for missing responses (Graham, Cumsille, & Elek-Fisk, 2003). Multiple imputation procedures have been shown to be robust to departures from normality assumptions and to provide unbiased results even for low sample sizes or high rates of missing data (Graham et al., 2003). For each cohort, five

Table 1

Sample size, distribution characteristics, means, and (standard deviation) of variables by cohort and gender.

Variables	MSC	MIV	MUV	SES	ASP	ACH
1999 Skewness Kurtosis	.63 .51	16 0	0 —.21	— .59 .58	- 1.09 .54	42 .7
$\begin{array}{l} \textit{Mean(SD)}\\ \textit{Boys} (N = 2624)\\ \textit{Girls} (N = 2554) \end{array}$	2.69 (.88) 2.59 (.81)	2.67 (.69) 2.56 (.61)	2.63 (.65) 2.39 (.63)	3.37 (.76) 3.50 (.66)	4.22 (1.16) 4.44 (1.02)	567.01 (65.98) 565.40 (57.94)
2003 Skewness Kurtosis Boys (N = 2466) Girls (N = 2506)	.08 40 2.62 (.68) 2.32 (.66)	.03 26 2.56 (.69) 2.37 (.66)	29 .57 2.97 (.58) 2.93 (.54)	.70 .45 3.06 (1.26) 3.06 (1.24)	- 1.09 .97 3.92 (1.21) 4.04 (1.05)	58 .61 581.42 (68.49) 583.9 (64.44)
2007 Skewness Kurtosis Boys (N = 1748) Girls (N = 1722)	.04 34 2.65 (.68) 2.35 (.65)	23 52 2.69 (.80) 2.55 (.75)	47 .79 2.99 (.63) 2.93 (.58)	.87 .42 2.73 (1.17) 2.75 (1.11)	89 .92 4.22 (1.28) 4.26 (1.04)	52 .14 563.42 (88.41) 569.88 (77.71)

imputed data sets were created and one of the five sets of plausible achievement scores was used with each of the imputed data sets. The final parameter estimates, standard errors and goodness-of-fit statistics of the structural equation model (SEM) with latent interaction were obtained with the automatic aggregation procedure implemented in Mplus 7.11 (Rubin, 1987). Furthermore, we used a standard metaanalysis approach (see Hox, 2010; Lipsey & Wilson, 2001) to provide aggregated estimates for the path coefficients of each cohort (i.e., the weighted mean effect size and standard errors; see Appendix D in Supplemental material).

6.3.2. Negatively worded items

Method effects associated with negative item wording have been reported in many studies (DiStefano & Motl, 2006; Marsh, 1986; Marsh & O'Mara, 2008; Marsh, Scalas, & Nagengast, 2010). These effects are likely to have adverse effects on goodness of fit, parameter estimates, and substantive interpretations. Correlations between the uniquenesses of all negatively worded items (two self-concept items and one intrinsic motivation item) were thus included to the model (Marsh et al., 2013; also see Appendix H in Supplemental material for example syntax).

6.3.3. Goodness of fit

A number of indices were used to assess model fit. Tucker–Lewis Index (TLI) and the Comparative Fit Index (CFI) with values greater than .90 and .95 typically reflect acceptable and excellent fit to the data respectively. For the Root Mean Square Error of Approximation (RMSEA), values of less than .06 and .08 reflect a close fit and a minimally acceptable fit to the data respectively. For model comparisons, decrease in fit for the more parsimonious model is less than .01 for incremental fit indices like the CFI or less than .015 for the RMSEA, then there is reasonable support for the more parsimonious model (Chen, 2007; Cheung & Rensvold, 2002).

7. Results

7.1. Descriptive statistics and correlations

Descriptive statistics are presented in Table 1. All of the scales are approximately normally distributed. Although multi-item scales demonstrated acceptable internal reliability at three cohorts, the fact that some items have modest factor loading reinforces the importance of using latent variables models that include a natural control for measurement errors (see Appendix C in Supplemental material). CFA was used to evaluate the patterns of correlations among motivation factors (MSC, MIV and MUV) and outcome variables (math achievement and

aspirations). Across the three waves, similarly high intercorrelations among motivation factors were observed (see Appendix E in Supplemental material). Math self-concept was closely associated with math intrinsic value (mean [*M*] r = .772, SE = .019). In terms of correlations between motivation factors and outcomes, self-concept was more strongly correlated with math achievement (M r = .434, SE = .019), while utility value was more strongly associated with educational aspirations (M r = .358, SE = .016). Achievement was moderately correlated with aspirations (M r = .432, SE = .030).

7.2. The hypothesized model

In our hypothesized model (Fig. 1), the effects of background variables on math achievement and educational aspirations were mediated by expectancy and values (self-concept, intrinsic value, and utility value) and the latent interactions (self-concept by intrinsic value, selfconcept by utility value) influenced the outcome variables. The SEM model fitted the data well in all three samples (2007 model: χ^2 = 1526.877, df = 283, CFI = .969, TLI = .962, RMSEA = .050; 2003 model: $\chi^2 = 1911.819$, df = 254, CFI = .978, TLI = .974, RMSEA = .051; 1999 model: $\chi^2 = 3193.741$, df = 499, CFI = .927, TLI = .917, RMSEA = .050). The total amount of variance explained was also similar across waves: 28% for math achievement and 27% for educational aspirations in TIMSS 1999, compared to 25% and 25% respectively in TIMSS 2003, and 26% and 25% respectively in TIMSS 2007. The effect sizes for the direct path coefficients of the standardized solution are shown in Fig. 2, while those for the indirect path coefficients are presented in Table 2 (also see Appendix F in Supplemental material).

7.3. Expectancy by task value

The path coefficients from self-concept and intrinsic and utility values to outcome variables were similar across the three cohorts (Fig. 2). Consistent with a priori predictions, the positive path from self-concept to achievement was much stronger than the corresponding paths from intrinsic value and utility value to achievement (i.e., main

effects). However, also consistent with predictions, the path from utility value to aspirations was greater than the corresponding path from self-concept. However, in contrast to a rich body of empirical research (Denissen, Zarret, & Eccles, 2007; Durik, Vida, & Eccles, 2006), the mean effect sizes across the three cohorts for the path from intrinsic value to achievement and to aspirations were not statistically significant. This could be due to the high correlation noted between intrinsic value and self-concept (expectancy), leading intrinsic value to have no unique effect on outcome variables when expectancy and values are considered together.

A key contribution of the present study is the simultaneous testing of two critical interactions. Consistent with our hypothesis, the multiplicative predictive effects of self-concept and utility value on math achievement and educational aspirations were both statistically significant. The simple-slopes (Preacher, Rucker, & Hayes, 2007) graphed in Fig. 3 showed that self-concept positively predicted achievement at different levels of utility value. However, particularly at lower levels of utility value, self-concept predicted achievement more positively than at higher levels of utility value. When self-concept was at nearly one standard deviation above the mean, different levels of utility value tended to predict similar levels of achievement, Likewise, a significant interaction between self-concept and utility value was also evident for educational aspirations (Fig. 3), showing that when utility value is low, self-concept contributes more positively to aspiration. Nevertheless, the predictive effects of self-concept on achievement at different levels of utility value were much stronger than those on aspiration, such that selfconcept was the dominant predictor of achievement. The results suggest that higher self-concept, higher utility value, and their positive interaction, all contributed to higher math achievement and educational aspiration.

In interpreting the latent interaction on aspiration, we need to note that all constructs are math-specific while the aspirations construct is composed of a single general indicator. Given that expectancy and values are highly domain specific, a student who has high verbal selfconcept or interest may contribute to his or her high aspirations in educational attainment. Likewise, and inconsistent with our expectations, the intrinsic value by self-concept interaction is not significantly



Fig. 2. Path model depicted the hypothesized relations. Only weighted mean effect size (standard errors) for statistically significant paths was presented in the model for clarity. Estimates displayed in rectangle box indicted the negative path coefficients. Note. MSC = mathematics self-concept; MIV = mathematics intrinsic value; MUV = mathematics utility value; SES = socioeconomic status; ACH = mathematics achievement; ASP = educational aspiration, MSC × MIV = mathematics self-concept by utility value interaction. MSC × MUV = mathematics self-concept by utility value interaction.

J. Guo et al. / Learning and Individual Differences 37 (2015) 161–168

166

 Table 2

 The direct, indirect and total effects of gender and SES on outcome variables.

Outcomes variables		Direct effect	Indirect effect			Total effect
			Via MSC	Via MIV	Via MUV	
Gender						
Math achievement	1999	090* (.028)	.052* (.019)	.005 (.012)	.001 (.002)	032 (.043)
	2003	116* (.027)	.102* (.014)	002 (.007)	.004* (.002)	012 (.055)
	2007	141* (.034)	.074* (.012)	.011 (.005)	.003 (.003)	.053 (.034)
	Mean(SE)	113* (.017)	.080* (.008)	.006 (.004)	.003 (.002)	.014 (.024)
Educational aspirations	1999	163* (.023)	.024* (.009)	018 (.011)	.008 (.006)	149* (.022)
	2003	099* (.019)	.026* (.011)	011 (.007)	.016* (.008)	068* (.040)
	2007	136* (.024)	.027* (.011)	003 (.004)	.009 (.006)	103* (.021)
	Mean(SE)	128* (.013)	.029* (.007)	006 (.004)	.010* (.004)	114* (.014)
Socioeconomic status (SES)						
Math achievement	1999	.175* (.041)	.038* (.013)	.002 (.007)	.014* (.006)	.229* (.043)
	2003	.164* (.032)	.032* (.010)	001 (.002)	.014* (.004)	.209* (.025)
	2007	.201* (.038)	.039* (.011)	.008 (.005)	.013* (.003)	.261* (.040)
	Mean(SE)	.178* (.021)	.036* (.006)	.001 (.002)	.013* (.002)	.225* (.019)
Educational aspirations	1999	.290* (.025)	.018* (.009)	008 (.005)	.054* (.009)	.354* (.020)
	2003	.290* (.024)	.008* (.004)	003 (.003)	.052* (.010)	.347* (.019)
	2007	.334* (.029)	.014* (.007)	002 (.003)	.045* (.010)	.391* (.021)
	Mean(SE)	.302* (.015)	.012* (.003)	003 (.002)	.051* (.006)	.364* (.012)

Note. t value > 1.96, * p < .05; MSC = mathematics self-concept; MIV = mathematics intrinsic value; MUV = mathematics utility value.

predictive of either achievement or aspirations. However, again this may be due to the high correlation between these self-concept and intrinsic value.

7.4. SES and gender

As shown in Fig. 2, the positive direct effects of SES on motivational beliefs and educational outcomes indicate that students from a high SES family were likely to have more positive motivation and higher math achievement and educational aspirations. More importantly, the indirect paths from SES to the educational outcomes were also significant and positive, showing the positive mediation by both self-concept and utility value. Consistent with a priori predictions and previous studies, our findings suggest that SES positively predicts achievement-related behaviors, directly or indirectly, by promoting self-concept and subjective task values (Parker et al., 2012; Schoon & Polek, 2011).

The observed predictive direct effect of gender on motivational beliefs indicates that boys tend to have high math self-concept and intrinsic value but not utility value, which is line with previous Western studies of gender stereotypes (Watt et al., 2012; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006). It is interesting to note that the direct path from gender to achievement was largely off-set by the corresponding indirect path. This finding suggests that boys are likely to have higher math self-concept, which leads to higher math achievement (the indirect path from gender), whereas girls tend to have higher math achievement when girls and boys have similar levels of self-concept and intrinsic value (the direct path from gender). Taken together, there was no gender difference in math achievement in terms of total effect. In relation to educational aspirations, the direct path favoring girls was only partially countered by the corresponding indirect path favoring boys. In total, educational aspirations favored girls to a small extent. This finding is in line with our expectations and the recently



Fig. 3. Simple-slopes depicted the effects of the latent-interaction variables (self-concept by utility value) on mathematics achievement and educational aspirations. Note. MSC = mathematics self-concept; MUV = mathematics utility value.

observed change in gender difference on educational attainment favoring girls (see Appendix F in Supplemental material).

Additionally, to test whether the relationships among SES, motivational beliefs and educational outcomes vary as a function of gender, we conducted multigroup analysis in which gender was treated as a grouping variable. We found that SES was more strongly associated with aspirations for boys than for girls (gender differences in magnitude of the path coefficient: 2007 model: ES = .125, SE = .043; 2003 model: ES = .094, SE = .040; 1999 model: ES = .116, SE = .040). This finding indicates that family SES is more important for boys' educational aspirations (see Appendix G in Supplemental material).

8. Discussion

In sum, drawing on EVT this study contributes to the literature by identifying the mediating and interactive roles of math self-concept and subjective task values in the relationships between individuals' characteristics (gender and SES) and mathematics achievement and educational aspiration. The results have substantive importance for EVT. First, statistically significant interaction suggests that routinely checking for potential interaction effect is needed for future studies using the Eccles et al. (EVT) model. Second, the consistent patterns of effects observed across three cohorts during this naturally occurring "intervention" provide strong evidence for the robustness of EVT predictions. Third, given that little research has examined the moderating role of gender based on EVT in an Asian context, our results have shed light on the gendered processes underlying students' choice of educational pathway.

At this stage, it is important to reinforce that the three cohorts considered in the present study related to a period in which the educational context in Hong Kong was changing substantially. For example, the new math curriculum and a series of new education policies were implemented at the same time of the handover of sovereignty from the UK to China in 1997. Further complicating the patterns is the fact that the instruments used to measure key constructs differed slightly across cohorts. However, despite these complications, the patterns of results were highly consistent, supporting the external validity of the results (see Shadish, Cook, & Campbell, 2002), and proving strong support to the robustness of the theory.

Nevertheless, limitations must also be taken into account. First, it is not clear how these results generalize to Western countries or to other Asian countries. Chiu and Xihua (2008) demonstrated that the effects of family characteristics on children's math achievement are stronger in individualistic and more affluent countries. Second, SES was narrowly defined and did not include parents' income and occupation. Third, in the present study, educational aspiration was a general rather than domain-specific construct, and was represented by a single item. Given that both expectancy and task values are highly domain specific (Eccles & Wigfield, 2002), there is a need for items to assess students' intention of studying math or taking up a math-related career. Fourth, prior studies have documented that teaching processes play a critical role in the development of various components of self-related beliefs in school contexts (e.g., De la Fuente & Justicia, 2007). Therefore, it is important to take teaching-learning processes into consideration in further motivation research. Fifth, this study could not address the issue of causality (or even directionality) between demographic or motivational factors and outcomes based on a single measurement point. It is always possible that models with a reversed direction (e.g., from aspirations to motivational beliefs) may exist in reality. Finally, replication of findings may benefit also from alternative statistical techniques (e.g., Rasch modeling) instead of SEM.

Our findings have important implications for policy, practice, and intervention. First, given the positive effects of the interaction between expectancy and value on educational outcomes, it is important that teachers place emphasis on simultaneously enhancing students' expectancy and value beliefs, with special attention on strengthening selfconcept for those with lower utility value. For example, teaching strategies and methodologies based on an interactive conception of teaching-learning and building achievement motivation have shown an essential contribution in promoting students' motivation (e.g., De la Fuente & Justicia, 2007). Second, despite evidence of negligible gender differences in math achievement, there is a continuing pattern of gender stereotypic differences in favor of boys in perceptions of competence and interest in math. These gender differences might lead to underrepresentation of girls in math-related fields (Parker et al., 2012), which is an important concern. Further, although the Hong Kong government has been seeking to reduce inequalities based on family wealth via progressive taxes, social support programs, and tuition-free schools since the early 2000s (OECD, 2004), inequalities continue to be evident in the close relation between SES and children's motivation and educational outcomes, even in the TIMSS 2007 cohort. Thus, stronger and more powerful steps in reducing inequalities on SES could help students, particularly boys, to not only improve their motivation but also achieve better academic outcomes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx. doi.org/10.1016/j.lindif.2015.01.008.

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Chapter 5: Study 2 - Directionality of the Associations of High School Expectancy-Value, Aspirations and Attainment over Eight Years: A Multiwave, Longitudinal study

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Preface

The thesis integrated and extended two major theories (i.e., EVT and ASC theory) in achievement motivation to provide a broader conceptual framework for understanding student motivation, engagement, aspirations, and long-term attainment. Although it has been documented that motivational beliefs play an important role in influencing educational attainment, little research has examined how motivational beliefs interact with aspirations and cognitive factors to shape educational pathways during the transition into early adulthood. The first aim of study 2 was to integrate one of the critical theoretical models of ASC – the reciprocal effect model (REM) – into EVT, by examining the reciprocal effects of ASC, intrinsic value, and utility value in relation to academic achievement and educational and occupational aspirations during post-high school transition, over an eight-year period. Another contribution of study 2 was to examine how multiple non-cognitive (motivation and aspirations) and cognitive (IQ and achievement) factors influenced educational attainment across time.

Finally, study 2 extended study 1 by exploring longitudinal evidence for ASC-byvalue interactions in predicting a variety of outcomes. It should be noted that latent interactions between ASC and values were not included in the main text of study 2, given that the journal editors and reviewers suggested that this issue would bring another complication to an already complex article. These tests of latent interactions were thus reported in Appendix 2-F of study 2 as supplemental materials and discussed in the final general discussion and conclusion chapters of this thesis.

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Directionality of the Associations of High School Expectancy-Value, Aspirations, and Attainment: A Longitudinal Study

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(This study examines the directionality of the associations among cognitive assets (IQ, academic achievement), motivational beliefs (academic self-concept, task values), and educational and occupational aspirations over time from late adolescence (Grade 10) into early adulthood (5 years post high school). Participants were from a nationally representative sample of U.S. boys N = 2,213). The results suggest that (a) self-concept and intrinsic value have reciprocal effects with academic achievement and predict educational aspirations, (c) the associations between achievement and aspirations are partially mediated by motivational beliefs, and (d) academic self-concept in high school had stronger long-term indirect effects on future occupational aspirations and educational attainment than task values and IQ.

KEYWORDS: self-concept, expectancy-value, educational attainment, educational and occupational aspiration, transition in adulthood

The post-high school transition into early adulthood marks an important developmental step in the educational and occupational career of young people. During this transition, individuals begin to make choices and engage in a variety of activities that will have a determining impact on the rest of their lives, including the decision about university or vocational study and entry into the workforce (Savickas, 2002). In the educational area, it is well documented that cognitive resources (e.g., IQ and prior academic achievement) are not the

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Guo et al.

only factors that can help adolescents make a successful transition into adulthood. Indeed, personal motivation (interest, valuing) and aspirations for education and learning and academic self-concept (competence belief, or expectations of success) also represent key determinants of educational attainment and career success (Dietrich, Parker, & Salmela-Aro, 2012; Eccles, 2009; Hauser, 2010; Sameroff, 2010; Zarrett & Eccles, 2006). These personal noncognitive assets have been widely identified in many developmental models, such as the expectancy-value theory (EVT) (Eccles, 1994; Eccles et al., 1983), the social-cognitive model of career choice (Lent, Brown, & Hackeet, 1994, 2000), the career construction model (Savickas, 2002, 2005; Super, 1957, 1990), and the phaseadequate engagement framework (Dietrich et al., 2012). Numerous empirical studies have tested and supported these positive associations between cognitive and noncognitive factors and educational attainment, perseverance, and success (Eccles, Wigfield, & Schiefele, 1998; Fouad, 2007; Hauser, 2010). However, the empirical studies that comprehensively examine the complex interplay between cognitive ability and personal noncognitive assets in influencing final educational attainment across the transition into adulthood are scarce (but see Parker et al., 2012; Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2013).

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372

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Expectancy-Value at Post-School Transition

From a practical perspective, much attention has been given to educational achievement—typically measured by standardized test scores—by educational evaluation and policy. However, an increasing number of international studies have demonstrated that educational attainment plays a more important role than cognitive ability and achievement in long-term socioeconomic success (Bowen, Chingos, & McPherson, 2009; Hauser, 2010). For example, Hauser (2010) conducted secondary data analysis of longitudinal data over a 50-year period that showed that IQ has little influence on occupational standing and wealth after controlling levels of schooling. Indeed, many capable students do not pursue pathways of higher education (Bowen et al., 2009). Given that it is easier to alter educational attainment compared to cognitive ability, in particular for IQ, these findings imply that it is pivotal to investigate the process through which individuals develop personal noncognitive assets (motivation and aspirations) that subsequently lead to educational attainment.

On the other hand, these findings have important practical implications for countries, seeking to build economic success. To maintain internationally competitive economies, the U.S. government has recognized the need to encourage tertiary education to meet the demand for highly skilled professionals (Lacey & Wright, 2009). For example, government programs such as the Obama administration's Race to the Top (RTTT) have been implemented to improve individual educational attainment and narrow achievement gaps. It is important then that more research is conducted to better understand exactly how motivation contributes to educational attainment.

Therefore, in the current research, we test a comprehensive model based on EVT (Eccles, 1994, 2009) to fully examine the complex interplay among cognitive variables (IQ, prior academic achievement) and motivational beliefs (expectancies and task values) and educational and occupational aspirations and their interrelationships across the transition from high school (Grade 10) into early adulthood (up to 5 years post high school).

Theory and Background Literature

Expectancy-Value Theory

The modern EVT model (Eccles, 1994; Eccles et al., 1983; Eccles & Wigfield, 2002) posits that achievement-related performance and choices are most directly influenced by the individual's expectancies of academic success and a subjective assessments of the inherent value of academic tasks; the socialization processes linked to various cultural and social settings (e.g., school and family) influence individual differences in motivational beliefs. In her extension of the model to educational and occupational choices, Eccles (2007, 2009) argued that individuals make choices based on their expectancies to meet the educational demands and success at a given career and for the value they place on that particular educational or occupational goal.

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Modern EVT (e.g., Eccles, 1994, 2009) defines expectancy of success as a task-specific belief about the possibility of experiencing future success in that task that is directly related to individuals' evaluations of their competencies (e.g., academic self-concept; Marsh, 1986) in a given domain. Harter (1990) and Marsh (1989) have conducted extensive research on adolescent self-concept in different areas, the measures of which are highly related to expectancy construct of expectancy-value theory (Wigfield & Cambria, 2010). Although ability beliefs (i.e., self-concepts) and expectancies of success are theoretically distinct constructs, these two constructs are empirically indistinguishable and collapse into a single construct in real-life settings (Eccles & Wigfield, 2002; Wigfield & Eccles, 1992). For this reason, we use academic self-concept in the current research as a measure of expectancies of success and use these terms (i.e., self-concept and expectancies) synonymously. Also, modern EVT distinguishes between multiple components of subjective task value (Wigfield & Eccles, 1992); for the present purposes we distinguish between *intrinsic value*, referring to the enjoyment a person gains from performing an activity (in line with intrinsic motivation and interest), and utility value, relating to how a specific task fits within individual future plans and objectives.

In relation to the developmental trajectory of motivational beliefs, it is well established that academic self-concept, intrinsic value, and utility values tend to be quite stable during the upper high school years (e.g., Gottfried, Fleming, & Gottfried, 2001; Marsh, Byrne, & Yeung, 1999; also see Wigfield & Cambria, 2010, for a review). However, research exploring the development of these motivational constructs during the post–high school transition has been surprisingly sparse.

Motivational Beliefs and Achievement

According to the EVT (Eccles, 2009), students' motivational beliefs as a function of prior achievement-related activities (e.g., prior academic achievement) influence subsequent academic achievement. Academic selfconcept has been demonstrated as a stronger predictor of academic achievement compared to value beliefs (e.g., Marsh et al., 2013; Trautwein et al., 2012; Wigfield & Eccles, 2002). Particularly in the later high school years, academic self-concept appears to be more systematically related to academic outcomes and the relationship appears to be reciprocal (Skaalvik & Hagtvet, 1990; Wigfield, 1994; Wigfield & Karpathian, 1991). To account for this reciprocal relationship, Marsh (1990, 1993; also see Marsh & Craven, 2006, for a review) proposed a reciprocal effects model where prior self-concept influences subsequent achievement and prior achievement influences subsequent self-concept. The generalizability of this reciprocal effects model has been widely supported in numerous empirical studies based on diverse sample of adolescents (e.g., Marsh, 2007; Marsh & Craven, 2006).

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The relation between intrinsic values and academic achievement was found to be reciprocal in some longitudinal studies of high school students, while the effects of intrinsic value were substantially attenuated by controlling for self-concept (Köller, Baumert, & Schnabel, 2001; Marsh et al., 2005; Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). However, only little, or weak, relations between utility value and achievement have been found when controlling for self-concept and intrinsic value (Eccles & Wigfield, 2002). Although studies investigating the reciprocal effects of selfconcept, intrinsic value, and utility value with achievement have been conducted within primary and high school settings, these reciprocal effects have never been explored during the post–high school transition.

Motivational Beliefs and Educational and Occupational Aspirations

According to the expectancy-value model, motivational beliefs influence engagement in different educational activities, as well as future educational and occupational choices (Eccles, 1994, 2009). People will select the achievement-related activities they think they can master and that have the highest subjective task value for them as education and career interests and choices across the set of options being considered (Eccles, 1994). Personal efficacy and self-concept in academic tasks have long been thought to be a determinant of behavioral choices by achievement theorists (Eccles, 2009), and this positive association has been supported across a diverse sample of students in numerous empirical studies (e.g., Betz & Hackett, 1983; Hackett & Betz, 1989; Lent, Lopez, & Bieschke, 1991). Although academic self-concept has typically been thought to be a crucial predictor of academic tasks selection within the school, academic self-concept has also been found to be an important predictor of educational and career choices in the recent literature (e.g., Marsh & Yeung, 1997; Nagengast & Marsh, 2012; Parker et al., 2012, 2013). For example, Parker et al. (2013) found that academic self-concept had significant effects on entrance into tertiary education at the end of high school, controlling for achievement. Further, Savickas's (2002, 2005) career construction theory, developed from the seminal work of Super (1957, 1990), proposes that self-concept is one of the determinants of how people choose their work and education trajectories and construct their careers during the school to work transition (e.g., posthigh school and post-university transition).

However, positive expectancies of success are a necessary, yet not sufficient, predictor of educational and occupational aspirations (Eccles, 2009). Based on the EVT, longitudinal studies found that educational aspirations were predicted by youths' task values controlling for prior achievement (Eccles, Vida, & Barber, 2004; Watt et al., 2012). Similarly, task values were found to be significant predictors of occupational aspirations when both expectancies and values are considered along with prior achievement (Eccles, Barber, & Jozefowicz, 1999). However, these findings are only based

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on high school students. Given that late adolescents' aspirations substantially affect future education and career trajectories (Beal & Crockett, 2010; Mello, 2008), recent studies pertaining to directionality of the association of motivational beliefs and aspirations have placed emphasis on post–high school transition (e.g., Parker et al., 2012, 2013). However, few studies have considered both self-concept and task value simultaneously when exploring directional and occupational aspirations across the timing of the transition into adulthood. In the current study, both academic self-concept and task value were taken into consideration to explore the nature of the relations between motivational beliefs and aspirations, controlling for achievement during the post–high school transition.

Motivational Beliefs, Aspirations, and Educational Attainment

Educational attainment contributes significantly in shaping people's occupational trajectories (Beal & Crockett, 2010; Mello, 2008; Ou & Reynolds, 2008). It is well documented that adolescents' cognitive ability (IQ) and academic achievement in high school have substantial influence on educational attainment later on (e.g., university entry and completion; Bowen et al., 2009; Hauser, 2010; Parker et al., 2012; Sewell & Hauser, 1975; Sewell, Haller, & Protes, 1969). Further, research and theory posit that IQ and academic achievement in high school affect educational attainment and career success through a causal chain in which agency-based factors and educational and occupational aspirations each play important intervening roles (Eccles, 1994, 2009; Hauser, 2010; Parker et al., 2012; Schoon, 2008). For example, Sewell et al. (1969) found the positive causal link between ability and educational and occupational aspiration, leading to educational attainment based on Wisconsin Longitudinal Study (see Sewell, Hauser, Springer, & Hauser, 2003, for a review). Similarly, Schoon (2008) found IQ scores and academic achievement in high school predicted school motivation, which in turn influences adults' educational attainment based on a long-term British National Child Development Study. However, few studies have focused on the directionality of the associations between these personal cognitive and noncognitive assets and on how this temporal process finally influences subsequent educational attainment across the transition into early adulthood.

The Present Investigation

The present study is based on the EVT framework (Eccles, 1994, 2009) and focuses on the process through which individuals develop personal qualities, such as abilities, motivation, and aspirations, that subsequently lead to educational attainment during the transition into early adulthood. In this study, five waves of data, ranging from high school to five years after graduation, are used not only to provide a clear picture of the expectancy-

value development process across the post-high school transition but also allow for a better understanding of how the temporal associations between motivational beliefs, achievement, and aspirations in shaping further educational attainment. Furthermore, this period is an important time for the development of the individual's aspirations as they transit from vague awareness of careers to a focused exploration and progressive narrowing of career options (Dietrich et al., 2012; Savickas, 2002; Super, 1990). This study thus provides critical insight into the development of aspirations.

Given that motivational beliefs are of particular interest to the present study, three specific research questions are addressed:

- *Research Question 1:* What role do motivational beliefs play in shaping academic achievement and subsequent educational attainment?
- *Research Question 2:* What role do motivational beliefs play in shaping educational and occupational aspirations?

Research Question 3: Taking into account all cognitive and noncognitive assets, what role do motivational beliefs play in shaping educational attainment?

In the present investigation, the hypothesized predictive model (see Figure 1) was built on the basis of the EVT framework and empirical research reviews. Academic self-concept, different components of task value, IQ, academic achievement and attainment, and educational and occupational aspirations were all assessed and included in the hypothesized model in order to provide a comprehensive test of the EVT framework. To provide a clear picture of the directionality of the associations between motivational beliefs and outcome variables, we started with Models 1 and 2, which were then extended to Model 3.

More specifically, in Model 1 (Figure 2), motivational beliefs were considered along with academic achievement and attainment. We hypothesized the significant reciprocal effects of academic self-concept and intrinsic value with academic achievement (e.g., Marsh & Craven, 2006; Marsh et al., 2005; Question 1). In contrast, given a relatively weak relationship between academic achievement and utility value after controlling self-concept and intrinsic value, we did not expect this relationship to be reciprocal. Furthermore, we also hypothesized that motivational beliefs (academic self-concept and intrinsic and utility values) would predict subsequent educational attainment (e.g., Parker et al., 2012, 2013; Question 1). Based on Model 2 (Figure 3), in which motivational beliefs were considered along with educational and occupational aspirations, we anticipated that academic self-concept, intrinsic value, and utility value would positively predict educational and occupational aspirations over time (e.g., Eccles et al., 1999, 2004; Question 2). However, it was unclear whether motivational beliefs and aspirations were reciprocally related during post-school transition, namely, whether aspirations would in turn predict later levels of motivational beliefs. Finally, to

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Figure 1. The hypothesized model.

Note. All variables were given a label that identifies the Time (T1 to T5). Academic achievements at T1 and T2 were measured by last year GPA at Grades 10 and 11, while achievement T3 represents current GPA. All aspirational variables were treated as prospective variables following by motivation factors within each time wave. The cross-time associations were specified as regression paths; prior outcome variables predict subsequent motivation factors and outcome variables, and then prior motivation factors predict subsequent outcome variables. Within-time associations between constructs were specified by the inclusion of time-specific covariance relationships (i.e., attainment is correlated to motivation factors at T4). In motivation constructs, the residual variances among the corresponding indicators are allowed to correlate over time. Of particular interest are motivational beliefs that are shaded in gray. Squares indicate the latent construct, while ovals indicate the manifest construct. IQ = intelligent test scores; ASC = academic self-concept; INV = intrinsic value; UV = utility value.



Figure 2. Structural path model of the relations between motivational beliefs, achievement, and attainment (Model 1).

Note. Only statistically significant regression paths (*t* value > 1.96; *p* < .05) were presented. All variables were given a label that identifies the Time (T1 to T5). Of particular interest are motivational beliefs that are shaded in gray. ASC = academic self-concept; INV = intrinsic value; UV = utility value.





Note. Only statistically significant regression paths (t value > 1.96; p <.05) were presented. All variables were given a label that identifies the Time (T1 to T5). Of particular interest are motivational beliefs that are shaded in gray. ASC = academic self-concept; INV = intrinsic value; UV = utility value.

address Question 3, all cognitive and noncognitive variables were assessed together in Model 3 (Figure 4). We expected that the relationships between achievement, aspirations, and attainment would be partially mediated by motivational beliefs (e.g., Hauser, 2010). We also expected that motivational beliefs, in particular self-concept, would be significantly related to long-term educational attainment when controlling for IQ, achievement, and aspirations in high school (Parker et al., 2012, 2013).

Method

Participants

The data used in the present study come from the Youth in Transition study (YIT; Bachman & O'Malley, 1977; also see Bachman, 2001, 2002). The YIT was a five-wave longitudinal follow-up study of a nationally representative sample of 10th-grade boys in the U.S. public high schools. A two-stage sampling procedure was employed; the first stage comprised a random sample of 87 public high schools; the second comprised around 25 students selected randomly from each sampled school. In total, five waves of data were collected between 1966 and 1974: Time 1 (T1, early 10th grade; N = 2,213), Time 2 (T2, late 11th grade; N = 1,886; 15% missing data), Time 3 (T3, late 12th grade; N = 1,799; 19% missing data), Time 4 (T4, one year after normal high school graduation; N = 1,620; 27% missing data), and Time 5

379





Figure 4. Structural path model of the relations between motivational beliefs, IQ, achievement, aspirations, and attainment (Model 3).

Note. Only statistically significant regression paths (*t* value > 1.96; *p* < .05) were presented. All variables were given a label that identifies the Time (T1 to T5). Of particular interest are motivational beliefs that are shaded in gray. ASC = academic self-concept; INV = intrinsic value; UV = utility value.

(T5, five years after normal high school graduation; N = 1,608; 27% missing data).

Measures

All variables used here are from the publicly available longitudinal data file from the Youth in Transition study (Bachman, 2001, 2002). It should be noted that not all observed outcome variables and motivational constructs are measured across five waves in the Youth in Transition data set (see Appendix 1 in the online journal for more details). For instance, the measure of latent constructs of students' self-concept and task values were available only for T1, T2, and T4. In addition, the number of items assessing motivation was not entirely consistent across these three occasions. All motivation items were coded on Likert scales, and scores used in this study were systematically recoded so that higher values consistently reflect higher levels of motivation (see Appendix 1 in the online journal for more detail regarding latent variables used; see also Bachman, 2001, 2002, for all item wordings and response frequencies). All outcome variables were standardized (M = 0, SD = 1) to ensure consistent responses scales across time waves.

380

Self-Concept

The scale consisted of three items measuring students' perception of their competencies in overall school ability, reading ability, and IQ compared with others of their age at T1 and T2 but only two items relative to reading ability and IQ at T4 (e.g., "How do you rate in school ability compared to others?").

Value

The scale of students' positive school attitude was used to assess the effect students experienced when studying in school (e.g., "How interesting are most of your courses to you?"), in line with the notion of *intrinsic value* in the modern EVT (Eccles et al., 1983). The *utility value* scale that assesses how important studying hard in school was used (e.g., "Are you studying hard to get good grades in school?").

IQ. IQ was measured using the quick test (Ammous & Ammons, 1962) at T1, an easily administered measure of intelligence based on visual-perceptual vocabulary performance. For each item, participants are given a card with four pictures and are asked to select the picture corresponding to a specific test word. This word-matching test has been found to be highly correlated with Wechsler Adult Intelligence Scale (WAIS) across diverse populations (Mortimer & Bowen, 1999).

Academic Achievement

Students' academic achievement used in the present study was derived from their overall grade point average (GPA) on the basis of a single selfreport item at T1 (Grade 10) and T2 (Grade 11)., GPA was collected in an individually administered personal interview in which participants were asked to report their GPA for the previous year, whereas at T3 (Grade 12), the GPA for the current year was requested in a self-administered questionnaire at T3. Reported GPA was recorded into 1 of 13 categories from A+ to F (or E), which also was recorded into numeric values (from 1 to 13, with 13 reflecting the highest possible grades) for the analysis, and then standardized.

Educational Attainment

Participants were asked a series of questions regarding the level of education they had attained or were in the process of attaining. These were used to construct a composite variable at T4 and T5. In line with recommendations from previous research (e.g., Bachman & O'Malley, 1977, 1986; Marsh & O'Mara, 2008, 2010), items regarding high/vocational school and college enrollment status are included in this outcome variable.¹ At T4 the scale was composed of (1) no high school diploma or other formal

educational qualifications, (2) currently at high school, (3) completed high school diploma, (4) currently attending vocational school after high school, (5) currently undertaking two-year college degree program, and (6) currently undertaking four-year college degree or university degree program. At T5, the scale consisted of nine categories and the first four categories were the same as categories 1 to 4 at T4; (5) graduate of vocational school, (6) currently undertaking two-year college degree, (7) graduate of two-year college degree program, and (9) graduate of four-year college degree program. If more than one category was chosen by participants, only the highest category was used to represent the highest level of educational attainment.

Educational Aspirations

Participants were asked a series of questions regarding the level of education that they hoped to attain. These were used to construct a composite variable with the response scale ranging from (1) no high school diploma; plans to drop out of high school to (4) postgraduate or professional school after college/university.

Occupational Aspirations

A single item was used in all of five waves of data to assess participants' occupational aspirations ("What sort of work do you think you might do for a living?"). The responses were then coded on rankings developed by Otis Duncan (1961) in terms of combination among reputation rating, education level required, and income (see Bachman, 2002, for further discussion). In the Duncan occupation scale, 100 indicated the highest occupational aspirations while 1 indicated the lowest.

Analysis

Estimation and Missing Data

Structural equation models (SEMs) used in data analysis were estimated in Mplus 7 (Muthén & Muthén, 2012). The nesting of the students into classes was treated as a clustering variable to take into account the nonindependence of the scores for students from the same school. The YIT weighting variable was applied throughout the data analysis in order to obtain population estimates (Bachman, O'Malley, & Johnston, 1978). SEMs were estimated using the Mplus robust maximum likelihood (MLR) estimator, which is robust to the nesting of the students within schools and to the Likert nature of items including four or more answer categories (Mplus's complex design option; Muthén & Muthén, 2012; e.g., Beauducel & Herzberg, 2006; Distefano & Motl, 2006). The MLR estimator was used

in conjunction with full information maximum likelihood (FIML) estimation in order to cope with the inevitable missing data present in longitudinal studies. In FIML, the parameters of a statistical model are estimated in the presence of missing data, and all of the information of the observed data is used to inform the parameters' values and standard errors. Studies show that FIML tends to perform as well as more computer-intensive multiple imputation procedures, even in the presence of elevated rates of missing responses or time waves (for additional details, see Enders, 2010).

Indirect Effect

Bootstrap confidence intervals with 1,000 bootstrap draws were used to test the significance of indirect path coefficients (Preacher & Hayes, 2008; Shrout & Bolger, 2002). If the confidence interval excludes zero, the indirect effect can be considered to be statistically significant. For present purposes, we report the 95% confidence interval that corresponds to the p < .05 alpha level using Mplus 7 (see Muthén & Muthén, 2012). Specifically, we presented the total indirect effect that is the sum of all of the indirect pathways by which the predictor exerts its influence on outcome variables via an indirect pathway through intervening variables. For example, in Figure 1, the paths from achievement to occupational aspirations via motivational factors at T1 are indirect paths, in which the T1 self-concept and intrinsic and utility value, respectively, mediate the effects of achievement on occupational aspirations at T1. The total indirect effect is then the sum of these three indirect effects. For clarity, we only present statistical significant direct effect based on Models 1 to 3 and indirect effects based on final Model (i.e., Model 3). Total effects is simply the sum of direct effect and total indirect effects between two variables (see Appendices 2-4 in the online journal for more details regarding direct, indirect, and total effects).

Goodness of Fit

In recent applied SEM research, there is a predominant focus on indices that are sample size independent (Marsh, Wen, & Hau, 2004), such as the root mean square error of approximation (RMSEA), the Tucker-Lewis Index (TLI), and the Comparative Fit Index (CFI) rather than chi-square tests of statistical significance because of oversensitivity to sample size and minor model misspecifications. Values greater than .90 and .95 for TLI and CFI, respectively, typically are acceptable and provide excellent fit to the data. RMSEA values of less than .06 and .08, respectively, are considered to reflect good and acceptable fit to the data.

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Tests of Invariance

In order to ensure that the constructs remained the same across time points, we tested the longitudinal invariance of the factor loadings. Although additional tests of invariance are possible, in a model like the one used in the present study that focuses on only the covariance between constructs, the only real prerequisite to valid longitudinal comparisons is the invariance of the factors loadings over time (Millsap, 2011). Other more stringent tests would have been necessary in order to support the test of latent mean differences over time or models based on the use of manifest, rather than latent, scale scores, which is not the case in the present study. For the comparison of the two models, the chi-square difference test suffers from more problems than that for single models (see Marsh, Hau, Balla, & Grayson, 1998). Other fit indices like the CFI and the RMSEA perform well for judging the adequacy of the invariance assumption (Morin, Marsh, & Nagengast, 2013). Cheung and Rensvold (2002) and Chen (2007) suggested that if the change in CFI is not more than .01 and the RMSEA increases by less than .015 for the more parsimonious model, the assumption of variance is tenable.

Results

Descriptive and Correlations

Descriptive results for the variables were presented in Table 1. All multiitem scales demonstrated acceptable internal reliability at all waves of data. All of the scales are approximately normally distributed.

To examine the factor structure of academic self-concept and task value, confirmatory factor analysis (CFA) was employed. The configurally invariant CFA model where no constraints are placed on any of the parameter estimates fit the data well (see Table 2). Testing for weak measurement invariance involves constraining each corresponding factor loading to be equal across time. The change in model fit between the configural and weak models was negligible (equivalent RMSEAs and CFIs and only slight decreases in TLIs).

Before testing the hypothesized model, intercorrelations among motivational factors and outcome variables were evaluated across time (see Table 1). These results showed that academic self-concept was significantly correlated with intrinsic (r = .303, p < .001) and utility values (r = .335, p < .001), while intrinsic value was also significantly correlated with utility value at T1 (r = .497, p < .001). Nonetheless, the pattern of correlations between academic self-concept and values decreased over time. Self-concept was more highly correlated with achievement and educational and occupational aspirations compared to intrinsic value and utility value. At each occasion, self-concept, academic achievement, and aspirations significantly correlated with educational attainment at T4 and T5 (r = .339-.565, p < .001), whereas the pattern of correlations between task value and attainment were less

				Estim	ated C	orrela	tion N	latrix	tor th	e Late	nt var	lables	Acro	SS OC	casions						
			Time 1	(T1)				Time 2 (T2)			Time	e 3 (T3)			Time	4 (T4)		Tim	e 5 (T5)	
Variables	1	2	6	4	Ś	9	7	×	6	10	11	12	13	14	15 16	17	18	19	20	21	22
1. IQ T1	I																				
2. Achievement T1	0.353*																				
3. Self-concept T1	0.485*	0.598*																			
4. Intrinsic value T1	0.019	0.273*	0.273*	I																	
5. Utility value T1	0.211^{*}	0.301^{*}	0.335*	0.497*																	
6. Occupational	0.372^{*}	0.346^{*}	0.431^{*}	0.202^{*}	0.266*																
aspirations T1																					
Self-concept T2	0.477^{*}	0.543*	0.844^{*}	0.228^{*}	0.254*	0.384^{*}															
8. Intrinsic value T2	0.027	0.225*	0.232^{*}	0.632^{*}	0.311^{*}	0.155*	0.229*														
9. Utility value T2	0.053	0.186^{*}	0.163^{*}	0.334^{*}	0.464^{*}	0.161^{*}	0.142* (0.511*													
10. Achievement T2	0.310^{*}	0.656*	0.585*	0.285*	0.290^{*}	0.314^{*}	0.598* (0.307* (0.209*												
11. Occupational	0.352*	0.385*	0.458*	0.176^{*}	0.244^{*}	0.626^{*}	0.464* (0.200* (0.174* (0.401*											
aspirations T2																					
12. Educational	0.233^{*}	0.396^{*}	0.451^{*}	0.281^{*}	0.265*	0.459*	0.447* (0.309* (0.243* (0.419* (0.567*										
aspirations T2																					
13. Achievement T3	0.309^{*}	0.588*	0.504*	0.236^{*}	0.278*	0.285*	0.545* (0.281* (0.188* (0.652* (0.362* C).328*									
14. Occupational	0.373^{*}	0.403^{*}	0.486^{*}	0.167^{*}	0.222^{*}	0.548*	0.477* (0.148* (0.144 [*] (0.389* (0.680* C).488* ().377*								
aspirations T3																					
15. Educational	0.287^{*}	0.431^{*}	0.481^{*}	0.240^{*}	0.248^{*}	0.452*	0.444* (0.268* (0.240* (0.393* (0.563* C).627* ().407* (0.604^{*}							
aspirations T3																					
16. Self-concept T4	0.355*	0.450*	0.714^{*}	0.270^{*}	0.270^{*}	0.286^{*}	0.779* (0.237* (0.142* (0.490* (0.374* C).389* ().471* (0.383* (0.388* —						
17. Intrinsic value T4	-0.046	0.038	0.039	0.255*	$0.123^{*} -$	-0.058	0.043 (0.352* (0.136* (0.106* (0.037 0).086 ().212* -(0.033 (0.065 0.131						
18. Utility value T4	0.054	0.002	0.049	0.172^{*}	0.278*	0.014	0.055 (0.326* (0.465* (0.014 (0.030 C	0.005 (0.034 ().040 (0.003 0.003	0.297*					
19. Occupational	0.348^{*}	0.401^{*}	0.458*	0.151^{*}	0.238*	0.499*	0.440* (0.164* (0.165* (0.383* (0.597* 0).482* ().375* ().640* (0.550* 0.383	* 0.095*	0.021				
aspirations T4																					
20. Educational	0.324^{*}	0.465*	0.475*	0.220^{*}	0.303^{*}	0.397^{*}	0.466* (0.238* (0.216* (0.475* (0.481* C).490* ().483* (0.527* (0.565* 0.339'	* 0.078*	-0.017	0.535*			
attainment T4																					
) (CC	ntinu	ed)

Table 1 ed Correlation Matrix for the Latent Variables

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Chapter 5: Study 2		
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			Time 1	(T1)				Time 24	(T2)			Tin	ie 3 (T3)				Time 4 ((T4)		Tim	e 5 (T5)	
Variables	1	7	6	4	Ś	9	\sim	8	6	10	11	12	13	14	15	16	17	18	19	20	21	22
21. Occupational aspirations T5	0.221*	0.313*	0.281*	0.117*	0.174*	0.245*	0.248*	0.063*	0.106*	0.290*	0.276*	0.242*	0.301*	0.297*	0.287* (.225*	.101*	0.053 (0.306*	0.708*		
22. Educational attainment T5	0.357*	0.478*	0.452*	0.203*	0.260*	0.417^{*}	0.462*	0.184^{*}	0.154*	0.470*	0.489*	0.475*	0.475*	0.506*	0.541* (.380* ().123*	0.024 (0.510*	0.329*	0.384^{*}	
M	108.64	39.97	4.15	3.16	5.15	61.21	4.23	3.1	5.06 4	£0.02	58.92	3.92	7.81	58.03	3.88 4	.13	3.47	4.84	4.20	57.72	5.76	36.75
SD	12.29	7.24	0.73	0.62	0.80	26.21	0.75	0.62	0.74	66.9	24.83	1.07	2.12	24.55	1.12 (.75	.83	0.74	1.47	24.43	2.37	23.02
Skewness	-0.66	-0.16	-0.03	-0.55 -	-1.18 -	-0.58	0.10 -	-0.48 -	0.73 -	-0.12 -	- 0.43 -	-0.79	0.02 -	- 0.44 -	-0.75 (.10 -	.52 -	0.38 -(0.35 -	-0.41 -	-0.14	0.47
Kurtosis	1.57	0.53	0.10	0.30	2.10 -	-1.01 -	-0.07	0.27	0.68	0.51 -	-1.03 -	-0.32 -	0.23 -	- 0.97	-0.49 (.02	.34	0.34 -(0.78 -	- 0.93	-1.06	96
Alpha			0.743	0.767	0.800		0.711	0.760	0.775					Ι		.649	.760 ^a	0.739				
^a Intrinsic valu	e at T4 is	s treate	d as a l	atent c	onstru	ct by fi	xing th	te stand	Jardize	ed me	asurem	ent err	or of t	he sing	gle ind	icator	to a pi	redete	rmine	ed valu	ie of	240
(reflecting a c	onserval	tive est.	imate c	of relia	bility c	of .760,	which	is the	same	as that	t at T2)	(for a	dditior	nal det	ails or	this p	roced	ure, se	ee e.g	., Boll	en, 19	89;
Töreskog. 197	.(6																					

Jöreskog, 1979). *p < .05.

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Model	χ^2	df	Comparative Fit Index	Tucker- Lewis Index	Root Mean Square Error of Approximation
CFA					
Configural	612.187	268	.974	.966	.024
Factor loading invariance	634.114	278	.974	.965	.024
SEM					
Model 1 (motivation, achievement, and attainment)	1,027.802	415	.966	.959	.026
Model 2 (motivation and educational and occupational	1,212.002	473	.967	.961	.027
aspirations) Model 3 (final hypothesized model)	1,388.491	613	.967	.960	.024

 Table 2

 Model Fit Statistics for the Longitudinal Confirmatory Factor

 Analysis (CFA) and Structural Equation Modeling (SEM) Models

pronounced (r = .078-.238, p < .05, for intrinsic value; r = .154-.260, p < .01, for utility value at T1 and T2). However, it is noted that the correlation between utility value at T4 and attainment was not statistically significant.

In relation to SEM, the hypothesized models were found to provide excellent fit: CFI and TLI were above .95 and RMSEA was less than .027 (see Table 2). The final model (Model 3), in which all cognitive and noncognitive variables were assessed together, respectively, accounted for 40%, 8%, and 11% of the variance in academic self-concept; intrinsic value and utility value at T1, 75%, 51%, and 34% at T2 and 67%, 38%, and 47% at T4. The final model accounted for a large portion of the variance in academic achievement (50% at T2, 47% at T3), educational attainment (43% at T4, 55% at Time 5), educational aspirations (36% at T2, 47% at T3), and occupational aspirations (24% at T1, 48% at T2, 50% at T3, 50% at T4, 16% at T5). Detailed results from these models are reported in Appendix 2 available in the online journal. Figures 2 through 4 present the standardized path coefficients for the hypothesized models.

Research Question 1: What Roles Do Motivational Beliefs Play in Shaping Academic Achievement and Subsequent Educational Attainment?

As can be seen in Figure 2 (Model 1), autoregressive paths of academic self-concept were extremely stable across time (β = .755-.764, *p* < .001). The

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patterns of autoregressive paths of intrinsic value ($\beta = .338$ -.576, p < .001) and utility value ($\beta = .489$ -.517, p < .001) are smaller than those of self-concept across time. Similarly, autoregressive stability coefficients relating to the measures of academic achievement and educational attainment on different occasions are all significant and positive.

The estimated cross-lagged effects reflect the unique direct effects of a variable on another variable measured at later time points controlling for the autoregressive effects, whereby each variable predicts itself over time. In other words, these cross-lagged paths reflect the relations between one variable and changes in another variable over time. T1 students' achievement (i.e., GPA from the previous year collected at T1) had stronger effects on T1 self-concept (β = .488, *p* = .037), intrinsic value (β = .284, *p* = .033), and utility value (β = .286, *p* = .030) compared to T1 IQ scores. In particular, IQ did not significantly predict intrinsic value. The effect of T2 achievement (i.e., GPA from the previous year collected at T2) on all of T2 motivational factors were somewhat weaker compared to the corresponding path coefficient at T1. However, T3 achievement had a positive and significant effect on T4 self-concept (β = .091, p = .034) and intrinsic value (β = .128, p = .026) but not on utility value. The effect of T1 self-concept on subsequent achievement is statistically significant ($\beta = .268, p = .034$) and similar in magnitude to the cross-time relation between T2 self-concept and T3 achievement (β = .260, p = .031). Controlling for self-concept, the effects of prior intrinsic value on subsequent achievement were rather small ($\beta = .080-.072$, p < .05), whereas corresponding paths relating utility value and achievement were not statistically significant. Similarly, at T4, self-concept more strongly predicted T5 educational attainment (β = .217, p = .029) than intrinsic value $(\beta = .072, p = .026)$, whereas the path from utility value to educational attainment was not statistically significant. In addition, controlling for motivational beliefs and prior achievement, the path from IQ to T2 achievement was not statistically significant.

Research Question 2: What Roles Do Motivational Beliefs Play in Shaping Educational and Occupational Aspirations?

The results showed that the coefficients of autoregressive paths involving motivation are similar between Model 1 (see Figure 2) and Model 2 (see Figure 3). The stability of occupational aspirations decreased after postschool transition (i.e., T4 and T5; $\beta = .331$, p = .026).

As we hypothesized, prior self-concept significantly predicted subsequent occupational aspirations ($\beta = .334-.265$, p < .05) while the magnitudes of path coefficients decreased across post-school transition. No paths from intrinsic value to occupational aspirations were statistically significant, whereas utility value only has a small and positive effect on occupational aspirations at T1 ($\beta = .114$, p = .031). T2 self-concept, intrinsic value, and

utility value exerted positive effects on T2 educational aspirations ($\beta = .295$, p = .011, for self-concept; $\beta = .145$, p = .014 for intrinsic value; $\beta = .065$, p = .029, for utility value). However, there was no significant path from occupational and educational aspirations to subsequent motivational beliefs over time, except for a somewhat small and negative path from T3 occupational aspirations to T4 intrinsic value ($\beta = -.112$, p = .042). In addition, prior occupational aspirations positively predicted subsequent educational aspirations on subsequent occupational aspirations were relatively small ($\beta = .159$, p = .026).

Research Question 3: Taking Into Account All Cognitive and Noncognitive Assets, What Roles Do Motivational Beliefs Play in Shaping Individuals' Educational Attainment?

To explore the complex interplay of motivational beliefs, aspirations, achievement, and attainment, all of variables were added in the final model (see Figure 4). Controlling for other variables, the corresponding path coefficients involving motivation are similar across the three models (Models 1, 2, and 3).

While academic achievement predicted positively subsequent occupational (β = .093-.134, *p* < .05) and educational aspirations, occupational and educational aspirations did not significantly predict subsequent achievement. Achievement and educational and occupational aspirations at T3 predicted educational attainment at T4 (β = .239-.324, *p* < .05). The reciprocal relations were found between occupational aspirations and educational attainment (i.e., from attainment to occupational aspirations at T4 and T5, from T4 occupational aspirations to T5 attainment; β = .162-.294, *p* < .05).

In relation to indirect effect (see Table 3 for the standardized path coefficients), the effects of achievement on occupational aspirations were partially mediated only by self-concept over time, whereas the effects of achievement on educational aspirations were partially mediated by all three motivational beliefs (i.e., self-concept, intrinsic value, and utility value). In addition, T1 and T2 academic self-concept had positive indirect effect on long-term T5 educational attainment (.288, .264; 95% CIs [.045, .332], [.210, 319], respectively), which is similar in size to the indirect effects of T1 achievement (last year GPA at T1) on T5 attainment (.276; 95% CI [.146, .306]). The magnitudes of these paths were larger than those of IQ (.081, 95% CI [.063, .099]). The paths of T2 and T3 educational aspirations on T5 educational attainment were positive and significant (.129, .227; 95% CIs [.101, .157], [.188, .266], respectively). Similarly, T1, T2, and T3 occupational aspirations had significant and positive indirect effects on T5 educational attainment (.141, .197, .191; 95% CIs [.116, .166], [.166, .229], [.148, .234], respectively). Academic achievement and self-concept at T1 and T2 had

significant and positive, albeit weaker indirect effects on T5 occupational aspirations, compared to the corresponding indirect effects on T5 academic achievement. The indirect effects of T1 and T2 intrinsic value on T4 and T5 outcome variables were significant but marginal, whereas the corresponding effects of utility value were not statistically significant.

Discussion

This is one of the few studies that applied the modern EVT to explore the longitudinal temporal associations between personal cognitive abilities, motivational beliefs, and educational/occupational aspirations as well as the impact of these constructs on educational attainment during the transition from late adolescence to adulthood over eight years. Our findings suggest that academic self-concept is not only a key determinant of educational achievement but also a stronger predictor of aspirations when task values and prior achievement are taken into account. Moreover, motivational beliefs play a mediating role in the relationship between achievement and subsequent aspirations. Self-concept and achievement in early high school were found to contribute more to the prediction of long-term occupational aspirations and educational attainment than task values and IQ.

Stability of Motivational Beliefs and Achievement

Academic self-concept and task values were stable from T1 to T2 (Grade 10 to Grade 11). However, during the transition period from T2 to T4 (Grade 11 to one year after high school graduation), high stability coefficients were shown for self-concept and utility value but not for intrinsic value. Köller et al. (2001) argued that the transition from school to higher education exerts pressure on students to select and reinforce specific fields of interest while focusing less on others. Further, the field of experience in college or vocational school broadens substantially, providing competing opportunities for interest development (Wigfield, Tonks, & Klauda, 2009; discussed in more detail in the following).

It was interesting to note that individuals' occupational aspirations stabilized during post–high school transition. However, it was much less stable from T4 to T5 (five years after normal high school graduation), and during this period most of participants finished vocational or college study and entered the labor market. This result was consistent with the motivational theory of life span development developed by Heckhausen, Wrosch, and Schulz (2010). They posit action cycles of setting, striving for, and disengaging from developmental goals as recurring cycles throughout an individual's life, and the transition from school to work easily triggers goal disengagement (see Dietrich et al., 2012, for a review).

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390

						-	Idirect	Effect	s From	the H	ypothe	sized M	odel							
	Q	AchT1	ASCT1	INVT1	UVT1	OaspT1	AchT2	ASCT2	INVT2	UVT2	OaspT2	EdaspT2	AchT3	OaspT3	EdaspT3	ASCT4	INVT4	UVT4	AttT4	OaspT4
Outcome																				
AchT2	*080.	.180*																		
OaspT1	.085*	.202*																		
ASCT2	.279*	.529*	.046*	.013*	:005															
INVT2	027	.258*	.037*	.011*	.002															
UVT2	.063*	.181*	.021*	.006*	.003															
OaspT2	.187*	.342*	.346*	.043*	.070	.003	.038*													
EdaspT2	.140*	.341*	.308*	.113*	.016*	.001	.061*													
AchT3	.107*	.454*	.327*	.077*	.022	.026	.050*	.007	003	000.										
OaspT3	.112*	.260*	.257*	.044*	.052*	.355*	.121*	.163*	.032	.028										
EdaspT3	.130*	.263*	.249*	.066*	.050*	.297*	.138*	.168*	.071*	.036*										
ASCT4	.224*	.440*	.643*	.017*	900.	.019	.156*	.018	900.	.002	.010	.016								
INVT4	007	.125*	.036	.129*	002	040	.119*	.020	.007	000.	062	015								
UVT4	.004	.049*	031	006	.238*	041	.007	028	008	005	067	039								
AttT4	.082*	.270*	.230*	.053*	.035*	.118*	.216*	.157*	.047*	.023	.262*	.179*								
OaspT4	.091*	.256*	.264*	.045*	.045*	.229*	.134*	.216*	.042*	.040*	.346*	$.170^{*}$.058*	.037*	.063*					
AttT5	.081*	.276*	.288*	.054*	.018	.141*	.178*	.264*	.054*	001	.197*	.129*	.186*	.191*	.227*	.015*	.003	:005	.024*	
OaspT5	.039*	.123*	.128*	.023*	.013*	*670.	.074*	.113*	.023*	900.	.114*	.066*	.065*	.130*	.102*	.077*	.024	004	.208*	.039*
<i>Note</i> . All educatio *Present	variab nal acl s 95%	les we nievem bootstr	re giver ent; Att ap perc	a labe = educ centile o	l that ic ational confide	dentifies attainm nce inte	the Ti the the Ti tent; O trval fai	me (T1 asp = o led to i	to T5). ccupati nclude	ASC = onal as 0, whic	academ ipiration: ch corree	ic self-c s; Eduas sponds	oncept; $p = ed^{-1}$ to p val	INV = ucation: lue < .(intrinsic al aspira)5 alpha	value; tions. level.	UV = 1	utility v	/alue; .	Ach =

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The Interplay Among Motivational Beliefs, Achievement, Aspirations, and Attainment

Consistent with previous findings (e.g., Marsh & Craven, 2006; Marsh et al., 2005), our results provide clear evidence about significant reciprocal effect between academic self-concept and academic achievement as well as between intrinsic value and achievement during post-school transition. The reciprocal effects relating to self-concept are stronger than those relating to intrinsic value, which was also in line with our expectation of stronger relationship between academic self-concept and achievement (Marsh et al., 2005). Furthermore, self-concept and intrinsic value are found to be predictive of educational attainment, indicating that adolescents who believe that they are skilled and have higher intrinsic value attached to coursework are more likely to have high educational attainment.

In addition, one of the unique contributions of the present study is to examine the temporal process of motivational beliefs and educational and occupational aspirations across late adolescence to adulthood. In supporting our expectations, each motivational belief uniquely predicted educational aspirations after controlling for prior achievement and aspirations. However, only self-concept was consistently found to predict occupational aspirations over time. Intrinsic and utility values contributed much less in the prediction of subsequent aspirations compared to self-concept. This finding adds to the growing evidence that academic self-concept plays a critical role in promoting career aspirations (e.g., Nagengast & Marsh, 2012; Parker et al., 2012; 2013). It is important to note that aspirations did not significantly predict subsequent motivational beliefs, expect for the negative effect of T3 (Grade 12) occupational aspirations on T4 intrinsic value. As noted previously, students' intrinsic motivations are likely to develop significantly after high school graduation. One attempt to explain this negative effect may be the mismatch between knowledge and skills taught in the curriculum and what is expected to fulfill their career goals. Indeed, community colleges have vocational aspects to the learning curriculum that may thus more directly reflect students' interest and career goals, while 4-year colleges/universities have more general educational requirements, especially in the first year of curriculum, which may not be directly related to the interests of students (see Appendix 5 in the online journal for additional analysis).

Indirect Link Between IQ, Motivational Beliefs, Achievement, Aspirations, and Attainment

Our results align with prior studies and the EVT (Eccles, 2009; Wang, 2012) in that prior academic achievement predict motivational beliefs, which in turn influence subsequent occupational and educational aspirations. Importantly, the current study is one of few studies to examine the long-

392

term indirect effect of cognitive and noncognitive assets on educational attainment over an eight-year span. Academic self-concept has stronger long-term indirect effects on future educational attainment compared to task values, which is consistent with our expectation. This finding indicates that in early high school, students' academic self-concept has substantial influence on their future educational attainment. Likewise, self-concept played a crucial role in shaping future occupational aspirations. However, the contributions of intrinsic and utility values were relatively small for aspirations and attainment.

In addition, it is worth noting that IQ was included in our hypothesized model and contributed to the prediction of occupational aspirations and educational attainment. However, the magnitudes of these indirect effects of IQ were substantially smaller than those of T1 achievement (GPA at the end of Grade 9). This finding is consistent with the prior empirical studies, which showed that high school grades account for almost all of the association between IQ and educational attainment (see Hauser, 2010, for a review).

Implication for Theory, Research, and Practice

The results of the present investigation have important implications for theory, research, and practice. Theoretically, by demonstrating the temporal process between motivational beliefs, achievement, and aspirations in influencing long-term educational attainment, the results provide strong support for modern EVT and extend the substantial evidence that attests to the effect of expectancy-value on achievement-related behaviors. Additionally, the results also provide new and additional support to academic self-concept theories stating that academic self-concept contributes to the prediction of important outcome variables beyond what can be explained by academic achievement.

With respect to instructional practices, the reciprocal effects of selfconcept and intrinsic value with academic achievement shown in the results suggest that educators should strive to improve both academic self-concept and intrinsic value along with achievement in order to produce positive changes in each of these constructs. For example, teachers can promote student motivation by creating a supportive school/classroom environment in which students feel free to ask questions and interact with instructors (Urdan & Schoenfelder, 2006; Wang & Degol, 2013; Wang & Eccles, 2012). The findings also suggest that teachers and parents should pay more attention to the changes in children's academic self-concept because stable selfconcept during the high school years appears to play a decisive role in shaping future occupational and educational aspirations and attainment. In the meta-analysis of self-concept interventions, Haney and Durlak (1998; also see Huang, 2011) showed that self-concept interventions would lead to improved academic achievement, consistent with the reciprocal effects model of the causal ordering of academic self-concept and achievement,

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suggesting that self-enhancement and skill development should be integrated in the intervention programs. In the other meta-analysis of selfconcept interventions, O'Mara, Marsh, Craven, and Debus (2006) noted that interventions targeting a specific academic self-concept domain and subsequently measuring that domain were much more effective than those solely targeting global or skill-based self-concept. They also reported that attributional feedback, goal feedback, and contingent praise yielded significantly higher effects sizes—particularly when coupled with skill training. This again emphasizes the importance of the reciprocal effects model that was a central feature of the present investigation.

In addition, the clear evidence about significant associations between educational attainment and aspirations across time implies that promoting students' occupational and educational aspirations is another imperative issue for educational policymakers and practitioners as these aspirations also seem to play a major role in shaping the course of individual development. Therefore, this study offers new insights into how expectancy-value motivation and aspirations have profound effects on the lives of students. We believe that our model, which encompasses the key elements of academic self-concept and task values, which are the prominent and wellvalidated theoretical propositions, is a fruitful vehicle in gaining some deeper insights into students' decisions and career paths.

Strengths, Limitations, and Directions for Future Studies

In interpreting the findings, some strengths and weakness of the present study have to be considered. Despite potential limitations, important design features of the YIT database were critical in terms of the present investigation and motivation research more generally. In particular, the YIT is one of few longitudinal data sets that provides diverse motivational constructs based on multiple items as well as measures of both cognitive and noncognitive assets, which all possess strong psychometric properties. Furthermore, YIT is one of the few studies spanning such a long period while covering the critically important post-school transition period. These specific characteristics of YIT enabled us to investigate the directionality of the temporal associations between these important factors corrected for measurement error and their role in the prediction of educational attainment across this important developmental period. The multiple wave design further enabled us to test indirect effects while respecting the assumed temporal ordering of all variables, and this allowed us to develop a better theoretical understanding of the roles that motivational beliefs play in shaping aspirations and attainment. To our knowledge, no other current data set presents all of these characteristics.

Consistent with this perspective, the YIT has been a traditional testing ground for new and evolving theoretical models in self-concept and motivation research as well as the central focus of critical debates in relation to

394

these constructs (e.g., Bachman & O'Malley, 1986; Brezina, 2010; Marsh, 1990; Marsh & O'Mara, 2008, 2010; Marsh, Scalas, & Nagengast, 2010; Sullivan, 2011). Thus, for example, the debate about the role of self-concept in predicting future outcomes between Baumeister and colleagues (Baumeister, Campbell, Krueger, & Vohs, 2003, 2005) and Marsh and Craven (2006) hinged on competing interpretations of results based on the YIT. The resolution of the claims and counterclaims underpinning this debate (Marsh & O'Mara, 2010) was then based on a subsequent reanalysis of YIT data, showing that academic self-concept emphasized by Marsh and Craven (2006) was a critical predictor of long-term academic outcomes, while self-esteem emphasized by Baumeister and colleagues was not. Given the importance of this YIT database in motivational and self-concept research on which the present investigation builds, it is particularly well suited to test the long-term implications of the juxtaposition of academic self-concept and academic task values that are at the heart of modern expectancy-value theory.

Nevertheless, there are also some important limitations to this study. We note that the sample used in this study only included U.S. boys and was dated (from the 1960s and 1970s), which leads to conclusions of unknown generalizability to modern youth, particularly for girls. Indeed, multiple previous studies have documented significant gender differences in self-concept and interest development as well as related differences in academic and career trajectories (e.g., Elder, 1999; Köller et al., 2001; Schoon & Polek, 2011). These observations suggest that future research is needed to test the generalizability of our results based on similar longitudinal research designs involving newer and mixed-gender nationally representative samples. Furthermore, future comparisons of longitudinal studies across different national/international samples or more diversified populations would be useful for clarifying whether the current findings are unique to this U.S. sample of male participants or whether they reflect a generalizable educational and occupational attainment process. Another limitation of this study is that students' academic achievement was assessed based on students' self-reports, which have previously been demonstrated to lack accuracy among lower-performing students (Kuncel, Credé, & Thomas, 2005). Also, the measure of motivational beliefs is inconsistent across measurement points. Specifically, although motivational beliefs were found in the present study to play critical roles during the post-school transition years, these variables were not available at Time 3 (late Grade 12), right before this transition. This makes the comparisons of pre, versus post, school transition results imprecise, as it is impossible to clearly assess whether the post-transition tendencies were already present in Grade 12. Furthermore, only a single indicator was used to assess intrinsic value at T4. Hence, there is a need for further research incorporating consistent measurement of the expectancy-value motivation and teacher/schoolbased academic achievement. Finally, an important direction for further

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research would be to consider the process through which students academically and socially integrate into their universities, colleges, or institutions. In doing so, a more nuanced understanding of the development of motivational beliefs during post-school transition and how this process is impacted by substantial educational choices would be obtained.

Conclusion

The aims of the present study were to disentangle the complex directionality of the associations among motivational beliefs, achievement, aspirations, and attainment and to address a critical gap in achievement motivation research related to the roles of motivational beliefs in associations between achievement, aspirations, and attainment during late adolescence to early adulthood. To this end, our study provides clear evidence that academic self-concept and intrinsic value have reciprocal effects with achievement over time, and both motivational beliefs also contribute to the prediction of educational attainment. In relation to aspirations, motivational beliefs partially mediate the relationship between achievement and educational and occupational aspirations, and self-concept plays a critical role in predicating aspirations. Finally, academic self-concept and achievement at early high school showed a stronger long-term effect on educational attainment compared to intrinsic and utility value, IQ, and aspirations. These main findings have practical implications for educational policymakers and practitioners seeking to promote individual's educational attainment.

Notes

This research was funded in part by a grant from the Australian Research Council (DP130102713) awarded to Herbert W. Marsh, Alexandre J. S. Morin, and Philip D. Parker. ¹We did additional analyses to address this issue. Another composite variable for T5 educational attainment by removing enrollment status items was created. And we found the magnitudes of the effect relating other variables to educational attainment did not change. Hence, consistent with prior research, enrollment status items have still been kept to measure attainment.

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400

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Chapter 6: Study 3 - Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective

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Preface

In the previous study, the complex interplay of general academic motivational beliefs, aspirations, achievement, and attainment over time from late adolescence into early adulthood was explored. Study 3 focused instead on domain-specific ASC, intrinsic value, and utility value in relation to math in particular. This study examines the impact of these factors, together with that of individual characteristics (gender and SES), prior academic achievement, and high school achievement-related behaviours (math advanced math course selection and matriculation results), on university and STEM educational pathways selections during post-high school transition. This study, therefore, provided a more nuanced understanding of individual and gender differences in choices of educational pathways in relation to mathematics.

Study 3 makes several important contributions to the literature. First, it is one of the first studies to examine longitudinal predictions of ASC, task values, and their interactions on educational outcomes, providing support for the theoretical assumption of classical EVT that ASC and task values interact in predicting educational outcomes. Second, study 3 integrated another critical theoretical model of ASC – the I/E model with its extension to DCT – into EVT, and examined how math, reading, and science achievement predicted math motivational beliefs. Importantly, study 3 extended both the I/E model and DCT, by finding evidence that students' internal comparison processes influence subsequent educational choices. Finally, study 3 explored the effects of gender and social stratification on university entry and STEM major selections. More specifically, this study extended study 1 and examined the long-term effects of gender and SES as moderators of motivational beliefs on choice behaviours was also explored in this study.

Running Head: MULTIPLICATIVE PERSPECTIVE ON EXPECTANCY AND VALUE

Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective

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Abstract

Drawing on the expectancy-value model, the present study explored individual and gender differences in university entry and selection of educational pathway (e.g., Science, Technology, Engineering, and Mathematics [STEM] course selection). In particular, we examined the multiplicative effects of expectancy and task values on educational outcomes during the transition into early adulthood. Participants were from a nationally representative longitudinal sample of 15-year-old Australian youths [N = 10,370]. The results suggest that (a) both math self-concept and intrinsic value interact in predicting advanced math course selection, matriculation results, entrance into university, and STEM fields of study; (b) prior reading achievement has negative effects on advanced math course selection and STEM fields through math motivational beliefs; (c) gender differences in educational outcomes are mediated by gender differences in motivational beliefs and prior academic achievement, while the processes underlying choice of educational pathway were similar for males and females.

Keywords: self-concept, expectancy-value, gender, STEM major, university entry

Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective

High-skilled professions often require university training, particularly in the STEMrelated fields (science, technology, engineering and mathematics) which are critical for industrialized countries seeking to recover from the global financial crisis (International Monetary Fund, 2010; OECD, 2010). Unfortunately, in Western countries, many students who have the requisite ability do not pursue university education (Bowen, Chingos, & McPherson, 2009), and the proportion of students taking advanced math and science courses in senior high school and subsequently pursuing STEM pathways has declined in Australia (Lyons & Quinn, 2010) and elsewhere (see review by Bøe, Henriksen, Lyons & Schreiner, 2011). While females have made great strides in university enrollment parity with males and are even better represented than males in undergraduate degrees (OECD, 2010; Parker et al., 2012; Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2014; Parker, Nagy, Trautwein, & Lüdtke, 2014; SchoonSchoon & Polek, 2011), they are still substantially underrepresented in many STEM fields (Bøe et al., 2011).

Drawing upon Expectancy-Value Theory (EVT; Atkinson, 1957; Eccles, 2009, 2011; Eccles, et al., 1983), a lot of studies have been dedicated to the identification of factors that contribute to gender imbalance in the pursuit of educational pathways (e.g., Guo, Marsh, Parker, Morin, & Yeung, 2015; Watt, et al., 2012; Watt, Eccles, & Durik, 2006). Given that academic engagement and aspirations in high school are highly associated with educational career of the youth (Bowen et al., 2009; Hauser, 2010; Kimmel, Miller, & Eccles, 2012), much attention has been given to the interplay between academic achievement, math selfconcept (expectancy), and task value in predicting high-school coursework choices and educational and occupational aspirations (e.g., Simpkins, Davis-Kean & Eccles, 2006; Wang,

2012; Watt et al., 2006, 2012). However, relatively little EVT research has been devoted to the post-high school transition, which represents a critical point in decision making about pathways to university and the STEM fields of study (but see Guo, Marsh, Morin, Parker, & Kaur, 2015; Parker et al., 2012; Parker, Nagy, et al., 2014). In the present study, we adopt a holistic view and use the EVT framework to comprehensively test the longitudinal relationships among students' prior achievement (i.e., reading, math, and science), and motivational beliefs (i.e., academic self-concept, intrinsic value, and utility value), in predicting two educational pathways – (a) high school math course selection and STEM major choices and (b) matriculation results and entry into university) – across the transition from high school (15-year-olds) into early adulthood (25-year-olds). More specifically, we mainly focus on the multiplicative effect of self-concept and task value, which was the critical feature of classical EVT (Atkinson, 1957) but which has been less researched for several decades. Furthermore, we examine how the internal comparison process (Internal/External Frame of Reference Model [I/E model]; Marsh, 1986, 2007) – where students contrast their own performance in one particular school subject against their performance in other school subjects – influences motivational beliefs and subsequent educational choices. Finally, we explore the gendered motivational process, thus providing insight into gender differences in the decision-making processes underlying educational pathway selections.

Expectancy Value Theory

Modern EVT (Eccles, 2009; Eccles, et al., 1983) is one of the major frameworks for achievement motivation and was developed to explain students' effort, choices and achievement in relation to academic and non-academic domains (e.g., sports, music, and social activities; Eccles & Wigfield, 2002). Modern EVT (Eccles, 2009, 2011) posits that

achievement-related outcomes like university entry and STEM pathways are composed of a series of achievement-related performances and choices in adolescence, which are directly influenced by domain-specific expectancies for success (i.e., academic self-concept, competence beliefs, etc.) and subjective task value. Put simply, expectancies represent beliefs by young people that they have the capacity to succeed within a given post-school pathway, while task value represents evaluations by young people about the potential costs and benefits that are associated with that pathway (Eccles, 2011). These motivational beliefs are influenced by previous achievement-related experiences (e.g., domain-specific academic achievement) and individual characteristics (e.g., gender-role stereotyped socialization and family socioeconomic status [SES]). Thus, individual characteristics and previous academic achievement shape the development of task-related expectancies and value beliefs, which in turn influence academic performance and coursework selection in high school and postsecondary educational and career choices (see Figure 1 for the conceptual model; also see Wang & Degol, 2013, for a review).

Expectancies for success is conceptualized as the task-specific beliefs about the possibility of experiencing future success in that task, which is directly linked to *ability self-concept* in a specific academic domain. Empirically, however, the two constructs (i.e., expectancies and self-concept) are indistinguishable (Eccles, 2009; Eccles & Wigfield, 2002). For this reason, academic self-concept has typically been used as a measure of the expectancies of success in empirical research (e.g., Simpkins, Fredricks & Eccles, 2012; Wang & Eccles, 2013). Also, subjective task value is known to be domain specific and is defined in terms of multiple components (Eccles & Wigfield, 2002). In the current study, we focus on two value components in the domain of math: *intrinsic value*, which refers to the enjoyment a person gains from performing an activity (in line with intrinsic motivation and

interest), and *utility value*, which relates to how a specific task fits an individual's future plans and objectives.

Relations Between Achievement, Motivational Beliefs and Choices

According to modern EVT (Eccles, 2009, 2011), achievement-related choices are influenced by a relative intra-individual hierarchy of self-concept and subjective task value across the set of perceived options. When individuals select the activities they want to pursue and make choices, domain comparisons within individuals are triggered (Eccles, 2009, 2011). All such behavioral choices are assumed to be associated with costs as one choice often eliminates other options (following an ipsative process; Eccles, 2009; Eccles & Wigfield, 2002). Also, Eccles (2009) states that students' relative self-concept is formed as a function of comparing their performance with those of their peers (i.e., external comparison) and with their own performance across domains (i.e., internal comparison). These two types of comparisons have been explicated in the I/E model (Marsh, 1986, 2007). Specifically, internal comparison is an ipsative process, such that achievement in one subject domain has a negative effect on self-concept in another domain (Marsh, 2007) after controlling for achievement in the matching domain. The internal comparison process for self-concept and achievement between math and verbal domains has been widely supported by cross-cultural, longitudinal and experimental studies (e.g., Marsh, 2007; Möller, Pohlmann, Köller, & Marsh, 2009). Xu (2010) incorporated task value into the I/E model and found I/E-like patterns for self-concept and intrinsic value, but they were much weaker for attainment value and utility value. In addition, Nagy et al. (2006, also see Nagy et al., 2008) integrated notions of ipsative-like processes from EVT and the I/E model in a study of advanced coursework selection. Consistent with EVT, prior achievement predicted self-concept and interest, which in turn influenced coursework selection. Also, consistent with the I/E model, domain-specific

86
self-concept and interest were positively related to achievement and course choices in the same domain, but negatively related to achievement and course choices in the other domain.

More recently, Möller and Marsh (2013) extended the I/E model into Dimensional Comparison Theory, and posited strong negative cross-subject effects of achievement on selfconcept only for contrasting domains at opposite ends of the math-verbal continuum of academic self-concept (e.g., math & science versus reading) but much weaker negative or even positive assimilation effects for similar or complementary domains (near domains; e.g., math and science; also see Jansen, Schroeders, Lüdtke, & Marsh, 2015; Marsh et al., 2014). Recently, Marsh et al. (2015) considered math/science-like subjects (i.e., biology, physics, and math) as near domain and found positive cross-subject effects of achievement on selfconcept in these three domains controlling for matching achievement. However, there is insufficient research on the generalizability of the internal comparison process to different components of task value, particularly between the math and science domains, and how this comparison process influences subsequent educational choices (Möller & Marsh, 2013).

In relation to math course selection, there is strong evidence that math self-concept and task values are important predictors over and above prior math achievement (Parker et al., 2012; Simpkins et al., 2006, 2012; Wang, 2012; Watt, et al., 2006, 2012). Although modern EVT (Eccles, 2009) emphasizes that different value components should play differential roles in influencing educational choices, very few studies have considered multiple task value together with self-concept to examine their prediction of math participation (for exceptions, see Eccles, Barber, & Jozefowicz, 1999; Watt et al., 2012). For example, Eccles et al. (1999) found that utility value had stronger predictive power than intrinsic value and self-concept, suggesting that student might weight the usefulness of math for their future plan heavily in making their choices whether to take an advance math course. Also, a recent cross-cultural research found that math self-concept was more related to math achievement, whereas

intrinsic and utility values were more related to math coursework selection (Marsh, Abduljabbar, et al., 2013). In addition, most EVT studies have focused on the unique contributions of self-concept and task value (i.e., examining the effect of value controlling for self-concept; or including either self-concept or one value component at one time in the regression model) on achievement-related choices. However, recent research found that selfconcept appeared to interact with task value in predicting educational outcomes (Nagengast et al., 2011; Trautwein et al., 2012; see further discussion below).

In relation to educational choices during the post-high school transition, it has been well documented that general high-stakes achievement (i.e., final school year matriculation results) is an important precursor of educational attainment, such as university entry and long-term occupational and socio-economic attainment, but not of STEM major selection during post-school transition (Bowen et al., 2009; Hauser, 2010; Wang & Dogel, 2013). Although high school achievement, motivational beliefs, and math course selection have been shown to significantly predict educational and career aspirations related to math (e.g., Watt et al., 2012; Wang, 2012), still little is known about how these high school predictors influence subsequent STEM major taking during the post-school transition.

Multiplicative Relation Between Self-Concept and Task Values

EVT had its origins in an early cognitive model (i.e., the risk-taking model of achievement motivation; Atkinson, 1957), superseding earlier behaviorist models of animal behavior. A core assumption of the original EVT (Atkinson, 1957) was the multiplicative combination of expectancies of success and subjective task value (i.e., expectancy by value interaction; also see Feather, 1982 for a review). The multiplicative relation between expectancy and value implies a synergistic relation - high expectancy alone is not sufficient to motivate behaviors. Rather, to choose an advanced math course, students not only need to think that they are good at math but also need to value it highly. Although Eccles (2009)

88

believes that "the motivational power of ability self concepts to influence task choice is, at least partially, determined by the value individuals attach to engaging in the domain" (p.84), in modern EVT (Eccles et al., 1983; Eccles, 2009) the relation between expectancies and task value is often implicitly assumed to be additive rather than multiplicative in predicting educational outcomes (also see Nagengast et al., 2011). Additive relation suggests that expectancy and task value uniquely and independently predict achievement-related outcomes. However, multiplicative relations suggest that the relation between self-concept (expectancy) and outcomes depends on the extent to which an individual values a given domain and vice versa.

Thus, the proposition of a multiplicative relation between expectancy and task value has important theoretical and practical implications for researchers in applied motivation. For example, tackling either self-related belief in isolation is unlikely to be an effective way to promote students' engagement with the subject domain.

Researchers have argued that this is due to methodological limitations in detecting multiplicative effects between latent constructs in non-experimental studies, rather than to any defined theoretical position favoring additive relationship (Nagengast et al., 2011; Nagengast, Trautwein, Kelava & Lüdtke, 2013; Trautwein et al., 2012). Indeed, classic approaches to interaction effects, in the context of multiple regression, rely on product terms of manifest variables that are not corrected for measurement error (thus multiplying error), considerably limiting the ability to detect interactions (Dimitruk, Schermelleh-Engel, Kelava & Moosbrugger, 2007; see Marsh, Hau, Wen, Nagengast, & Morin, 2013 for further discussion).

Recently, two empirical studies have used Structural Equation Models (SEMs) with latent interactions corrected for measurement error, providing important evidence for a multiplicative relation of self-concept and task value in predicting achievement-related 89

behaviors (Nagengast et al., 2011; Trauwein et al., 2012). Nagengast et al. (2011) conducted a strong cross-national test using the Programme for International Student Assessment (PISA) 2006 data, demonstrating significant multiplicative effects of science self-concept and intrinsic value across 57 countries, both on engagement in science activities and intention to pursue scientific careers. Trautwein et al. (2012) also revealed, based on a large sample of German high school students, that the multiplicative terms self-concept and four subcomponents of value beliefs (attainment, intrinsic value, utility value, and cost) had positive effects on English and mathematics achievement. However, an important limitation of these studies is their reliance on a single wave of data. Longitudinal studies would allow us to draw stronger conclusion about directional influences of self-concept and task value and the importance of their interactions. Thus, the present study is unique in that it draws on a longitudinal national sample to explore the interactive role of self-concept and task value in the process leading to entry into university and STEM fields of study.

Gender Effects

According to modern EVT (Eccles, 2009), gendered socialization experiences influence individuals' motivated achievement-related choices through the relation of the hierarchy associated with individuals' domain-specific self-concepts and subjective task values. Although growing evidence in cross-national meta-analyses showed gender similarities in math achievement (Else-Quest, Hyde, & Linn, 2012; Lindbery, Hyde, Petersen, & Linn, 2012), female adolescents had lower self-concept in math compared with male adolescents (Marsh, Abduljabbar, et al., 2013; Marsh & Hau, 2007; Parker et al., 2012, Parker, Marsh, et al., 2014). However, there was no gender difference in math task value when treated as a single, general value scale (Jacobs et al., 2002; Wang, 2012; Wang & Eccles, 2012; see Gaspard et al., 2014 more discuss). Nevertheless, researchers differentiating components of task value (intrinsic vs. utility value) have shown that male 90

adolescents have higher interest in math and perceived math as more useful than female adolescents (e.g., Eccles et al., 1999; Gaspard et al., 2014; Marsh, Abduljabbar, et al., 2013; Updegraff, Eccles, Barber, & O'Brien, 1996). Importantly, their differences in motivational beliefs predict disproportionate gendered enrollment in math courses (Eccles et al., 1999; Nagy, et al., 2006, 2008; Wang, 2012; Watt et al., 2012) and subsequent math-intensive major selection in university (Parker et al., 2012, Parker, Nagy, et al., 2014).

Furthermore, to better understand gendered processes underlying choice of educational pathway, Eccles (2009) suggests that research should focus on gender differences, not only in mean-level of motivational beliefs and educational choices, but also in the relationships between these constructs. However, on the basis of EVT, the extant research investigating gender as a moderator has been limited and has yielded mixed evidence (e.g., Simpkins et al., 2012; Wang, 2012; Watt, et al., 2012). For example, based on a multi-cohort study using data from Australia, Canada and USA, math utility value was found to be a stronger unique predictor of female adolescents' math-related career choices compared to math self-concept and intrinsic value (Watt et al, 2012). In contrast, Wang (2012) found that the relations between math self-concept and task value, and math-related career aspirations and math course taken are invariant across gender based on U.S. high school students. Taken together, it is pivotal to integrate both types of gender effects to gain a better understanding of gender differences in decision-making process leading to different educational pathways.

The Present Investigation

Drawing on EVT (Eccles, 2009), this study aims to examine a development model describing the gendered process through which 15-year-old students' prior achievement (reading, math and science) and motivational beliefs (self-concept, intrinsic value and utility value) influence math course selection at Grade 11 and 12, high-stakes achievement (i.e., Tertiary Entrance Rank [TER]; final school year matriculation results); subsequent STEM

fields of study; and university entry during transition into early adulthood. The underlying conceptual model is presented in Figure 1. These relationships are tested using data from a 10-year longitudinal follow-up of a large nationally representative sample of Australian youth. Specifically, we attempted to fill a gap in the literature on the motivation pathways to educational choices during the critical transition point with respect to three deficiencies. First, little longitudinal research has explored the interactive role of self-concept and task value on long-term educational outcomes. Second, few studies have investigated internal comparison processes between multidimensional achievement and motivational constructs and how these internal comparison processes influence educational choices. Third, attempts to systematically examine whether the gendered relationships among academic achievement, motivational beliefs, and long-term educational outcomes are lacking.

It should be noted that although the hypothesized model depicts paths leading for prior achievement to motivational construct and subsequent educational outcomes, we do not make assumptions about the directions of causal relations among these constructs in the context of the current research. Our main research hypotheses were as follows:

Hypothesis 1: Of central importance to the investigation, we hypothesized that selfconcept, task value and their interaction would positively predict TER scores and math course selection (e.g., Nagengast et al., 2011; Trautwein, et al., 2012), which would be respectively associated with a greater likelihood of entering university (e.g., Hauser, 2010) and undertaking a STEM major (e.g., Parker et al., 2012, Parker, Marsh, et al., 2014).

Hypothesis 2: Prior domain-specific achievement would influence educational achievement and choices, directly or indirectly, through math self-concept and task value (e.g., Nagy et al., 2006, 2008; Parker et al., 2012). More specifically, according to the internal comparison process posited in I/E model (Marsh, 2007) and Dimensional Comparison Theory (Möller and Marsh, 2013), it is expected that prior reading achievement would

92

negatively predict motivational beliefs and choices related to math, while prior science and math achievement would positively predict math-related motivational beliefs and choices. Nonetheless, domain-specific achievement scores would positively predict general (non-domain-specific) high-stakes TER scores.

Hypothesis 3: In relation to the effect of gender, we expect the predictive effect of gender in educational outcomes would in part be mediated through motivational beliefs (e.g., Eccles et al., 1999; Parker et al., 2012; Schoon & Polek, 2011). Further, given the absence of strong theoretical or empirical evidence regarding the extent to which the proposed relations vary by gender, we explore whether the effects of EVT predictors on educational outcomes differ as a function of gender.

In the present investigation, we reintroduce a longstanding substantively important issue—the omission of multiplicative relationships between expectancy and task value—and extend the integration of substantive theories (i.e., EVT and DCT models). To tackle these complex issues, we apply strong and evolving methodological approaches to create more appropriate tests of latent-variable models of the direct and indirect effects of continuous and dichotomous outcomes. Thus, our study is a substantive-methodological synergy (Marsh & Hau, 2007), using advanced statistical methodology to address substantive issues with important theoretical and practical implications for researchers in applied motivation.

Method

Participants

The data used in the present study came from the 2003 cohort of the Longitudinal Study of Australian Youth (LSAY03) extension of PISA 2003 (PISA2003). The LSAY03 was a multi-wave longitudinal follow-up study with a nationally representative sample of 15-year-old students in Australia secondary schools (N = 10370). At the initial survey wave,

integrated with PISA2003, a two-stage sampling procedure was employed. The first stage comprised a sample of 314 schools selected from a complete list of schools, with probabilities proportional to their size, and then an average of roughly 33 students were elected randomly from each of the selected schools. As a result of this selection process, the majority of the sample was in the first year of upper high school in Australia (Year 10, N = 7,378,71.1%), followed by Year 11 students (N = 2,105, 30.3%) and Year 9 students (N = 868, 8.4%). The sample comprised nearly equal numbers of females (N = 5,149) and males (N = 5,221). These participants were then surveyed each subsequent year, for the ten years following 2003.

Measures

Although academic achievement in reading, mathematics, and science were assessed in PISA2003, only math-related motivation items were included in the questionnaire (see OECD, 2005). All motivation items were coded on a Likert scale, with 1 indicating that the participants *strongly agree* and 4 indicating *strongly disagree*. However, for the present purposes, responses were reverse-scored, so that higher values represent more favorable responses and thus higher levels of motivation (see Appendix 1 in the Supplemental Materials for more detail regarding the items used and the scale-score reliability estimates).

Math self-concept. Mathematics self-concept in the PISA2003 database was measured with five items (e.g., "I learn Mathematics quickly."). These items were partly based on the Academic Self-Description Questionnaire-II (Marsh, 1990, 1993).

Math intrinsic value. Four items were used to assess the affect students experienced when participating in mathematics-related activities (e.g., "I am interested in the things I learn in mathematics").

Math utility value. In line with the notion of utility value in the modern EVT (Eccles, et al., 1983), four items were used to assess how well mathematics learning relates to current

and future goals (e.g., "Learning mathematics is worthwhile for me because it will improve my career").

Academic achievement. Participants' academic abilities were measured by academic achievement test items, a combination of multiple choice and written tasks in pencil and paper format. To prevent biased population estimates, the PISA2003 measured reading, mathematics, and science abilities using five plausible values for each subject (with a mean of 500, standard deviation of 100). Hence, in the current study, to be able to correct the measurement error appropriately, these sets of plausible values were used to measure students' achievement (see OECD, 2005).

High school mathematics course selection. Participants were asked to report the level of mathematics class they had taken or were taking in Grade 11 and Grade 12, when Math coursework is no longer a compulsory subject and Math courses are designed according to course demand and difficulty. We treated the response of math course selection as a continuous variable, ranging from (1) "no math course", (2) "basic math course" (i.e., Essential Mathematics), (3) "general math course" (i.e., General Mathematics), (4) "medium math course" (i.e., Mathematical Method), to (5) "advanced math course" (i.e., Specialist Mathematics). A higher value on these items indicates that students took a more complex math course in senior high school. If more than one category was chosen by participants, the more complex math class was coded.

Postsecondary STEM major selection. Participants were asked whether they were studying in a STEM major at the tertiary level. This dichotomous item was only available at Wave 5 (2 year post-secondary education), when participants were 19 years old. Those studying in a STEM major were coded as 1, while those who were not were coded as 0.

Tertiary entrance rank (TER). The TER was a tertiary entrance score, consisting of standardized tests and school-based assessment. These ranks were awarded to students at

Year 12 (average age 17), the final year of high school, and were the primary metric on which university and university course placement were determined in Australian universities. This item was collected from Wave 3 to Wave 6, in which each participant only has one TER score. TER was measured by a combination of school-based achievement and state-wide standardized testing, with a 100-point scale in all states except Queensland (100 being the highest possible TER rank). However, a 25-point scale instead was used in Queensland, with 1 being the highest possible TER rank (see Marks, McMillan, & Hillman, 2001, for more details). For the present purposes, the TER scores in Queensland were reversed, and all the TER scores were standardized (z-scored) within each state.

University entry. Participants were asked if they were studying or had studied in university since Wave 1. This item had been updated at the following wave. Those who entered university study at any stage from 2003 to 2012 were coded 1, whereas those who had never entered university prior to 2012 were coded 0.

Covariates. Gender (0 = male, 1 = female), and SES (Economic, Social and Cultural Index [ESCS]; see OECD, 2005) were treated as covariates, in which the effect on all variables was freely estimated. Specifically, the ESCS was created on the basis of the variables relating to family background, including the highest occupational status of parents, the highest educational level, and an estimate related to household possessions. Furthermore, given that the PISA samples are age-based, grade level (hereafter "year") differed across participants and was found to be significantly associated with motivational beliefs and educational outcomes in the PISA data (Parker, Marsh, et al., 2014). Therefore, the year was also included as a covariate in our hypothesized model.

Data Analysis

Missing data. The amount of missing data for motivational items and academic achievement at Time 1 was small (ranging from .6% to 1.4% per item). Since the LSAY03

data cover a ten-year period and include post-high school transition, the sample attrition rate was relatively large, particularly for postschool outcomes, which typically were estimated several years after the initial time wave (14.8% for Mathematics course selection; 26.5% for university entry; 28.2% for TER scores; 34.8% for STEM major selection). In the present study, missing data were handled using multiple imputation, which has been shown to be robust to departures from normality assumptions and to provide adequate results even for high rates of missing data (Graham, Cumsille, & Elek-Fisk, 2003; Schafer & Graham, 2002). Given that participants who come from more disadvantaged SES backgrounds or have lower self-beliefs are much more likely to drop out of the study (see Parker, Marsh, et al., 2014), the items pertaining to demographic background and motivational beliefs were all included as auxiliary variables in multiple imputations.¹ To fully account for the plausible values of academic achievement, two sets of missing data imputations were created for each plausible value, meaning that in total, ten imputations were created for the analysis, using the R package Amelia II (Honaker, King, & Blackwell, 2011). All categorical variables (e.g., STEM and University entry) were treated as nominal variables in multiple imputation process. All data analyses were run separately, and the results were aggregated appropriately in order to obtain unbiased estimates (Rubin, 1987).

Estimator. Structural equation modeling (SEM) with Mplus 7.11 (Muthén & Muthén, 2008 —2013) was used to examine the hypothesized relations among latent constructs and outcome variables. In the present study, three latent constructs were measured: math self-concept, intrinsic value, and utility value. In relation to estimator, robust maximum likelihood (MLR) with the LINK = PROBIT option was used. The relationships between covariates, prior academic achievement, motivational constructs, math high school course selection and

¹ Supplemental analysis: we created an attrition group variable coded one for participants who left the study during the post-secondary school transition and zero otherwise. We used t-tests to examine mean differences by two groups (attrition group vs the group with full data) in SES and motivational beliefs. The results revealed that compared to the group with full data, attrition group was lower on SES (.40 *SD*), math self-concept (.51 *SD*), intrinsic value (.39 *SD*) and utility value (.38 *SD*).

TER were estimated by MLR, while probit regression was used to estimate the relations to binary outcomes—university entry and STEM major selection.

To allow for probit regression coefficients to be interpreted in a more intuitive manner, these coefficients were converted to probability value according to the instruction presented in the *Mplus User's Guide* (Muthén & Muthén, 1998-2013, p.492). The probability differences presented in Figure 2 indicated that the likelihood of entering university or choosing a STEM major, with changes of one SD increase in the continuous predictor variable, when all other continuous independent variables were held at their mean and discrete independent variable (i.e., gender) was set to its mode value. For gender, a positive probability value indicated a higher probability to enter university and STEM fields of study in favor of females (also see Wang, 2013, p. 24 for more discuss).

Analysis plan. To address the research questions, we began with a SEM based on the conceptual model (Figure 1) but excluded latent interactions. The indirect and total effects were assessed using the MODEL CONSTRAINT command, where the delta method was utilized to estimate the standard errors of indirect effects (MacKinnon, 2008). After examining direct and indirect relations, latent interactions between math self-concept and task values were incorporated into the path model using the latent moderated structural (LMS) equations approach (Klein & Moosbrugger, 2000). The advantage of the LMS approach is that it corrects for measurement error of latent constructs and provides unbiased estimates of latent interaction effects. Further, LMS represents the nonnormal distribution as a mixture of conditionally normal distributions; thus, separate indicators of the product terms are not required (Kelava et al., 2011).

The LSAY03 database has a nested data structure in which students are nested within schools. To account for this nested structure, we used the TYPE = COMPLEX option in Mplus to adjust the standard errors. In relation to fit indices, the comparative fit index (CFI),

98

the root-mean-square error of approximation (RMSEA) and the Tucker-Lewis Index (TLI) were used to determine model fit. Values greater than .95 and .90 for CFI and TLI typically indicate excellent and acceptable fits respectively, to the data. RMSEA values of less than .06 and .08 are considered to reflect good and acceptable statistical fits, respectively, to the data (Marsh, Hau, & Grayson, 2005).

To explore whether the hypothesized relations in the final model vary as a function of gender, we conducted a multi-group comparison analysis in SEM (Bollen, 1989) and tested a series of increasingly stringent invariance constraints on the parameters of measurement and structural model, in which little or no change in goodness of fit supported invariance of the factor structure (Millsap, 2011, see Appendix 3 in the Supplemental Materials for more detail).

In order to enhance the interpretation of the results, we standardized (z-scored) all the variables to be Mean (M) = 0, Standard Deviation (SD) = 1, except for the dichotomous variables (see Raudenbush & Bryk, 2002).

Results

A Confirmatory Factor Analysis (CFA) was employed to examine the factor structure of math self-concept and task values. The measurement model provided an adequate fit (CFA model: $\chi^2(42)=1523.437$, df = 62, CFI = .977, TLI = .971, RMSEA = .048). Latent correlations indicated that math self-concept was moderately correlated with utility value (r= .49) and somewhat more highly correlated with intrinsic value (r = .70), while the correlation between intrinsic value and utility value was .59. Further, supporting the construct validity of motivational beliefs, math self-concept, and task values were all more highly correlated with achievement in math than in reading and science. Compared to task values, math self-concept was more strongly correlated with academic achievement, math course

selection and TER. Gender differences in math motivational beliefs and math course selection favoring males were moderate in size, whilst males were favored to a small extent in math achievement. However, females scored substantially higher in reading achievement and TER than males. Females were more likely to attend university but opted out of advanced math courses and further STEM majors (see Appendices 2–3 of the Supplemental Materials for the full correlation matrix and more details about gender difference).

To explore direct and indirect relationships between domain-specific academic achievement, motivational factors, TER, and educational choices, the SEM model was analyzed, based on the whole sample. The model accounted for 53.1%, 22.4%, 40.7% and 27.5% of the variance in university entry, STEM major selection, TER, and high school math course selection respectively. The model also explained 25.4%, 10.2% and 10.4% of the variance in math self-concept, intrinsic value, and utility value respectively. The standardized path coefficients of direct, indirect, and total effects are presented in Tables 1 and 2. Probability differences for statistically significant direct effect on university entry and STEM major selection are also included.

Effects of Prior Achievement on Motivational Beliefs and Educational Outcomes

Consistent with our hypotheses, three achievements (math, reading, and science) were all statistically significantly associated with motivational beliefs. Specifically, math and science achievement were each positively associated with math self-concept and intrinsic and utility values, although the effect sizes relating to science achievement were relatively small. Nevertheless, reading achievement was negatively associated with math motivational beliefs. Only math achievement significantly positively predicted math course selection, and there were no significant direct effects of prior achievement on STEM major selection. All three achievements were positively associated with TER, whereas math and reading achievement were significant predictors of university entry. In terms of probability difference, the results 100

revealed that 1 standard deviation increase from the mean in math and reading scores led to .04 and .06 increases, respectively, in the probability of entering university.

In addition, motivational beliefs fully mediated the relationships between reading and science achievements and selections of math course and STEM major. Specifically, reading achievement had negative indirect effects on math course and STEM major selections, whereas science slightly positively predicted these outcomes. Similarly, reading achievement exerted negative indirect effects on TER via math motivational beliefs but was offset by the positive corresponding direct effect. Math achievement indirectly and positively predicted all educational outcomes.

Effects of Motivational Beliefs on Educational Outcomes

Math self-concept, intrinsic value, and utility value positively predicted math course selection in high school, whereas only math intrinsic value and utility value had positive direct effects on STEM major selection. As stated previously, in probability terms, 1 standard deviation increase from the mean in math intrinsic value and utility value led to similar probability increases (.04 and .06 respectively) of selecting a STEM major. The relationship between math self-concept and STEM major selection was fully mediated by math course selection. Although math self-concept and intrinsic value were significant predictors of TER, they did not directly predict subsequent university entry. In contrast, utility value positively predicted university entry but not TER. The relationships between math self-concept and intrinsic value and university entry were fully mediated by TER. In total, each motivational belief had similar predictive power on university and STEM entrance.

Finally, postsecondary STEM major choice was predicted by math high school course selection, while university entry was substantially predicted by TER. In probability terms, here, 1 standard deviation increase from the mean in math course selection and TER led to a

relatively higher probability increase (.08 and .15 respectively) of entering a STEM major and university respectively.

Multiplicative Effect of Math Self-Concept and Task Value

To test the multiplicative relation between math self-concept and task values, we added the latent interaction between self-concept and intrinsic value and between self-concept and utility value to predict TER and educational choices, based on the conceptual model (Figure 1²). The results show that the interaction between math self-concept and intrinsic value positively predicted math course selection – main effect: self-concept (β = .18),

intrinsic value ($\beta = .07$); interaction effect: ($\beta = .07$) – and TER – main effect: self-concept

(β = .18), intrinsic value (β = .08); interaction effect: (β = .08), p < .001. The simple slopes

in Figure 3 showed that math self-concept had a positive effect on the two outcomes at different levels of intrinsic value (i.e., mean and 1 standard deviation below and above the mean). When self-concept was at nearly 1 standard deviation below the mean, different levels of intrinsic value tended to predict similar outcome levels. This finding supports the synergistic relation of math self-concept and intrinsic value in predicting the two outcomes: Choice of advanced mathematics course, and high TER scores, occurred only when self-concept and intrinsic value were both relatively high. Interestingly, math self-concept and

102

² Supplemental analyses: we examined the interaction effect between self-concept and value based on two hypothesized models where only one value component (intrinsic or utility value) was included. We found self-concept, intrinsic value, and their interaction significantly positively predicted TER and math course selection (ranging from .07 to .20). However, only intrinsic value had a direct predictive effect on entrance into university and STEM major selection (.17 and .14 respectively). Similar patterns were found for the model involving utility value, with an exception that the predictive effect of self-concept on STEM major selection became significant (.10). In sum, for the model involving one value component, the interactions between self-concept and intrinsic value as well as between self-concept and utility value positively predicted TER and math course selection, whereas only the interaction between self-concept and intrinsic value was statistically significant interaction effects for different models were similar in size. The interaction effects on entrance into university and STEM major selection were fully mediated by TER and math course selection respectively (also see Appendix 7-8 in the Supplemental Materials for more details).

intrinsic value positively interact in predicting university entry and STEM major selection through their influence on the TER and math course selection (i.e., *moderated mediation;* Preacher, Rucker, & Hayes, 2007; also see Muller, Judd, & Yzerbyt, 2005). The indirect effect of math self-concept on university entry and STEM major selection, via TER, varied with level of intrinsic value (i.e., the indirect effect became larger as intrinsic value increased; also see Appendix 4 in the Supplemental Materials). However, the multiplicative effects between self-concept and utility value on course selection and TER were not statistically significant. All path coefficients in the model with interactions are similar with those without interactions (i.e., Figure 2; see Appendix 5 in the Supplemental Materials for more details).

Predictive Effects of Gender on motivational beliefs and educational outcomes

As hypothesized, gender was negatively associated with math achievement, math selfconcept, and intrinsic and utility values, indicating that males had higher math achievement and motivation beliefs, controlling for SES and school year. Similarly, gender was negatively associated with math course and STEM major selection. Nonetheless, gender was positively associated with reading achievement, TER and university entry. The results indicate that, in terms of gender difference in probability, males had a higher probability of opting for a STEM major (-.04), whereas females had a higher probability of entering university (.06). In relation to indirect effects, academic achievement partially mediated the relationships among gender, self-concept, and intrinsic value. Similarly, academic achievement and motivational beliefs partially mediated the relationship between gender and math course and STEM major selections.

In addition, we conducted supplemental analyses to test the moderating role of SES on gendered relations among achievement, motivation beliefs and educational outcomes. Specifically, we added the product term between gender and SES into the hypothesized model to examine the effects of this interaction on prior achievement, educational beliefs and

educational outcomes. However, this interaction effect was statistically non-significant, indicating that SES did not moderate the relations between gender and achievement, motivational beliefs, and educational outcomes. Detailed results and discussion of the effect of SES are provided in Appendix 6 in Supplemental Materials.

Moderation Effect of Gender

Before examining whether the hypothesized relations vary by gender, based on the final structural model, we tested the invariance of the CFA measurement model for males and females. The measurement invariance test showed that the changes in model fits were negligible (see Appendix 3 in the Supplemental Materials for more details).

After examining measurement invariance, all paths were constrained to be equal in multigroup SEM models. As fit statistics are not available for models that have categorical outcomes, -2 times the log-likelihood difference (i.e., $-2\Delta LL$), which was distributed as Chisquare and equivalent to the chi-square difference test ($\Delta \chi^2$), was used to compare nested models. The change in -2LL between the unconstrained (i.e., path-non-invariant) and pathinvariant SEM model was statistically significant (- $2\Delta LL$ (53) = 71.79, p < .001). Given the sample size, however, this difference was marginal. Further post hoc analyses showed that there were significant differences across gender in the relation between math achievement and utility value ($\Delta \chi^2(1) = 4.61$, p < .05) as well as between reading achievement and utility value ($\Delta \chi^2(1) = 8.50$, p < .01). Math achievement was more strongly associated with utility value for males (.24, p < .001) than for females (.15, p < .001). Reading achievement was a negative predictor of utility value for males (-.14, $p \le .001$), whereas the corresponding effect was not statistically significant for females (-.02, p = .593). In addition, the result showed gender differences in the relation between math achievement and math course selection $(\Delta \chi^2(1) = 5.21, p < .05)$. Similarly, math achievement was more strongly associated with math course selection for males (.24, p < .001) than for females (.17, p < .001). All other

23

relations in the conceptual model did not vary as a function of gender. Taken together, we found only three significant gender-differentiated patterns out of 63 cases.

Discussion

The current study represents one of the most comprehensive tests of Eccles's (2009, 2011) model of achievement-related choices, simultaneously testing the effect of achievement, expectancy, value, and expectancy-value interactions, in predicting a sequence of educational choice, both before and after the transition from high-school. As expected, students' achievement predicts math self-concept, math intrinsic value and utility value. In turn, students who master math skills and find math interesting or useful are more likely to take advanced math courses and to achieve high TER scores, which predict post-secondary educational choices. More importantly, these results provide longitudinal support for the multiplicative effect of math self-concept and intrinsic value in predicting educational outcomes.

Predictive Effect of Self-Concept, Task Value and Their Interaction

This study extends prior research on motivational pathways to STEM choices by linking high school math motivational beliefs and math course selection to further STEM major enrollment. Each math motivation belief has a significant contribution in math course selection after controlling for prior achievement, suggesting that expectancy-value motivations are independent predictors and facilitates students' willingness to take the more difficult math courses in senior high school, over and above achievement. However, the task value that students attach to math, particularly for utility value, is more directly related to STEM major selection and university entrance compared to math self-concept, even though these three motivation beliefs have similar predictive power on postsecondary educational choices in terms of the total effects. In contrast, math self-concept is a stronger predictor of 105

high-stakes TER scores compared to task value but relates to STEM major selection and university entrance via the different level of math courses students adopt and TER scores in senior high school respectively. These findings are partially consistent with those of previous studies demonstrating that academic self-concept is more related to academic achievement, whereas task value is more related to educational choices. (e.g., Eccles et al., 1999; Marsh, Abduljabbar, et al., 2013; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). Given that most EVT research only included a general task value or one of value components in the regression model to assess educational choices (e.g., Wang, 2012; Simpkins et al., 2006; Watt et al., 2006), our finding adds further nuances to our understanding of how self-concept and different value components contribute to the decision making process, thus providing empirical evidence for the importance of differentiating and incorporating multiple value components.

One of the central contributions of this study is the examination of longitudinal predictions of the self-concept-by-value interaction in relation to modern EVT (Eccles, 2009). Consistent with our expectations, we found that the synergistic, multiplicative relation between math self-concept and intrinsic value predicted both math course selection and TER. More importantly, this is the first study to test this hypothesized latent interaction between self-concept and task value on long-term attainment and critical educational choices. Our finding indicates that the multiplicative effects of self-concept and intrinsic value on postsecondary educational choices are fully mediated through math course selection and TER. The observed synergistic relations suggest that students with high math self-concept and intrinsic value are more likely to select advanced math courses, achieve more academically, enter university, and pursue STEM fields of study. However, students with high self-concept are unlikely to attain these educational outcomes if they ascribe a low level of intrinsic value to math. Similarly, students who value math are also unlikely to attain these outcomes if their

106

math self-concept remains low. Aligning with recent cross-sectional studies of the interactive role of self-concept and value (Trautwein et al., 2012; Nagengast et al., 2011; 2013), our results provide longitudinal evidence and strong support for theoretical assumption that self-concept and value interact in predicting achievement-related outcomes and underscore the importance of taking the expectancy-by-value interaction into account in future EVT studies.

These findings suggest that interventions targeting the promotion of academic performance and math participation, as well as university and STEM pathways, should seek to enhance both math self-concept and intrinsic value. To do this, utility-value interventions, such as identifying personal utility-value connections between students' lives and what they are learning in class, have been found to be effective to trigger students' interest and promote academic performance in STEM topics (Hulleman & Harackiewicz, 2009; Hulleman, Godes, Hendricks & Harackiewicz, 2010; also see Harackiewicz, Tibbetts, Canning, & Hyde, 2014 for a review). For interventions aiming to increase academic self-concept, meta-analyses (Huang, 2011; O'Mara, Marsh, Craven, & Debus, 2006) suggest that self-enhancement and skill development should be integrated in interventions targeting a specific domain rather than global or skill-based self-concepts. More importantly, the observed synergistic relation also suggests that multicomponent interventions (e.g., Martin, 2008; Guthrie, Wigfield, & VonSecker, 2000) may be more effective in promoting students' motivation than those based on self-concept and value interventions individually. For example, the Concept-Oriented Reading Instruction (CORI) intervention (Guthrie et al., 2000) was designed to target five motivational processes, including self-efficacy and mastery (self-concept) and intrinsically motivating activities (task value). The CORI has been shown to boost students' reading motivation (Guthrie, McRae, & Lutz Klauda, 2007). However, such multiple-component intervention has not yet been fully investigated in relation to math and science school learning.

107

Internal Comparison Process

Consistent with our hypotheses, math self-concept, intrinsic value, and utility value are positively associated with prior math and science achievements, but negatively associated with prior reading achievement. These findings suggest that academic self-concept and task value are involved in the internal comparison process between math and verbal domains, while the ipsative process is not triggered between the math and science domains, due to their proximity on the academic continuum. In addition, all achievements are found to be more strongly predictive of math self-concept than task values. This result is consistent with previous studies (e.g., Eccles et al., 1999; Eccles, 2009) suggesting that the formation of relative task value is more dependent on prior performance, while the formation of relative task value is more dependent on an individual's personal and collective identities, as well as on social and psychological experiences (also see Marsh et al., 2005). For instance, the value of participating in a particular task depends on the individual's needs, motives and personal values (i.e., their personal identity) and on whether the task fulfills his/her collective/social role (e.g., gender role; Eccles, 2009).

Importantly, our results explicitly explain how the internal comparison process influences math-related educational choices. Students with high reading ability are more likely to have relatively low math self-concept and task values. This in turn adversely influences math course taking and subsequent STEM major selection. Hence, this finding adds to the notable evidence that individuals who have both high mathematical and verbal ability are less likely to pursue careers in the STEM fields compared to those with high mathematical but only moderate verbal ability (Chow & Salmela-Aro, 2011; Wang, Eccles, Kenny, 2013).

Gender Differences

As expected, gender differences in achievement-related behaviors are partially mediated by gender differences in prior academic achievement and math motivational beliefs. Specifically, gender differences in math motivational beliefs favoring boys partially mediate gender disparity in math course and STEM major selections when prior achievement is controlled. This finding supports the premise that girls would, on average, be less likely than boys to enroll in advanced math courses, as a result of their having lower math self-concepts and lower intrinsic math motivation, and due to placing less extrinsic value than boys on math (Nagy et al., 2006; 2008; Eccles et al., 1999; Simpkins et al., 2006). Consequently, gender difference in STEM is partially mediated by gender difference in math course selection. This finding aligns with other research (Watt, 2010; Watt et al., 2012) showing that girls often opt out of the math "pipeline" during senior high school, leading to the constraining of educational choice related to STEM fields. Effective preventative interventions that aim to enhance girls' retention in math through high school would be beneficial in supporting girls to pursue STEM careers. In contrast, girls' overrepresentation in tertiary education is partially mediated by gender difference in TER marks, and thus particular interventions that focus on boys' underperformance in high school are required.

In spite of gender differences in the mean-level of math motivational beliefs and educational outcomes, gender did not largely moderate the relations between these factors. Post hoc analysis showed that only three paths did vary by gender (see Appendix 3 in Supplemental Materials for more discuss). These results suggest that similar interventions would promote adolescent males' and females' pursuit of math course and STEM majors. However, given that the effect sizes of gender-differentiated patterns are marginal based on the large sample size of the present study, replication studies are warranted. 109

Limitations of This Study

Some limitations should be considered when interpreting the results. First, this study only examines the roles of students' math motivational beliefs in the process leading to entrance into university and STEM fields of study. Given that reading and science selfconcept and task values also have substantial impacts on this process, the further inclusion of multiple domain-specific self-concept and task values would provide a more comprehensive picture to illuminate the roles of motivational beliefs. Second, while our model addresses the reciprocal process between academic achievement and the motivational beliefs described in Eccles's expectancy-value model (Eccles, 2009, 2011), the data related to domain-specific achievement and motivational beliefs was collected within a single wave. Also, Eccles (2009, 2011) notes that the relations between motivational beliefs and educational choices appear to be reciprocal. For example, attending a different level of math course would provide a different social context to students, in which their math motivation beliefs, subsequently, would be shaped by their subjective interpretation of those experiences within the new class context (Eccles, 2009). Therefore, further research using fine-grained longitudinal studies is needed, to explore the reciprocal processes of motivational beliefs and achievement-related behaviors. Additionally, motivational beliefs are likely to play different roles in the decisionmaking processes in educational pathways across different countries (Parker et al., 2012; Watt et al., 2012). Future comparison of longitudinal studies across different national/international samples would be of use in clarifying whether the findings identified in the present study are unique to this Australian sample, or whether they represent a generalizable decision-making process. Finally, an important direction for further research would be to take ethnicity and its interaction with gender into account, thus providing a more nuanced understanding of individual ethnic and gender differences in choices of education pathways.

Conclusion

This present research shows a vital secondary-postsecondary nexus in the pursuit of university and STEM educational pathways, by revealing the impact of individual characteristics, prior domain-specific achievement, math motivational beliefs, and achievement-related behaviors. One important conclusion of this study is that to achieve high academic performance and take more advanced math courses in senior high school, both math self-concept and intrinsic value need to be high. Also, the synergistic relation between self-concept and intrinsic value contributes to the prediction of entrance into university and STEM fields of study. Furthermore, prior math and science achievement positively predicted math motivational beliefs and all educational outcomes, whereas prior reading achievement had adverse influences on math courses and STEM major selection, through its negative association with math motivational beliefs. Finally, gender differences in educational outcomes are mediated by gender differences in motivational beliefs and prior academic achievement, while the process underlying choice of educational pathways was similar for males and females. Taken together, and supporting the importance of substantivemethodological synergies (Marsh & Hau, 2007), the application of strong and evolving methodological approaches in the present study leads to substantively important findings with practical implications for educational policy-makers and practitioners seeking to promote equity engagement in university and STEM fields of study.

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12

Figure 1. Conceptual model



Figure 2. Path model depicting the hypothesized relations, excluding latent interaction, controlling for gender, Grade and SES. Only statistically significant paths are presented in the model, for clarity; all coefficients shown are standardized. Coefficients displayed in boldface type are the probability differences calculated from probit regression.

Note. Dashed arrows represent negative association between reading achievement and motivational beliefs. ASC = math academic self-concept; MIV = math intrinsic value; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; * p < .05, ** p < .01, *** p < .001.



14

Figure 3. Simple-slopes for the multiplicative effects of math self-concept and intrinsic values on math course selection and Tertiary Entrance Rank [TER]

Note. MIV = math intrinsic value.

15

Table 1

Standardized Direct.	Indirect. and	Total Effect	for the	Path Model	Without Late	ent Interaction
·····						

Predictor and		Course			TER			STEM		Uni	_entry	
covariate	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Math_ach	.20***	.16***	.36***	.26***	.14***	.40***	.02	.18***	.21***	.10** [.04]	.25***	.35***
Read_ach	.01	09***	09***	.11***	08***	.03	.00	08**	08*	.14*** [.05]	02	.12**
Sci_ach	.04	.04***	.08***	.10***	.03**	.12***	.05	.04**	.09*	.04	.05**	.10*
MSC	.18***	_	_	.19***	-	_	.06	.04**	.10*	.03	.09***	.12**
INV	.08**	—	-	.08***	-	-	.09* [.04]	.02	.11*	.06	.04**	.10*
MUV	.13***	_	-	.01	-	-	.16*** [.06]	.03*	.19***	.10*** [.04]	.01	.11**
Course	_	_	_	_	_	_	.20*** [.08]	_	_		_	_
TER	-	_	_	-	_	_		-	_	.48*** [.15]	_	_
Covariate												
Gender	04**	07***	11***	.11***	04**	.07**	10*** [04]	06**	17***	.17*** [.06]	.06**	.23***
SES	.01	.13***	.14***	.12***	.20***	.32***	01	.08**	.07*	.16*** [.06]	.27***	.43***
Year	.15***	.04**	.19***	07***	.09***	.02	01	.03	.02	.04* [.02]	.06**	.10*

Note. Coefficients in brackets are the probability differences calculated from probit regression. ASC = math academic self-concept; MIV = math intrinsic value; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; * p < .05, ** p < .01, *** p < .001. Dashes indicate that it was not possible to compute coefficients.

16

Table 2

Standardized Direct, Indirect, and Total Effect for the Path Model Without Latent Interaction

Predictor		MSC			INV			MUV			Read_ach	Sci_ach
and covariate	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Direct	Direct
Math ach	.57***	_	_	.40***	_	_	.24***	_	_	_	_	_
Read ach	29***	_	_	26***	_	_	15***	_	_	_	_	_
Sci_ach	.13***	_	_	.05**	-	_	.11***	_	_	_	_	-
Covariate												
Gender	09***	09***	18***	04**	07***	11***	07***	04	11***	06***	.18***	02
SES	02	.15***	.13***	.00	.07***	.07***	.01	.08***	.08***	.37***	.38***	.39***
Year	08***	.10***	.02	05***	.05***	.00	12***	.05***	07***	.22***	.18***	.18***

Note. ASC = math academic self-concept; MIV = math intrinsic value; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; p < .05, ** p < .01, *** p < .001. Dashes indicate that it was not possible to compute coefficients.

Table 3

The Conditional Indirect Effect of Self-Concept on University Entry and STEM Major Selection

	STEM	Uni_Entry
Moderator	(via Math_course)	(via TER)
MIV = +1SD	.05**	.13***
MIV = mean	.04**	.09***
MIV = -1SD	.02*	.05***

Note. MIV = math intrinsic value; UV = math utility value; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; p < .05, ** p < .01, *** p < .001.

Chapter 7: Study 4 - Extending Expectancy-Value Theory Predictions of Achievement and Aspirations in Physics, Chemistry, Earth Sciences and Biology: Internal Comparison Processes and Expectancy-by-Value Interactions

Note. This study is in review. The final submitted version of the article was presented in this thesis.

Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S. (in review). Extending Expectancy-Value Theory Predictions of Achievement and Aspirations in Physics, Chemistry, Earth Sciences and Biology: Internal Comparison Processes and Expectancy-by-Value Interactions.

Preface

In the previous study, the I/E model with its extension to DCT was integrated into EVT by testing associations between multiple academic achievement (math, reading and science), math motivational beliefs, and postsecondary educational choices. The internal comparison process indicated that prior reading adversely influenced math-related coursework selection through its negative association with math motivational beliefs. This suggests that understanding motivation and choices in relation to one academic domain requires researchers to juxtapose constructs in that domain with those in opposing domains. Study 4 extended prior research and both EVT and DCT to explore complex and seemingly paradoxical theoretical predictions about the relations between academic achievement, motivational beliefs (ASC, intrinsic value, utility value) and coursework aspirations across four science subjects (physics, chemistry, earth science, and biology). Notably, earth science has rarely been considered along with other science domains in academic motivation research.

The inclusion of ASC and multiple value beliefs also allowed the domain specific models of ASC (i.e., domain specificity) to be integrated into EVT and tested in relation to four science subjects, representing a narrower spectrum of the verbal-mathematical continuum (Marsh, 1990). The other unique feature is that study 4 is apparently the first to examine the distinctiveness of ASC-by-value interactions in predicting coursework aspirations across domains. Therefore, this study broadened the theoretical understanding of the dynamics of the motivation pathways leading to different STEM careers (e.g., physical science versus biological science).

Running head: EXPECTANCY VALUE IN SCIENCE SUBDISCIPLINE

Extending Expectancy-Value Theory Predictions of Achievement and Aspirations in Science: Internal Comparison Processes and Expectancy-by-Value Interactions

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Abstract

There is a dire shortage of able students pursuing careers in science. Based on TIMSS data (18,047 Grade 8 students from four OECD countries) in relation to four science domains (physics, chemistry, earth science, and biology), this study tested predictions about how self-concept and task value are related to students' achievement and coursework aspirations. The findings revealed that (a) we found negative contrast effects of achievement on self-concept and intrinsic value between contrasting domains (e.g., physics vs. biology) but positive assimilation effects between complementary domains that were close to each other (near domain, e.g., physics vs. chemistry); (b) similar patterns were found for the effects of self-concept and intrinsic value on coursework aspirations, and (c) synergistic self-concept-by-value interactions contributed to the prediction of aspirations. The results were consistent across all four OECD countries that collected data for multiple science disciplines, offering support for the robustness and generalizability of the findings.

Keywords: self-concept, expectancy-value, science subjects, coursework aspirations, latent interaction

Extending Expectancy-Value Theory Predictions of Achievement and Aspirations in Science: Internal Comparison Processes and Expectancy-by-Value Interactions

The issue of talented and capable students opting out of the STEM (i.e., science, technology, engineering, and mathematics) pipeline has been a topic of enduring interest in the science education community. Given that dropping out of science coursework at high school makes it very difficult to undertake STEM college majors and STEM-related careers (Kimmel, Miller, & Eccles, 2012), growing attention in research on science motivation has focused on disentangling the relationship between students' motivational beliefs and achievement in science on one hand, and high-school science course taking, aspirations, and persistence on the other (e.g., Guo, Parker, Marsh, & Morin, 2015; Nagy et al., 2006; Nagy, Trautwein, Baumert, Köller, & Garrett, 2008; Parker et al., 2012; Parker, Nagy, Trautwein, & Lüdtke, 2014, Watt et al., 2012).

These studies have demonstrated that motivation beliefs (such as academic self-concept and value beliefs) represent important determinants of achievement-related decisions in STEM subjects, net of individual's actual ability and achievement (Wang & Degol, 2013). However, much of this research has focused on motivational beliefs in general science, whereas science choices and aspirations (e.g., coursework and careers) are often measured in specific science domains (Wang & Degol, 2013). Indeed, the process of subject selection is inherently comparative: students are likely to select those coursework domains in which they hold the highest motivational beliefs (Eccles, 2009). Intraindividual cross-domain (internal) comparisons (e.g., between the math and verbal domain) have been found to be useful for predicting academic choices (Nagy et al., 2006; Parker et al., 2012, 2014). Thus, focusing on motivational beliefs in general science or a single subject domain would result in a very limited perspective in explaining achievement-related behavior choices in STEM fields of study and may even be counterproductive in understanding coursework selection and aspirations in particular science disciplines (Eccles, 2009).

The aim of this study was to overcome the shortcomings of prior research, by testing complex and seemingly paradoxical theoretical assumptions of the relations between academic

133

achievement, motivational beliefs, and coursework aspirations taking into account several different science disciplines. In pursuing this overarching aim, we integrated and extended two major theoretical models of academic motivation (i.e., dimensional comparison theory [DCT], Möller & Marsh, 2013; expectancy-value theory [EVT], Eccles, 2009) in relation to four major science domains (physics, chemistry, biology, and earth science; Binns & Bell, 2015). First, contrasting achievement and motivation, we tested how students' subject-specific self-concept and intrinsic and utility values in the sciences were shaped by internal comparisons. Second, extending theoretical developments based on DCT, we explored how such internal comparison processes predicted coursework aspirations across different science domains. Third, extending recent developments based on EVT, we tested how academic self-concept interacted with value beliefs in predicting aspirations in each of these four science domains.

The present study drew on eight-grade students from the Trends in International Mathematics and Science Study (TIMSS 2007). TIMSS has been a major basis of international comparisons of countries in terms of educational motivation and achievement in the four major science domains. Thus, it presents an unprecedented opportunity for researchers to investigate students' motivational pathways to different STEM-related fields. This study was among the first to take advantage of the TIMSS data to address this substantive issue. In order to test the crossnational generalizability of our results, we included the Czech Republic, Hungary, Slovenia, and Sweden, which were the *only* OECD countries who chose to conduct separate assessments in physics, chemistry, biology and earth science (Olson, Martin, & Mullis, 2008).

Internal Comparison Processes

The I/E Model and Its Extension to DCT

Academic self-concept, the self-evaluation of a student's ability in a given domain, has been assumed to be a multifaceted, hierarchical construct including a number of self-perceptions in different academic domains (Marsh, 1990). In order to evaluate their strengths and weaknesses, students compare and contrast their own performances across different school disciplines (Möller & Marsh, 2013). Such internal comparison processes were developed to explain the apparently paradoxical relations among domain-specific self-concepts and achievement: near zero-correlations between math and verbal self-concepts despite math and

verbal achievement being moderately to strongly correlated (Marsh, 1986, 2007). The I/E model posits that students form their verbal and math self-concepts as a function of two underlying comparison processes or frames of reference: a) externally comparing their self-perceived performance in a subject domain with that of their peers in the same school or classroom (i.e., an external frame of reference); and b) by internally comparing their performances in one particular subject domain against their performance in other subject domains (i.e., an internal frame of reference). The external comparison process leads to a positive prediction from achievement and self-concept within a subject domain. However, the internal comparison process is ipsative, so that high levels of math ability should lead to lower verbal self-concept once the positive effect of verbal ability is controlled for. The I/E model has been widely supported by experimental, cross-cultural, and longitudinal studies (Marsh, 2007).

More recently, the I/E model has been extended into DCT (Möller & Marsh, 2013) by incorporating a wider variety of disciplines based on a verbal-math continuum of academic domains (Marsh, 1990). More specifically, physics and chemistry are assumed to be located closer to the math domain, whereas biology is assumed to be located closer to be the middle of the continuum. This is consistent with recent empirical findings that have shown that the correlation between physics and chemistry self-concepts was slightly higher than correlations of biology to physics and to chemistry self-concepts respectively (Jansen, Schroeders, & Lüdtke, 2014). However, earth science has not been positioned in this academic continuum. Given that topics covered in the teaching and learning of earth science are usually intertwined with some concepts also covered in biology, physics and chemistry (Thomas, Ivey, & Puckette, 2013), earth science should be located in the middle of the physics/chemistry and biology on the continuum.

DCT postulates that academic self-concepts are formed by different dimensional comparisons (Marsh et al., 2015). On the one hand, *contrasting* dimensional comparison processes predict that good performance in one domain leads to lower self-concept in other domains (i.e., assimilation effects). On the other hand, *assimilating* dimensional comparison processes are characterized by good performance in one domain leading to higher self-concept in other domains (i.e., assimilation effects). According to the verbal-math continuum of school subjects, assimilation effects are assumed to occur between domains that are close to each other

on the continuum ("near" domains, e.g., physics vs. chemistry), whereas contrast effects are assumed to occur between "far" domains (physics vs. reading). More recently, Jansen et al. (2014) contrasted achievement and self-concept in physics, chemistry, and biology and found that associations of self-concept with achievement and grades were substantial in the same domains. For cross-subject relations, they revealed slight negative contrast effects between biology and physics but assimilation effects between chemistry and physics (Jansen et al, 2014, 2015). However, these two previous studies focus on German high school students and the findings have yet to be replicated with other populations across different science curricula. Moreover, these studies have not included earth science and thus miss out on the opportunities to gain insight into internal comparison processes between four major science disciplines.

The particular strength of DCT is the ipsative-like process of internal comparison, which provides an important theoretical framework for analyzing the relations between achievement and academic self-concepts across multiple domains in predicting achievement-related choice behaviors. However, only recently have studies begun to explore this potential (Parker et al., 2012, 2014, see subsequent discussion).

Expectancy-Value Framework

Modern EVT

Unlike the DCT, which mainly focus on the formation of academic self-concept, modern EVT (EVT, Eccles, 2009; Eccles, et al., 1983) has been widely used to explain students' academic choice behaviors. Modern EVT (Eccles, 2009) posits that educational aspirations and choices are most directly influenced by the intraindividual hierarchy of expectancies for success and the relative task values individuals attach to various achievement-related options. Expectancies and values, in turn, are influenced by previous achievement-related experience and the socialization processes linked to various cultural and social settings (e.g., school and family).

Modern EVT (Eccles, 2009) defines *expectancies of success* as a task-specific belief about the possibility of experiencing future success in that task. Expectancies of success are typically operationalized as self-conceptions (Marsh, 1986, 2007) in a given domain (Eccles, 2009; Nagengast et al., 2011; Trautwein et al., 2012). Thus, the present study relies on academic self-concept as a reflection of students' expectancies of success in particular STEM domains.

Modern EVT distinguishes between multiple components of task value (Wigfield, Tonks, & Klauda, 2009). In the current study, we focus on two of these components: intrinsic value, referring to the extent to which the person gains enjoyment from performing an activity, and utility value, the perceived usefulness of a specific task for the individual. It has been well documented that academic self-concept is more strongly correlated with intrinsic value than with utility value (Wigfield et al., 2009). Although value beliefs are assumed to be domain-specific (Wigfield et al., 2009), recent research has revealed that compared to intrinsic value, utility value is less distinctive between math and verbal domains (Xu, 2010) as well as between math and science (Marsh et al., 2013). However, the majority of this EVT research has rarely considered multiple science domains.

Internal Comparison Processes: Integration of DCT and EVT

According to modern EVT (Eccles, 2009), previous achievement-related activities and achievement affect students' expectancies of success and how they prioritize or rank task value across various subject domains. In turn, these motivational beliefs influence their academic and occupational aspirations, and their decision to pursue additional coursework in a particular domain. When an individual has to select the activities they want to pursue, domain comparisons within individuals are triggered (Eccles, 2009, 2011). All such behavioral choices are considered to be associated with costs, given that (following an ipsative-like process) selecting one option often results in forfeiting other options (Eccles, 2009).

Relatively little empirical work, however, has integrated notions of ipsative-like processes from EVT and DCT to predict achievement-related choices. Nagy et al. (2008; Nagy et al., 2006; Parker et al., 2012, 2014) present one of the few exceptions, which incorporated intrinsic value and self-concept in math and verbal to test relations between achievement, motivational beliefs, and advanced coursework selection. Consistent with EVT, prior achievement predicted self-concept and intrinsic value, which in turn influenced coursework selection. Also, consistent with the I/E model, self-concept and intrinsic value were positively associated with achievement and course choices in the same domain but were negatively associated with achievement and course choices in the other domain.

137

In addition, Xu (2010) tested the I/E model for utility value, finding that I/E-like patterns involving utility value were much weaker than those with self-concept and intrinsic value. However, most of this extant research has only compared self-concept and intrinsic and utility values between math and verbal domains, which are perceived as maximally dissimilar dimensions (Möller & Marsh, 2013) and are placed at the end points of the academic continuum (Marsh, 1990). This leaves open the question as to how such internal comparison processes influence achievement-related outcomes for domains that are close to each other on the continuum (i.e., "near" domains), for example, between science subdisciplines. Thus, this study integrated EVT with new insights from DCT and draws on multiple, similar (science) domains to explore how internal comparison processes predict coursework aspirations.

Interaction Between Self-Concept and Task Values

In addition to having the first-order effects, competence beliefs and value beliefs are assumed to interact with each other in influencing achievement-related behaviors and choices in early EVT (Atkinson, 1957; also see Feather, 1982). The expectancy-by-value interaction suggests that if students do not have confidence in their abilities to succeed in a task (i.e., low expectancies of success), then even high value beliefs will not be sufficient to motivate students to pursue the task. Eccles (2009) also suggested the presence of a multiplicative relation between expectancies for success and task value in noting that: "the motivational power of ability self-concepts to influence task choice is, at least partially, determined by the value individuals attach to engaging in the domain" (p. 84). However, this multiplicative relation, which was the central assumption of classic EVT, has not been widely studied in modern EVT. Nagengast et al. (2011) attributed this to weak statistical methodology in testing interaction effects and that the expectancy-by-value interaction should be returned "to its rightful place at the heart of EVT" (p. 1064).

Recently empirical studies have successfully reintroduced examination of interaction effects between expectancy and value in predicting educational outcomes based on the newer approaches (e.g., the unconstrained approach; Marsh et al., 2004,). For example, based on a nationally representative sample of Australian youth, Guo, Parker et al. (2015) reported that the interactions between high school math self-concept and values significantly predicted math

course selection, matriculation results, subsequent STEM major choices and entry into university when value components (intrinsic value or utility value) were considered separately. Although intrinsic value and utility value had differential first-order ("main") effects on educational outcomes, the interaction effects for both value components were similar in size (also see Trautwein et al., 2012). However, most of this research only considered a single domain (e.g., science), and the researchers did not test the domain specificity of the patterns of results across different science domains. As a consequence, their research did not explore the ipsative (internal comparison) process in the I/E model; a matter that has been subsequently addressed with the extension to DCT and its integration into EVT.

The present investigation

Drawing on DCT and EVT, the present investigation aims to examine the distinctiveness of relationships between domain-specific achievement, motivation beliefs (self-concept, intrinsic value and utility value), and coursework aspirations across four major science subjects (physics, chemistry, earth science, and biology). Importantly, we explore the roles of expectancy-by-value interactions with internal comparison processes in predicting coursework aspirations. Hence, the present study is unique in that it takes multiple science disciplines into account and integrates DCT and EVT to provide greater understanding of the motivational dynamics leading students to making academic choices within STEM-related fields.

Hypotheses

Relations between achievement and motivational beliefs

a. We predict matching paths from each of the four achievement domains to self-concept, intrinsic value, and utility value in the same domain (e.g., physics achievement \rightarrow physics self-concept) to be significantly positive.

b. For physics, chemistry, and biology, according to the verbal-math continuum of academic domains (Marsh, 1990), we predict non-matching paths (cross-paths) relating to "far" domains (e.g., physics achievement → biology self-concept) to be negative (contrast effects), whereas we predict these cross-paths relating to "near" domains (e.g., physics achievement → chemistry self-concept) to be positive (assimilation effects). We hypothesize that earth

science, which has not previously been incorporated in the academic continuum, is located in the middle of physics/chemistry and biology on the continuum (see early discussion).

Relations between motivational beliefs and coursework aspirations

a. We predict matching paths to be significantly positive from self-concept, intrinsic value, and utility value in each domain to coursework aspirations in the same domain, even after controlling for achievement (e.g., physics self-concept \rightarrow physics aspirations). Based on previous research, in predicting coursework aspirations, we hypothesize matching path coefficients for intrinsic value to be stronger than those for utility value and self-concept.

b. We predict non-matching paths (cross-paths) relating to "far" domain (e.g., biology self-concept → physics aspirations) to be negative, whereas these cross-paths relating to "near domain" (e.g., physics self-concept → chemistry aspirations) might be positive. Again, we leave the pattern of the predictions in relation to earth science as a research question.

c. Consistent with the recent re-introduction of expectancy-by-value interactions into EVT, we predict that latent interactions between self-concept and values (intrinsic value and utility value) will affect aspirations beyond the effects of the first-order ("main") effects of these latent constructs.

Generalizability of results

Students were exposed to different science curricula in different OECD countries (See Appendix A in the supplemental materials), which would provide a strong test of the robustness of our findings. We predict that the pattern of results outlined in Hypotheses 1–3 (above) generalize across the four OECD countries, but leave as a research question whether the actual sizes of paths differ when subjected to formal tests of invariance (i.e., holding the paths invariant in multiple-group SEMs across the four countries).

Method

Participants

In the present study the sample consisted of Grade 8 students who participated in the TIMSS 2007 study from four OECD countries (Czech Republic, Hungary, Slovenia, and Sweden). In TIMSS 2007 data, these four countries were the only OECD countries in which students completed surveys in relation to four science domains (physics, chemistry, earth

140

science, and biology), although standardized tests in four science disciplines were administered for eighth grade students in all participating countries. (Olson et al., 2008; also see Appendix A in the supplemental materials). Therefore, in the present study, we considered data from 18,047 students (51% boys) in 1,025 classes and 598 schools in the four OECD countries described above (see Appendix B in the supplemental materials for more details).

Measure

Motivational factors. The measures of expectancy-value constructs were selected from the student-background questionnaire administered in TIMSS2007. All motivation items were coded on a Likert scale, with 1 indicating that the participants "agree a lot" and 4 indicating "disagree a lot". However, for the present purposes, responses were reverse-scored, so that higher values represented more favorable responses and thus, higher levels of motivation. The wording of the items was strictly parallel across the science domains (see Appendix B in the supplemental materials for the wording of the items and a priori factor structure of motivational factors in the four OECD countries).

A scale of students' Self-confidence in Learning Science (SCS) was created for TIMSS (Olson et al., 2008) to assess how students think about their ability in specific domains. This scale has been used to measure academic self-concept in TIMSS studies (e.g., Marsh et al., 2013). The students' Positive Affect Toward Science (PATS) scale was applied to assess the affect experienced by students when participating in domain-related activities, in line with the notion of *intrinsic value* in the EVT (Eccles et al., 1983). Likewise, the TIMSS Students Valuing Science (SVS) scale was similar to utility value in the modern EVT (Eccles et al., 1983), which assesses how well achievement in specific domains relates to current and future goals. These three latent constructs demonstrated satisfactory reliability across the four countries (see Appendix B for more detail)

Academic achievement. Participants' academic abilities of science are assessed though a range of questions in the four science subdomains. Two question formats were used in the TIMSS assessment – multiple-choice and written-response questions that involved a mixture of knowing, applying, and reasoning process (Olson et al., 2008). In total, TIMSS Grade 8

assessment comprised 216 science achievement items, of which 25%, 20%, 20%, and 35% were respectively related to physics, chemistry, biology, and earth science.

Coursework aspirations. As there was only one item measuring students' achievementrelated decisions in the TIMSS2007, following Marsh, Abduljabbar et al. (2013), this single item was used students' coursework aspirations in each subject area ("I would like to do more in Biology/Physics/Earth science/Chemistry in school."). The response scale ranged from 1, indicating that the participants "disagree a lot" to 4, indicating "agree a lot".

Data Analysis

In the present study, all data analyses, confirmatory factor analysis (CFAs) and SEMs, were conducted with Mplus 7.11 (Muthén & Muthén, 1998–2014) using the robust maximum likelihood estimator. The unconstrained approach (Marsh, Wen, & Hau, 2004) was utilized to model the latent interactions between self-concept and task values in predicting coursework aspirations (e.g., Marsh et al., 2004;). We relied on the Mplus MODEL CONSTRAINT command to compute the mean of matching and non-matching paths between science subjects in relation to a priori predictions. In addition, to correct for standard errors and model fit statistics for the nesting of classes, schools and countries, the four OECD countries were treated as grouping variables in multigroup analyses, and the classroom clustering and weighting variables were used to control for the clustering sample (see Appendix C and D in the supplemental materials for more details regarding unconstrained approach, weight, goodness of fit, and missing data).

Missing data. In order to account for the five plausible values for each achievement score, all data analyses involving achievement were run separately for each of the five plausible values. For each of the five data sets based on different plausible values, we used full information maximum likelihood (FIML) estimation to handle missing data on the remaining items (Enders, 2010), given that a relatively small amount of missing data (an average of less than 2% missing data for motivation items for each country, except for Sweden, which presented 6.3% to 18.2% missing data). Final parameter estimates, standard errors and goodness-of-fit statistics were obtained with the automatic aggregation procedure implemented in Mplus, for multiple imputation to properly handle plausible values (Enders, 2010).

Preliminary Analyses

Our main substantive interest is in relations among self-concept, intrinsic value and utility value, and their relations to parallel measures of achievement and coursework aspirations across the four science domain. Preliminary analyses described in details Appendix E in the supplemental materials demonstrate: (a) there was good support for the factor structures underlying the multiple domains of self-concept, intrinsic value, and utility value; (b) rigorous tests of factorial invariance showed that factor loadings, variances and covariances for motivational beliefs, achievement, and aspirations were invariant over the four OECD countries (Models MG1–MG4, See Table 1), and (c) there was good support for the convergent and discriminant validity of motivation beliefs in relation to achievement and aspirations, particularly for self-concept and intrinsic value, to a lesser extent, but also for utility value (based on the latent correlation matrix of relations among the constructs).

Results

Tests of Predictions Relating Achievement to Motivation Beliefs: Hypothesis 1

Matching paths. In this SEM model, we included one set of 16 (4 x 4; 1 matching paths + 3 non-matching paths for each domain;) paths leading from achievement in each science domain to each of the four self-concept responses, and two additional sets of 16 paths from achievement to each of the four intrinsic value and each of the four utility value latent factors (Models MG5–MG6, See Table 1). As seen in see Figure 1-3, of particular importance were the substantial path coefficients between matching paths from achievement to motivation constructs in matching domains compared to those in non-matching domains. To clarify these critical path coefficients, we computed summary statistics for matching paths, non-matching paths, and their difference (see Appendix F in supplemental materials). The matching paths leading from achievement to matching self-concept (M = .19, SE = .01) and intrinsic value (M = .14, SE = .01) factors were positive across the four science disciplines. However, the matching paths for utility value were relatively small (M = .05, SE = .01).

Non-matching paths. The means across the 12 remaining non-matching path coefficients leading from achievement in each domain to non-matching motivational beliefs were substantially smaller than the corresponding matching coefficients (self-concept: Δ [mean of

matching paths – mean of non-matching paths] M = .15, SE = .01; intrinsic value: $\Delta M = .16$, SE = .01; utility value: $\Delta M = .07$, SE = .01). More specifically, consistent with predictions from Hypothesis 2b, cross-paths between physics and biology were negative, whereas those between physics and chemistry were positive. We also found that cross-paths between chemistry and biology were slightly positive but significantly weaker than those between physics and chemistry ($\Delta M = .07$, SE = .01 for self-concept; $\Delta M = .04$, SE = .01 for intrinsic value). Cross-paths between earth science and the other science domains were slightly positive or non-significant. It should be noted these patterns of results were only evident in relation to self-concept and intrinsic value.

In summary, consistent with Hypothesis 1, there was strong support for the domain specificity of predictions relating achievement to self-concept and intrinsic value but relatively weaker support for utility value in terms of the sizes of path coefficients¹.

Tests of Predictions Relating Motivational Beliefs to Aspirations: Hypothesis 2

Matching paths. We began with an evaluation of models without latent interactions. Consistent with predictions from Hypothesis 2a, matching paths leading from self-concept, intrinsic value and utility value in each domain to coursework aspirations, were substantially positive, controlling for achievement (see Figure 1-3). The mean across the four matching path coefficients for intrinsic value (M = .67, SE = .01) was substantially larger than that for self-concept (M = .10, SE = .01) and utility value (M = .06, SE = .01).

Non-matching paths. Non-matching path (cross-path) coefficients relating to motivational beliefs to aspirations smaller than the corresponding matching paths (self-concept: $\Delta M = .09$, SE = .02; intrinsic value: $\Delta M = .66$, SE = .01; utility value: $\Delta M = .05$, SE = .01) In line with predictions from Hypothesis 2b, cross-paths between physics and biology were significantly negative. Again, the pattern of results was found for self-concept and intrinsic value but not utility value. However, the majority of cross-paths involving self-concept, intrinsic value, and utility value were non-significant or slightly positive. Similar pattern of results was found in

¹ The results also provided good support for domain specificity of predictions relating achievement to coursework aspirations. Motivational constructs largely mediated the relation between each of the four achievement domains and the corresponding measure of aspirations

Model MG8b in which the self-concept-by-utility-value interaction was considered.

Latent interactions. We added two sets of domain-specific latent product variables to the Model MG6: one based on product indicators for the self-concept and intrinsic value (MG7a-MG7b), and one based on those for self-concept and utility value items (MG8a-MG8b). It should be noted that all path coefficients in the model with interactions are similar to those without interactions (see Appendix F in the supplemental materials). Of particular relevance, the mean of matching paths involving latent interactions were significantly positive (M = .12, SE = .01). Given that the sizes of matching interaction path coefficients for different domains were similar, a simple-slopes plot was constructed, based on the mean of matching interaction path coefficients. As seen in Figure 4, the simple-slopes plot shows that the regression line of self-concept is relatively flat at -1*SD* value, increasing in steepness with incremental intrinsic value, and substantially steeper at +*1SD*. This finding indicates the synergistic relation of self-concept and intrinsic value in predicting coursework aspirations, providing good support for a priori predictions (Hypothesis 3b).

When self-concept-by-utility value interactions instead of self-concept-by-intrinsic value interactions were included (Model MG8a-MG8b), the simple-slopes plot based on the means of matching interaction path coefficients (see Figure 4) shows that the effects of self-concept were a function of utility value, being weaker with low value and substantially stronger with high value, indicating a synergistic interaction in predicting aspirations (M = .07, SE = .01). Supplemental analyses suggest that both types of domain-specific latent interactions (self-concept-by-intrinsic value and self-concept-by-utility value) make similar contributions to the prediction of coursework aspirations when both product variables are considered simultaneously (see Appendix G in the supplemental materials for more details).

In summary, consistent with Hypothesis 3, there was good support for the domain specificity of predictions relating the three motivation constructs to coursework aspirations, particularly for latent interactions between self-concept and task value, in terms of substantial matching path coefficients.

Tests of Predictive Relations Over Countries: Hypothesis 3

In order to test the generalizability of our results across the four countries, we estimated a series of multiple-group SEMs in which path coefficients were constrained to be invariant across the four countries (Models MG5–MG8b). More specifically, in each model, invariance constraints were imposed on the path coefficients in combination with the invariance of additional sets of parameters: factor loadings, factor variances, and factor covariances. Although the imposition of these additional constraints resulted in some decrease in model fit, these decreases were negligible in relation to traditional guidelines of fit, and all models provided a satisfactory level of fit to the data (see Appendix E in the supplemental materials). In summary, consistent with Hypothesis 3, there was support for the invariance of path coefficients over the four countries.

Discussion

In the present investigation we adopted a multidimensional perspective on academic selfconcept and task value (intrinsic and utility values) in multiple science domains, and examined the domain specificity of associations relating achievement, motivational beliefs and coursework aspirations. Although numerous studies have applied EVT to a generalized science construct, or in relation to specific science subjects, ours is apparently the first to evaluate EVT constructs representing physics, chemistry, earth science and biology in a single model. This is particularly important in evaluating the internal comparison process posited in DCT and self-concept-byvalue interactions posited in classical EVT, in which outcomes in any one domain depend not only on accomplishments, self-concept beliefs, and value perceptions in that domain, but also on how these constructs compare to those in other, contrasting domains.

The Relations between Achievement and Motivational beliefs

Consistent with a priori predictions, the results provide strong evidence for domainspecific relations between achievement and motivational beliefs, particularly for self-concept and intrinsic value, in which paths for matching domains were substantially stronger than those for non-matching domains.

Internal comparison processes involving self-concept. More importantly, this study extends previous research and provides clear support for the internal comparison process in DCT with regard to cross-paths from achievement to non-matching domains of self-concept. In

particular, the results reveal negative cross-paths between physics and biology which are separated by the greatest distance on the continuum of academic self-concepts (relative to other science domains). However, most previous support for the negative cross-paths is based on studies of math and verbal domains that are at opposite ends of the academic self-concept continuum posited by Marsh (1990).

However, internal comparison processes in relation to self-concept were apparently weaker between physics and chemistry, resulting in small positive cross-paths. This result is also consistent with DCT, such that accomplishments in one domain will contribute positively—not negatively—to self-concept in a closely related domain. This indicates that higher levels of achievement in chemistry contribute positively to self-concept in physics. Hence, students apparently perceive physics and chemistry to be similar and complementary subjects, such that skills acquired in one subject will help success in the other subject, and achievement feedback in one subject may generalize to the other subject.

The positive cross-paths are also evident between chemistry and biology, but they are significantly smaller than those between physics and chemistry. This result is in line with the verbal-math academic continuum, suggesting that chemistry and physics would be perceived as more similar to each other than chemistry and biology. However, these assimilation effects are not contradictory to the contrasting dimensional comparisons between physics and biology. Having high ability in chemistry leads to positive self-concept in both physics and biology, while highly able in biology leads to low self-concept in physics (and vice versa).

With respect to earth science, the internal comparison process apparently was not triggered in relation to other science domains. Instead, small and positive cross-paths involving earth science indicate that students are likely to engage in assimilating dimensional comparisons between earth science and other science domains. This study is among the first to incorporate earth science and explore its location in the math-verbal academic continuum. The similar pattern of cross-paths relating earth science to different science domains is consistent with our expectation that earth science would be located between physics/chemistry and biology. Thus, the results provide new theoretical and substantive insights into I/E model and DCT.

147

Internal comparison processes involving value beliefs. The pattern of results was similar for self-concept and intrinsic value. This finding suggests that when students perceive school subjects to be similar (e.g., physics and biology), intrinsic motivation in one is likely to generalize to the other, whereas when they perceive those subjects to be distinct (physics vs. biology), high achievement in one domain would lead to liking of the other domain being wane. However, in relation to utility value, we found relatively weak support for the a priori predictions posited in DCT. For instance, the non-significant matching paths for biology and earth sciences appear inconsistent with DCT. A theoretical reason for this may be the low degree of domain specificity of utility value across science domains (see Appendix E for more details). The domain specificity of the construct is one of the bases underlying dimensional comparison mechanisms. The pattern of relations between the motivational factors and achievement is largely a function of the domain-specific nature of this factor (Marsh et al., 2001). Previous research has suggested that a lower degree of domain specificity for the motivational constructs is associated with weaker support for the I/E model (Xu, 2010).

The Relations between Motivational beliefs and Aspirations

Consistent with a prior prediction, this study found strong evidence for domain-specific relations of self-concept and intrinsic value to coursework aspirations. Despite the lack of domain specificity of utility value in relation to achievement, we found reasonable support for domain specificity for utility value in relation to coursework aspirations. Indeed, students decide whether or not a subject domain is useful based on certain characteristics that can be related to their needs and personal values (i.e., their personal identity) rather than on performance in that domain (see subsequent discussion), and these characteristics are in line with their coursework aspirations.

Distinctiveness of self-concept-by-value interactions. This study is among the first to test latent expectancy-by-value interactions for multiple science domains within the same model, thus extending the results of previous research by incorporating a more multidimensional perspective. In line with a priori predictions, there is strong evidence of the high domain specificity of synergistic relations in predicting coursework aspirations, suggesting that aspiring to engage in one science subject occurs especially when self-concept and value (intrinsic value or

utility value) are both relatively high. Therefore, this study provides strong support for the theoretical claim that self-concept and value interact in predicting achievement-related outcomes.

Internal comparison processes involving self-concept and value beliefs. This study extends prior research by integrating EVT and the internal comparison processes of DCT, in relating motivational beliefs to educational aspirations. Consistent with the a priori predictions, support for the internal comparison process is particularly evident for the physics and biology domains, where the cross-paths from self-concept and intrinsic value in one domain to aspirations in the other domain are negative (see Figure 1-2). Thus, for example, students who have high self-concept and interest in physics but even higher self-concept and interest in biology are likely to have lower aspirations in physics compared to students who have the same level of self-concept and interest in physics but lower self-concept and interest in biology. Thus, aspirations in one science domain depend not only on abilities, self-concept, and intrinsic value in that domain, but also on relative abilities and motivation in other science domains. These findings shed further light on the important roles played by internal comparison processes in shaping academic pathways to different STEM fields, and underline the importance of differentiating motivational beliefs across science domains.

However, it should be noted that all cross-paths between achievement, motivational beliefs and coursework aspirations were relatively weak, particularly for the assimilation effects. These results are consistent with recent self-concept research on science domains (Jansen et al., 2014, 2015). This may be because the four science subjects considered here are all relatively similar, compared to the more obviously contrasted academic continuum, ranging from relatively pure verbal subjects to relatively pure mathematical subjects (Marsh, 1990). Nevertheless, mathematics and verbal skills are posited as the endpoints of the academic continuum were not considered in this study.

Generalizability of the results

How science subjects are taught in a given learning environment varies as a function of the country, state or school system, and this is particularly so for earth science. In this study, physics, chemistry and biology were taught separately in the four countries, although the timing for introducing these distinct subjects varied across countries. Earth science was integrated into

physics or chemistry in Slovenia and Sweden, whereas it was treated as a separate subject in the Czech Republic and in Hungary. Nevertheless, despite these variations in science curricula, the pattern of results is invariant across countries, supporting the external validity of the results and and providing strong support for the robustness of the domain specificity of motivation constructs in science.

Implications for Instructional Practices

With respect to instructional practices, the high domain specificity of self-concept and intrinsic value suggests that interventions targeting general academic, or even a general science, self-concept and intrinsic value, may not be beneficial in promoting students' motivation in STEM areas. Rather, interventions targeting a specific academic self-concept domain, with the integration of self-enhancement (self-concept enhances ability) and skill development (ability improves self-concept) strategies, have been shown to be much more effective than those solely targeting a global or skill-based self-concept (O'Mara, Marsh, Craven, & Debus, 2006). Interventions designed to increase students' perceptions of the relevance of academic subjects to their lives through teachers and parents have been found to be effective in triggering students' interest and to promote academic performance in STEM topics (Harackiewicz, Rozek, Hulleman, & Hyde, 2012).

Furthermore, we recommend that teachers should be aware of the comparison processes underlying the formation of students' self-concept and intrinsic value. This would help teachers provide effective feedback to students. In particular, attributional feedback, goal feedback, and contingent praise, as forms of constructive feedback, have been identified as effective methods of boosting self-concept (O'Mara et al., 2006). Teachers should be also aware of the comparison processes that lead to different levels of coursework engagement, particularly between physics and biology.

In addition, the distinctiveness of the synergistic relations between self-concept and value beliefs across science domains, suggests that interventions targeting the promotion of aspirations to STEM majors should seek to enhance both domain-specific self-concept and task value. This suggests that multicomponent interventions (e.g., Gläser-Zikuda, Fuß, Laukenmann, Metz & Randler, 2005) might be more effective in promoting students' motivation than those based on

self-concept and value interventions considered separately. For example, The ECOLE (Emotional and Cognitive Aspects of Learning) intervention combines student- and teachercentered instruction targeting multiple aspects of the learning process, including competence (self-concept) and value (intrinsic and utility values). The ECOLE intervention has been shown to enhance students' motivation and achievement in physics and biology (Gläser-Zikuda, et al., 2005).

Limitations and Directions for Further Research

Several limitations to this study, and some caveats, must be noted. First, in the present cross-sectional study, the issue of the temporal or causal ordering among achievement, motivational beliefs and coursework aspirations could not be addressed on the basis of a single measurement point. For example, there may be reciprocal relations between achievement and motivational beliefs, since high motivational beliefs would result in high academic performance. Thus, a longitudinal replication would enable us to draw stronger conclusions about the directional influences of self-concept and value and the importance of their interactions.

Second, as our study is limited to the four OECD countries where science is taught as separate subjects, it is also important to replicate the results in settings where students are taught science as an interdisciplinary, unified subject. Relatedly, the domain specificity of EVT predictions in science is likely to vary as a function of age, as the further students go in school the more differentiated the coursework is likely to be. This is particularly the case as students move into higher education. Thus, research across different international samples covering multiple age groups, school subjects and schooling systems would be useful, to clarify the generalizability of our findings.

Third, given that the present investigation only focuses on two out of four major value components and single-item coursework aspirations, future research should consider psychometrically stronger, multi-item measures of the four value components and coursework aspirations. Finally, future studies would benefit from including a broader range of subject domains (e.g., arts, physical education, social sciences) across multiple informants (i.e., teacher as well as peer reports). In particular, self-concept, intrinsic values, utility value, and aspirations 151

were only measured by student self-reports so that it would allow us to provide a more nuanced understanding of how internal comparison processes influence STEM pathway choices.

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Figure 1. Structural path model of the relations between achievement, self-concept, and coursework aspirations across the four science domains Model MG6. *Note*. Only statistically significant regression paths (p < .05) are presented. Negative, significant paths are shaded in gray.



Figure 2. Structural path model of the relations between achievement, self-concept, and coursework aspirations across the four science domains Model MG6. *Note*. Only statistically significant regression paths (p < .05) are presented. Negative, significant paths are shaded in gray.
EXPECTANCY VALUE IN SCIENCE SUBDISCIPLINES



Figure 3. Structural path model of the relations between achievement, self-concept, and coursework aspirations across the four science domains Model MG6. *Note.* Only statistically significant regression paths (p < .05) are presented. Negative, significant paths are shaded in gray.

29

EXPECTANCY VALUE IN SCIENCE SUBDISCIPLINES



Figure 4. Simple-slopes depicting the effects of latent interactions (self-concept by intrinsic value and self-concept by utility value) on coursework aspirations. *Note.* IV = intrinsic value; UV = utility value.

30

Model Fit Statistics for the CFA and SEM Models Used in the Present Study

Model	Description	χ^2	df	CFI	TLI	RMSEA
Multi-gro	oup (MG) analysis					
CFA						
MG1	SC + IV + UV + ACH + ASP, Correlated Uniqueness + configural	18038	3912	.964	.951	.028
MG2	MG1 + FL invariance	19416	4008	.961	.948	.029
MG3	MG2 + FV invariance	20138	4068	,959	.947	.030
MG4	MG3 + FC invariance	23961	4638	.951	.944	.030
SEM						
MG5	MG2 + PC invariance	21088	4344	.958	.948	.029
MG6	MG4 + PC invariance	23961	4638	.951	.944	.030
MG7b	MG6 + FL, FV, CV, PC invariance relating to SCxIV	31512	7228	.942	.936	.027
MG8a	MG6 + freely estimated FL, FV, CV, PC relating to SCxUV	25644	7740	.955	.947	.023
MG8b	MG6 + FL, FV, CV, PC invariance relating to SCxUV	28647	8184	.948	.942	.024
MG7a	MG6 + freely estimated FL, FV, CV, PC relating to SCxIV	29880	6934	.945	.936	.027

Note. PC = path coefficients; SC = self-concept; IV= intrinsic value; UV = utility value; ASP = coursework aspirations; SCxIV = the product term of self-concept by intrinsic value interaction; SCxUV = the product term of self-concept by utility value interaction; FL = factor loading; FV = factor variances; CV = factor covariances.

Chapter 8: Study 5 - Probing Unique Contributions of Self-Concept, Task Values and Their Interactions Using Multiple Value Facets and Multiple Academic Outcomes

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Preface

Studies 1-4 incorporated two value components (intrinsic value and utility value) together with ASC to explore the unique predictive power of these motivational beliefs as well as their interactions on diverse achievement-related outcomes. Study 5 extended these studies and examined the unique contributions of four value components (intrinsic value, utility value, attainment value, and cost) to the prediction of academic achievement, effort, and engagement in math, by employing a newly developed multifaceted measure of value beliefs. In particular, an innovative bi-factor model was used to deal with relatively high correlations among the four value components, which had plagued previous EVT research.

The other key feature of this study was to incorporate student self-reported and teacher-rated educational outcomes (e.g., self-rated effort and teacher-reported engagement). In particular, the use of non-self-rated variables has received scant attention in research on expectancy-by-value interactions. Taken together with the previous studies (1-4), the thesis built a comprehensive understanding of the contributions of motivational beliefs on both short-term educational engagement and subject choices, but also long-term educational and occupational outcomes.

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Probing the Unique Contributions of Self-Concept, Task Values, and Their Interactions Using Multiple Value Facets and Multiple Academic Outcomes

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Drawing on expectancy-value theory, the present study examined the unique contributions of the four major value beliefs and self-concept on achievement, self-reported effort, and teacher-rated behavioral engagement in mathematics. In particular, we examined the multiplicative effects of self-concept and task values on educational outcomes using the latent moderated structural equation approach. Participants were 1,868 German ninth-grade students. The data analyses relied on a higher-order structure of value beliefs, which is suited to parsing the differential patterns of predictive relations for different value beliefs. The findings revealed that (a) self-concept was more predictive of achievement, whereas value beliefs were more predictive of self-rated effort; (b) self-concept and value beliefs emerged as equally important predictors of teacher-reported engagement; (c) among the four value beliefs, achievement was more associated with low cost, whereas effort was more associated with attainment value; and (d) latent interactions between self-concept and value beliefs predicted the three outcomes synergistically.

Keywords: self-concept, expectancy-value theory, mathematics, achievement, effort, engagement, latent interaction

EXPECTANCY-VALUE theory (EVT; Eccles, 2009; Eccles et al., 1983; Wigfield & Eccles, 2002) is one of the major frameworks for achievement motivation and has been widely used to explain students' effort, choices, and achievement in relation to academic and nonacademic domains (e.g., sports, music, and social activities). Research based on EVT has demonstrated that competence beliefs and value beliefs represent the most proximal precursors of academic achievement, effort, and engagement

(e.g., Eccles, 2009; Guo, Marsh, Morin, Parker, & Kaur, 2015; Wang & Eccles, 2013; Watt et al., 2012). Value beliefs are postulated to be multidimensional-composed of intrinsic value, attainment value, utility value, and cost (Eccles et al., 1983; Eccles & Wigfield, 2002). Although these four components can be empirically differentiated (Conley, 2012; Luttrell et al., 2010; Trautwein et al., 2012), rarely have all four value components been considered simultaneously in one empirical study,



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Guo et al.

particularly in one regression model, to examine the unique contribution of specific value components to the prediction of achievement-related outcomes.

In addition to their first-order effects, competence beliefs and value beliefs are assumed to interact with each other in influencing achievement-related behaviors and choices (see Atkinson, 1957; Atkinson & Feather, 1966; Feather, 1982; Vroom, 1964). In other words, the interactive associations suggest that the relation between competence beliefs and outcomes depends on the extent to which an individual values a given domain and vice versa. However, empirical research examining interaction effects of motivational beliefs on achievement-related behaviors in nonexperimental settings is surprisingly sparse (for exceptions, see Guo, Parker, Marsh, & Morin, 2015; Nagengast et al., 2011; Trautwein et al., 2012). One of the reasons for this sparsity has been the error-prone specification of interaction effects in latent variable models that account for measurement error (e.g., Bollen, 1996; Jöreskog & Yang, 1996; Kenny & Judd, 1984). In recent years, less-complicated specifications have been published (Marsh, Wen, & Hau, 2004), and new approaches (e.g., Klein & Moosbrugger, 2000; Kelava & Nagengast, 2012; Kelava, Nagengast, & Brandt, 2014) have become available with standard latent variable modeling software (e.g., Mplus; Muthén & Muthén, 1998-2014).

In this study, we draw on the framework of modern EVT (Eccles, 2009), using a large sample of high school students in Germany, to investigate predictive relationships between math motivational beliefs and three achievement-related outcomes: math achievement, self-reported math effort, and teacher-rated behavioral engagement. Of central importance, the present study captured the multidimensional nature of task values (Eccles et al., 1983; Eccles & Wigfield, 2002) to explore the unique predictive power of the four math value components, along with self-concept, on the educational outcomes. The interactive roles of self-concept and value beliefs were also examined in order to address this gap in the literature. In particular, the use of non-self-rated variables has received scant attention in research on expectancy-byvalue interactions. Finally, by juxtaposing the recent literature and the results of the present investigation, we provide a more complete evaluation of the nature of expectancy-byvalue interactions in support of EVT.

EVT

The modern EVT (Eccles, 2009; Eccles et al., 1983) posits that achievement-related performance and choices are most directly influenced by an individual's expectations of academic success and a subjective assessment of the inherent value of academic tasks. Modern EVT (Eccles et al., 1983) defines *expectancies of success* as task-specific beliefs about the possibility of experiencing future success in that task, which is assumed to be mainly influenced by a person's beliefs about her or his abilities (i.e., ability self-concepts; Marsh, 1986, 2007). However, Eccles (2009) states, "Empirically, we have found that ability self-concepts are so directly linked to expectations for success that it is quite difficult to distinguish between these two constructs" (p. 82). Similarly, in their review of competence self-perceptions more generally, Schunk and Pajares (2005) also emphasize that expectancy-value theorists have concluded that expectations of success and academic self-concept are not empirically separable. This has led to the routine use of academic self-concept in recent EVT studies (e.g., Musu-Gillette, Wigfield, Harring, & Eccles, 2015; Simpkins, Fredricks, & Eccles, 2012; Wang & Eccles, 2013; Wang, Eccles, & Kenny, 2013) as a measure of expectancies of success, particularly so with those examining expectancy-by-value interaction (e.g., Nagengast et al., 2011; Trautwein et al., 2012; Guo, Parker, et al., 2015). Following this tradition, academic self-concept was used in this research to measure expectancies of success.

Modern EVT distinguishes between multiple components of value (Wigfield & Eccles, 1992; Eccles & Wigfield, 2002): *Intrinsic value* refers to the extent to which the person gains enjoyment from performing an activity. *Attainment value* is the degree of importance attached to successful performance of a specific task and has been also linked to relevance of a task to one's personal and social identities (Eccles, 2009, 2011). *Utility value* is the degree of usefulness that a specific task has for the individual. *Cost* includes the degree of potential loss of time; effort demands; the loss of valued alternatives, such as spending time with friends; or additional negative experiences, such as stress. Cost is the leaststudied component of task value.

Recently, evidence has emerged that the four value components can be empirically differentiated in the math domain (Conley, 2012; Luttrell et al., 2010; Trautwein et al., 2012). These studies found a similar correlation pattern among the value components, with the highest correlations being between intrinsic and attainment value. It has been well documented that correlations between academic self-concept and the value components are usually moderate to large in size (see Wigfield & Eccles, 2002; Wigfield, Tonks, & Klauda, 2009, for reviews). In particular, self-concept is more highly correlated with intrinsic value than other value components within a specific domain (Wigfield et al., 2009). Thus, it is imperative to differentiate and consider all value components along with self-concept in one regression model, which allows us to further disentangle the interactive relationships between self-concept and value beliefs in predicting achievementrelated outcomes (see subsequent discussion).

Association of Self-Concept, Task Value, and Achievement-Related Behaviors

An extensive body of EVT research has demonstrated that self-concept is more closely associated with academic achievement than is task value, whereas task value is

generally a stronger predictor of course-taking decisions (e.g., Eccles, Barber, & Jozefowicz, 1999; Perez, Cromley, & Kaplan, 2014; Watt, Eccles, & Durik, 2006), academic engagement and effort (e.g., Cole, Bergin, & Whittaker, 2008; Trautwein & Lüdtke, 2009; Wang & Eccles, 2013), and educational and career aspirations (e.g., Simpkins, Davis-Kean, & Eccles, 2006; Watt et al., 2012). However, most of this research has focused predominantly on a single value construct measured by a small number of items or only on one or two of the expected components of value. Utility value and attainment value have often been combined as importance value (Durik, Vida, & Eccles, 2006; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Watt et al., 2012). For example, Watt et al. (2012) found that importance value was more predictive of educational aspirations than was intrinsic value, whereas intrinsic value more strongly predicted math participation than did importance value, controlling for self-concept. Of particular relevance, no previous studies have simultaneously considered all four components of value, along with self-concept, in the same regression model, although EVT (Eccles, 2009) emphasizes that different value components should play differential roles in influencing educational outcomes.

However, Wigfield and Eccles (2000), along with many others (e.g., Wigfield & Cambria, 2010), have acknowledged that overlapping elements among task values might exist. Indeed, an apparent problem in previous research has been that the four value components have been so highly correlated that the resulting multicollinearity has made it difficult to identify the separate and unique contribution of each value component. Thus, previous studies of the multiple value components have conducted separate analyses of each value component, rather than considering them simultaneously in a single model (e.g., Trautwein et al., 2012). Recognizing this as a limitation in most previous research, the challenge for us was to resolve this problem so that the four value components could be considered together in the same model. In an apparent resolution of this issue, we applied an innovative higher-order bi-factor model that is specifically designed to capture the multidimensional nature of task value to test the unique contribution of value components to students' academic achievement, behavior engagement, and effort (see subsequent discussion).

The Multiplicative Relation Between Expectancy and Value

Although Eccles (2009) suggested that "the motivational power of ability self-concepts to influence task choice is, at least partially, determined by the value individuals attach to engaging in the domain" (p. 84), the multiplicative relation between expectancies for success and task values, which was the core assumption of classic EVT (Atkinson, 1957; also see Feather, 1982; Vroom, 1967), has not been widely

Expectancy-Value Interaction and Unique Prediction

examined. In modern EVT (Eccles, 2009; Eccles et al., 1983), the effects of self-concept and value are often implicitly assumed to be additive, which would suggest that self-concept and task value predict achievement-related behaviors uniquely and independently. A multiplicative relation, on the other hand, would imply that the effect of self-concept on outcomes depends on the extent to which an individual values a given domain and vice versa.

Typically, an interaction between two independent predictors (i.e., self-concept and task value) has been described as having either a compensatory or a synergistic relation to the outcome. The nature of the interactions in relation to the two taxonomies is considerably different; this has theoretical and substantive implications for motivation researchers. Specifically, a compensatory relation suggests that as long as individuals have high expectancy or high value attached to a given academic task, they will be motivated to engage in it. In other words, high expectancy can compensate for low value and vice versa. In contrast, a synergistic relation would suggest that either high expectancy or high value alone is not sufficient to motivate behaviors. Rather, individuals must have both high selfconcept and high value to engage in a given academic task. More specifically, recent studies of expectancy-by-value interactions (Nagengast et al., 2011; Trautwein et al., 2012) have argued that support for EVT implies a synergistic expectancy-by-value interaction, suggesting that compensatory interaction might not support EVT.

The omission of the multiplicative relation in modern EVT may be partly due to the shift from experimental designs focusing on intraindividual differences to real-world settings focusing on interindividual differences (for further discussion, see Nagengast et al., 2011; Trautwein et al., 2012). Methodologically, it is difficult to detect interaction effects in nonexperimental designs (Marsh et al., 2004; also see Appendix A in the supplemental materials). However, recently, researchers have been able to examine interaction effects using structural equation modeling (SEM; Bollen, 1989) techniques, such as the latent moderated structural equation approach (LMS; Klein & Moosbrugger, 2000) and the unconstrained product indicator approach (Marsh et al., 2004), in which the measurement error of the predictor variables is accounted for (for an overview, see Schumacker & Marcoulides, 1998).

On the basis of these recent approaches, there is now some recent empirical support for a synergistic relation between expectancy and task value in predicting educational outcomes. For example, Nagengast et al. (2011) found that science self-concept, intrinsic value, and their interaction significantly positively predicted engagement in science extracurricular activities and intentions to pursue a scientific career. Importantly, the pattern of results was similar across 57 countries in the Programme for International Student Assessment 2006 data (Nagengast et al., 2011). In addition,

Guo et al.

on the basis of a nationally representative sample of Australian youth, Guo, Parker, et al. (2015) reported that the interactions between high school mathematics self-concept and value significantly predicted mathematics course selection; matriculation results; subsequent science, technology, engineering, and mathematics [STEM] major choices; and entry into university when value components (intrinsic value and utility value) are considered separately (also see Guo, Marsh, Parker, Morin, & Yeung, 2015; Nagengast, Trautwein, Kelava, & Lüdtke, 2013; Trautwein et al., 2012). However, when the model included both value components and their interactions with self-concept, only the interaction between self-concept and intrinsic value was found to predict the outcomes significantly.

Although these empirical studies successfully reintroduced the multiplicative relation between expectancy and value in motivation research, three important limitations need to be addressed. First, as discussed above, the multidimensional nature of task value has not been fully taken into account in previous studies, particularly in those with expectancy-by-value interaction.

Second, little is known about whether self-concept and task value interact in predicting academic effort and behavioral engagement, particularly in a classroom setting; these are important determinants of academic success (Wang & Degol, 2014). Students' effort in learning tasks is highly correlated with their behavioral engagement in classroom and is usually treated as a part of measures of engagement (e.g., Furrer, Skinner, Marchand, & Kindermann, 2006; Skinner, Kindermann, & Furrer, 2008; Skinner, Zimmer-Gembeck, & Connell, 1998). Students' behavioral engagement is also determined by their attention, self-direction, and persistence in learning activities (Furrer et al., 2006; Skinner et al., 1998, 2008).

Most empirical studies investigating how motivational beliefs relate to academic effort and engagement have relied heavily on student self-report measures (e.g., Trautwein & Lüdtke, 2009; Wang, 2012; Wang & Eccles, 2013). Monitoring the extent to which students are engaged with and make an effort in learning activities is important for teachers in order to provide constructive feedback in the classroom. However, teacher perceptions of student engagement and effort might differ from those of their students. In previous research, the correlation between self-reported and teacher-rated engagement was found to be moderate (average r= .30-.35; Lee & Reeve, 2012; Skinner et al., 2008). Collecting information from teachers can provide an alternative and important perspective on student engagement and effort. To date, little EVT research has simultaneously considered multiple informants (i.e., student as well as teacher reports) with respect to engagement or effort and has examined associations between motivation beliefs and outcomes. Therefore, in this study, we fill this gap in the literature by exploring the interactive relations between math self-concept

and all value components in predicting student self-reported effort and teacher-rated engagement. Third, insufficient attention has been given to the nature

of first-order effects ("main" effects of self-concept and value) and interactions (self-concept by value) in support of EVT predictions. Although positive interaction effects indicate synergistic relations, and negative interaction effects indicate compensatory relations, the interpretation of the results in relation to EVT depends fundamentally on the combination of first-order and interaction effects. In particular, superficial interpretations of interaction effects that do not also take into account the size and nature of the firstorder effects can be misleading. Rather, interpretation of interaction effects should always be based on a graph of the results in relation to a priori predictions. In this study, we provide a more complete evaluation of the nature of multiplicative relations in support of EVT, showing that compensatory interactions are not necessarily inconsistent with EVT predictions, whereas synergistic interactions are not necessarily consistent with EVT predictions (see subsequent discussion).

The Present Study

Drawing on EVT, we operationalize math subjective task value as a multidimensional construct to examine self-concept, the four value components, and their interactions in predicting three math-related outcomes: objective achievement, self-reported effort, and teacher-rated behavioral engagement. The present study is unique in that it simultaneously includes the four latent value components in the latent SEM to explore the unique contribution of each value component to the prediction of achievement-related outcomes by integrating a second-order model and a bi-factor model.

This integration allows us to extend past research on the application of modern EVT and leads to the following research hypotheses:

Hypothesis 1: We examined whether student self-concept and the four value components predict the three outcomes differentially. Generally, we expected that self-concept would be a stronger predictor of academic achievement, whereas task value would be more predictive of self-reported effort and teacherrated engagement (e.g., Eccles & Wigfield, 2002). However, specific hypotheses about which value components play more important roles in promoting student' academic effort and engagement are lacking in the EVT literature. Theoretically, intrinsic value and, perhaps, cost are the most closely tied to effort and engagement. When students value an activity intrinsically, they often become deeply engaged in it and can persist at it for a long time (Wigfield & Cambria, 2010). Perceived negative aspects of engaging in a specific task (i.e., anticipated effort, time, and energy) might also be directly associated with students' exertion of effort and engagement (Barron & Hulleman, 2015; Flake, Barron, Hulleman, McCoach, & Welsh, 2015). Thus, we expect intrinsic value and cost would make unique contributions to the prediction of self-reported effort and teacher-rated engagement, after controlling for self-concept and other value components.

Hypothesis 2: Of particular importance to the investigation, we expect a synergistic relation between self-concept and value in predicting the outcomes (e.g., Guo, Parker, et al., 2015; Nagengast et al., 2011). Importantly, we also provide a more complete evaluation of the nature of multiplicative relations in support of EVT by juxtaposing the recent literature and the results of the present investigation.

Method

Participants

The data set used in the present study (see Gaspard et al., 2015) is part of the larger Motivation in Mathematics (MoMa) project. The current study's sample was drawn from ninth-grade high school students from 82 classes in 25 academic track schools (Gymnasium schools) in the German state of Baden-Württemberg in 2012. A total of 1,978 students who had active parental consent participated in the study (53.5% female; age, M= 14.62). The questionnaires were administered to the students in class by trained research assistants.

Measures

Students' motivational beliefs were measured through student ratings with a 4-point Likert-type scale, systematically recoded so that higher values represented more favorable responses and, thus, higher levels of motivation. In particular, we assessed math-related value beliefs with an instrument developed to measure the multidimensional nature of task beliefs, based on the modern EVT model (Eccles et al., 1983).

Value components/facets. There is recent empirical support that subjective task value not only is defined by four components but could be further characterized by multiple facets within each major component (Trautwein et al., 2013). This is similar to the Big Five personality factor structure, in which each of the Big Five factors is represented by multiple facets and each facet in turn is represented by multiple items (Goldberg, 1992, 1999). But it is worth noting that these facets are merely a means to get at the Big Five factors (Costa & McCrae, 1995; Goldberg, 1992, 1999). Thus, in this study, 37 items were used to measure a total of 10 facets, which

form the four value components (see Table 1 for descriptive statistics, sample items, and reliability of value scales).

Specifically, intrinsic value was measured by four items and attainment value by 10 items tapping two facets (importance of achievement and personal importance; Eccles, 2009; Wigfield & Eccles, 1992). Utility value consisted of 12 items assessing the utility of different life domains from a short-term (school, daily life, social life; Eccles et al., 1983; Hulleman & Harackiewicz, 2009) as well as from a long-term perspective (job, future life in general; Conley, 2012; Hulleman, Durik, Schweigert, & Harackiewicz, 2008). Cost was measured by 11 items tapping three facets (opportunity cost, effort required, and emotional cost; Perez et al., 2014; Wigfield & Eccles, 2002). For a detailed description of the scales and the total set of items, see Gaspard et al. (2015). All value items were measured with a 4-point Likert scale ranging from *completely disagree* to completely agree. Scale reliabilities for value facets were acceptable (see Table 1).

Self-concept. Math self-concept was assessed with five items (e.g., "I am good at math"; see Appendix B in the supplemental materials), each with a 4-point response format ranging from *completely disagree* to *completely agree*. All items were validated and came from the German adaptation (Schwanzer, Trautwein, Lüdtke, & Sydow, 2005) of the Self-Description Questionnaire III (Marsh et al., 2004) as well as from previous large-scale national studies (e.g., Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). The reliability of this scale was acceptable (Cronbach's α = .92).

Math achievement. A validated and comprehensive test developed by the statewide school quality assurance agency (Landesinstitut für Schulentwicklung) was utilized to measure math achievement. The math test is used to assess the quality development of schools on an empirically established, targeted, and systematic basis. To ensure reliable testing and evaluation, this instrument comprises a balance of closed, partially open, and open test item formats. The official test results reported by the schools were used to operationalize students' math achievement.

Student self-reported effort. This scale consisted of six items measuring students' effort in math class as well as on math tasks and homework (Organisation for Economic Cooperation and Development, 2003; e.g., "I work hard in math"; $1 = strongly \ disagree$ to $4 = strongly \ agree$; see Appendix B in supplemental materials). Reliability of this scale was good ($\alpha = .81$).

Teacher-rated engagement. This scale comprised two items measuring students' classroom engagement ("This student participates in math lessons as well as he/she can") and effort expenditure on homework ("This student works on all of his/

Sample Items, ICCs, Reliabilities, and Factor Loadings of Motivational Beliefs and Outcome Scales

Variable	Sample items	Number of items	ICC	Scale reliability	Loadings (Model SO-4V)	Loadings (Model SO-B-4V)
Intrinsic value (IV)	Math is fun to me.	4	.07	.94		
Attainment value (AV)						
Importance of achievement (ACH)	Good grades in math are very important to me.	4	.07	.88	.83	.79
Personal importance (PER)	Math is very important to me personally.	6	.04	.83	1.00	.84
Utility value (UV)						
Utility for school (SCH)	Being good at math pays off, because it is simply needed at school.	2	.03	.52	.65	.39
Utility for daily life (DAI)	Understanding math has many benefits in my daily life.	3	.06	.83	.83	.75
Social utility (SOC)	I can impress others with intimate knowledge in math.	3	.05	.76	.41	.11
Utility for job (JOB)	Good grades in math can be of great value to me later on.	2	.04	.68	.76	.63
General utility for future life (FUT)	I will often need math in my life.	2	.05	.78	.95	.99
Cost (CO)						
Effort required (EFF)	Doing math is exhausting to me.	4	.04	.90	.91	.84
Emotional cost (EMO)	Doing math makes me really nervous.	4	.04	.87	.99	.93
Opportunity cost (OPP)	I have to give up a lot to do well in math.	2	.02	.79	.68	.60
Self-concept	I'm good at math.	5	.03	.92	_	_
Self-reported effort	I work hard in math.	6	.15	.81	_	_
Teacher-rated engagement	This student participates in math lessons as well as he/she can	2	.02	.50		

Note. ICC = intraclass correlation; Model SO-4V = first-order bi-factor for four value components; Model SO-B-4V = second-order bi-factor for four value components with 11 value facets.

her tasks and homework thoroughly"). We again used a Likert-type scale ranging from $1 = strongly \ disagree$ to $4 = strongly \ agree$.

Statistical Analyses

In the present study, all data analyses, confirmatory factor analyses (CFAs), and SEMs were conducted with Mplus 7.11 (Muthén & Muthén, 1998-2014) using the robust maximum likelihood estimator. The LMS approach (Klein & Moosbrugger, 2000) was utilized to model the latent interactions between self-concept and task values in predicting the three outcomes. The advantage of the LMS approach is that it corrects for measurement error of latent constructs and provides unbiased estimates of latent interaction effects. Further, LMS represents non-normal distribution as a mixture of conditionally normal distributions; thus, separate indicators of the product terms (latent interaction) are not required (Kelava et al., 2011).

Four value components: Higher-order structure. As emphasized earlier, the multiple facets of the four value components are merely a means to an end. Although further research into specific outcomes might identify the important predictions specific to each of the 10 value facets, the focus in the present investigation is on the four value components originally posited by modern EVT (Eccles et al., 1983; Wigfield & Eccles, 2000). In this respect, our focus is on second-order factors representing the four value components rather than on the first-order factors representing the 10 value facets. Thus, a second-order model was employed to define the hierarchical representation of each value component from multiple dimensions of value facets tapped by multiple items (see Figure 1).

TABLE 1



FIGURE 1. Second-order confirmatory factor analysis models presenting the four value components. All value facets are labeled by their acronym (see Table 1).

Bi-factor models provide a more flexible alternative, a way of capturing the hierarchical and multidimensional nature of task value (Chen, West, & Sousa, 2006; Reise, 2012). The assumption underlying the bi-factor models is that an f-factor solution exists for a set of n items with one global factor (G-factor) and f-1 domain-specific factor (S-factor); the total covariance is partitioned into a G-factor underlying all indicators and f-1 S-factors that reflect the residual covariance not explained by the G-factor (Gustafsson, & Balke, 1993; Holzinger & Swineford, 1937; Morin, Arens, & Marsh, 2015; Mulaik & Quartetti, 1997). This bi-factor specification is consistent with EVT, in which task values might overlap with each other to a certain degree, even though the four value components have emerged from different theoretical perspectives and can be defined separately (Eccles & Wigfield, 2002). These overlapping elements might reflect an overall sense of values students attach to various tasks. Furthermore, as discussed above, these overlapping elements might lead to high correlations among value components, which would make it difficult to isolate and detect the unique contribution of each value component. One of the key features of the bi-factor model is that the residual S-factors typically are specified as uncorrelated (orthogonal) to one another and with the G-factor (Chen et al., 2006). This makes the bi-factor model particularly useful for researchers to study the unique roles of a subset of S-factors in predicting external variables, over and above the general factors.

In this study, we integrated a second-order model and a bi-factor model. More specifically, we applied an innovative second-order bi-factor model that was uniquely suited not only to capture hierarchical and multidimensional features of task value but also to address the challenge of detecting the unique contribution of value components. As illustrated in Figure 1, in the second-order bi-factor model, the covariance among value items is attributable to three major

Guo et al.

sources: (a) a global (general) value factor representing the common variation shared by all 37 value items; (b) 10 domain-specific first-order factors based on value facets, which represent the unique variances represented by each facet that are independent of the global value factor; and (c) second-order value factors representing the four value components posited in EVT, which are the main focus of the present investigation. In this model, the relations of global task value to first-order value facets and second-order value components were assumed to be orthogonal; the second-order value component make a unique contribution to the prediction of the three outcomes, over and above the global value.

Model fit indices. The comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the Tucker-Lewis index (TLI) were used to determine the fit of CFA models. Values greater than .95 and .90 for CFI and TLI typically provide excellent and acceptable fits, respectively, to the data (Hu & Bentler, 1999). RMSEA values of less than .06 and .08 are considered to reflect good and acceptable statistical fits, respectively (Marsh et al., 2004). Nonetheless, these fit statistics are not available for the SEM models including latent interactions (Klein & Moosbrugger, 2000). Akaike information criteria (AIC) and Bayes information criteria (BIC) were utilized for model comparison in the present study (e.g., Kelava et al., 2011; Pek, Losardo, & Bauer, 2011). These indexes have the advantage that they not only consider how well a model fits the data but also reward more parsimonious models in contrast to more complex models in which many parameters are estimated. Smaller values of AIC and BIC indicate better fits to the data (Kelava et al., 2011).

Hierarchical data structure and missing data. The data set has a nested data structure in which students are nested within schools and classes. To account for this nested structure, we used the TYPE = COMPLEX with the CLUSTER and STRATIFICATION options in Mplus to adjust the standard errors. For the variables considered here, the percentage of missing data was low (2.9% at maximum). Full information maximum likelihood (FIML) estimation was used to cope with the missing data. In FIML, the parameters of a statistical model are estimated in the presence of missing data, and all of the information of the observed data is used to inform the parameters' values and standard errors (Enders, 2010).

Results

In order to test the hierarchical and multidimensional nature of the value components, we employed two alternative models within the CFA framework: second-order models and bi-factor models. Following Gaspard et al. (2015), we began by evaluating a series of CFAs based on secondorder models and examined intercorrelations among value components, self-concept, and outcome variables. Subsequently, we tested an innovative second-order bi-factor model that is uniquely suited to parsing the differential patterns of predictive relations for different value beliefs. Finally, a series of SEMs was conducted to explore the unique predictive power of self-concept, value components, and their interactions on math achievement, effort, and engagement.

Second-Order CFA

For each value (except for intrinsic value), the models differentiating value facets consistently yielded better fits to the data, thus providing good support for the dimensionality of value components (Models IV to CO2; see Table 2). To further assess the separability of value components, we evaluated high-order CFAs. The second-order model (Model SO-4V: CFI=.939, TLI=.934, RMSEA=.044; see Figure 1 and Appendix C in the supplemental materials; also see Gaspard et al., 2015), where the four value components were formed by 10 value facets, fitted the data much better than did the first-order four-factor models (Model FO-4V: CFI=.849, TLI=.838, RMSEA=.069). This finding demonstrates the differentiation of value components into distinct facets (see Gaspard et al., 2015, for further discussion).

Correlations among value beliefs, self-concept, and outcomes. Based on Model FO-4V, latent correlations indicated that the four value components were moderately or highly correlated, ranging from .41 (utility value and low cost) to .77 (intrinsic value and low cost). Math self-concept was moderately correlated with math attainment value (r= .55) and utility value (r= .45) and more highly correlated with intrinsic value (r= .80) and low cost (r= .82; see Table 3).

Correlations between motivational beliefs and the three outcomes were all statistically significant and positive (see Appendix D in the supplemental materials for correlations involving value facets). Specifically, achievement was more highly correlated with self-concept, intrinsic value, and low cost (r = .53, 46, and 42), and self-reported effort was more highly correlated with attainment value (r = .60). Correlations of teacher-rated engagement to motivational beliefs are somewhat smaller (r = .16 to .32, M = .24). In line with prior studies (Lee & Reeve, 2012; Skinner et al., 2008), the correlation between self-reported effort and teacher-rated engagement was moderate in size (r = .32), while both were significantly correlated with achievement (r = .18 and .36, respectively).

Second-Order Bi-Factor CFA

The second-order bi-factor CFA model (SO-B-4V; Table 2; also see Figure 1) posits one global value, 10 first-order value

TABLE 2

Model Fit Statistics for	• the Hypothesi	zed CFA Models
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Model	Description	χ^2	df	CFI	TLI	RMSEA
Value compos	nents (separated)					
IV	Intrinsic value	3.41	2	1.000	.999	.019
AV1	Attainment value (1 factor)	404.55	34	0.951	.935	.076
AV2	Attainment value (2 factors)	140.63	33	0.986	.981	.042
UV1	Utility value (1 factor)	1,830.35	54	0.748	.692	.133
UV2	Utility value (4 factors)	174.34	44	0.982	.972	.040
CO1	Cost (1 factor)	1,301.96	44	0.869	.836	.124
CO2	Cost (3 factors)	259.85	41	0.977	.969	.053
All value com	ponents (combined)					
FO-4V	First-order four value components	6,117.08	622	0.849	.838	.069
SO-4V	Second-order four value components (11 first-order factors) ^a	2,827.14	613	0.939	.934	.044
FO-B-4V	First-order bi-factor four value components	4,397.09	580	0.895	.880	.059
SO-B-4V	Second-order bi-factor four value components (11 first-order factors) ^a	2,207.26	581	0.955	.949	.039
All value com	ponents + self-concept + outcomes					
ModelA1	Model SO-4V + self-concept + outcomes	4,859.10	1177	0.929	.923	.040
ModelB1	Model SO-B-4V + self-concept + outcomes	4,147.66	1142	0.942	.935	.037

Note. CFA = confirmatory factor analysis; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation. ^aThe first-order factors representing the facets of attainment value, utility value, and cost were set to load on a second-order factor representing the corresponding value component. Given that there were no value facets for intrinsic value, it was still treated as a first-order factor and included in the second-order factor model (see Gaspard et al., 2015).

TABLE 3

Intercorrelations Among	g Self-Concept,	Value Component.	s, and Outcomes
-------------------------	-----------------	------------------	-----------------

Variable	1	2	3	4	5	6	7
1. Self-concept	_						
2. Intrinsic value	.80 (.02)	_					
3. Attainment value	.55 (.02)	.72 (.02)	_				
4. Utility value	.45 (.02)	.57 (.02)	.75 (.02)				
5. Low cost	.82 (.01)	.76 (.01)	.50 (.02)	.41 (.03)			
6. Achievement	.53 (.02)	.42 (.03)	.27 (.03)	.24 (.03)	.46 (.02)		
7. Self-reported effort	.30 (.03)	.40 (.03)	.60 (.03)	.36 (.03)	.25 (.03)	.18 (.03)	
8. Teacher-rated engagement	.32 (.04)	.26 (.03)	.23 (.04)	.16 (.04)	.25 (.03)	.36 (.03)	.30 (.03)

Note. For presentational purpose, the low cost scale was reverse coded. The correlation coefficients reported above were based on the second-order confirmatory factor analysis model (Model SO-4V).

facet factors, and four second-order value factors. This model provided a better fit to the data (CFI= .955; TLI= .949; RMSEA= .039) than did second-order CFA model (Model SO-4V).¹ In Model SO-B-4V, the global value factor was well defined, with generally moderate loadings ($|\lambda|$ = .19 to .85, M = .51; see Appendix D in the supplemental materials for more details). Beyond this G-factor, the specific first-order factors were also well defined, with largely moderate to strong item loadings ($|\lambda|$ = .22 to .94, M = .57). The loadings on the second-order factors were substantial for value facets ($|\lambda|$ = .39 to .99, M = .73), except for the social utility facet. In summary, Model SO-B-4V showed the four well-defined second-order value components along with a global value factor, providing good support for the hierarchical and multidimensional representation of task value as posited in EVT.

Four value components: Unique contributions to outcomes. What is the unique contribution of the four value components and the global value factor to the prediction of our three outcome variables? We tested the predictive effects of the four secondorder value components, self-concept, and the global value as well as self-concept-by-value interactions on achievement,

TABLE 4

Standardized Path Coefficients of Self-Concept, Value Components on Three Outcomes Based on the Second-Order Bi-Factor Model

Predictor	Model C1	Model C2	Model C3	Model C4
Achievement				
Self-concept	.53 (.02)***		.48 (.04)***	.47 (.06)***
Intrinsic value		.15 (.05)**	.07 (.06)	.07 (.05)
Attainment value		.01 (.04)	.01 (.03)	.01 (.03)
Utility value		.04 (.03)	.05 (.03)	.05 (.03)
Low cost		.26 (.03)***	.09 (.04)*	.09 (.04)*
Global value		.38 (.03)***		.01 (.06)
Self-reported effort				
Self-concept	.32 (.03)***		.30 (.05)***	02 (.11)
Intrinsic value		.25 (.06)***	.20 (.08)*	.25 (.06)***
Attainment value		.58 (.03)***	.57 (.04)***	.58 (.04)***
Utility value		.02 (.03)	.03 (.04)	.02 (.03)
Low cost		$.08(.04)^{\dagger}$.02 (.05)	$.09(.05)^{\dagger}$
Global value		.33 (.04)***		.35 (.10)***
Teacher-rated engagement				
Self-concept	.36 (.04)***		.29 (.05)***	.28 (.10)**
Intrinsic value		.22 (.06)***	.18 (.07)*	.18 (.07)**
Attainment value		.23 (.04)***	.23 (.04)***	.23 (.04)**
Utility value		.01 (.04)	.01 (.04)	.01 (.04)
Low cost		.22 (.04)***	.12 (.05)*	.13 (.06)*
Global value		.23 (.04)***	· · /	.02 (.09)

p < .10. p < .05. p < .01. p < .001.

self-reported effort, and teacher-rated engagement. We began with the evaluation of a CFA model (Model B1) in which the second-order bi-factor structure of the value components was incorporated with self-concept and the three outcomes. This model fitted the data well (e.g., CFI= .942; TLI= .935). It should be noted that the bi-factor second-order model was applied only to the set of 37 items assessing all value facets. Thus, in Model B1, self-concept is allowed to correlate with the four value components as well as with the global value, whereas the value components are orthogonal to each other and to the global value. Next, we evaluated a series of SEM models (Models C1 through C4). In each of the models considered here, we included all variables, noting that a model with all variables simply correlated is equivalent (in terms of degrees of freedom and goodness of fit) to a model where some of the correlations are represented as path coefficients. Thus, for example, in a preliminary model (Model C1; see Table 4), relations among self-concept and the three outcomes were represented by paths, whereas all other relations were represented as correlations. In the subsequent model, additional correlations were represented by appropriate paths in the SEM. Using this approach, all the different models incorporated the same variables and resulted in the same model fit. This strategy had important advantages for the comparison of models based on different sets of variables that potentially

confound aspects of the measurement and structural models (see Marsh et al., 2015, for further discussion).

As seen in Table 4, self-concept substantially predicted selfrated effort, teacher-rated engagement, and in particular, academic achievement, without controlling for value beliefs (β = .32, .36, and .53, respectively; see Model C1). Model C2, in which the four value components were considered along with the global value, intrinsic value, low cost, and global values consistently predicted the three outcomes (β = .15 to .25, .08 to .26, and .23 to .38, respectively). Attainment value had positive predictive effects on engagement (β = .23) and, in particular, on effort (β = .58) but not on achievement. However, the predictive effects of utility value were nonsignificant for each of the outcomes considered here after controlling for the global value.

The sizes of the path coefficients involving self-concept were not altered when the four value components were also considered as predictors excluding global value (see Model C3). However, the predictive effects of intrinsic value and low cost became substantially smaller and even nonsignificant. Finally, in the extended SEM model (Model C4), we included predictive paths from global value to the three outcomes. The model results in similar patterns for achievement and engagement with Model C3. However, the predictive effect of self-concept on effort became nonsignificant. Instead, global value substantially predicted effort (β = .35) but not achievement and engagement. TABLE 5

Standardized Path Coefficients of Self-Concept, Value Components, and Their Interactions on Three Outcomes Based on the Second-Order Bi-Factor Model

Predictor	Model D1	Model D2	Model D3	Model D4	Model D5
Achievement					
Self-concept (SC)	.52 (.05)***	.52 (.05)***	.52 (.05)***	.52 (.05)***	.50 (.06)***
Intrinsic value (IV)	.02 (.06)	.01 (.10)	.00 (.06)	.01 (.06)	.05 (.06)
Attainment value (AV)	01 (.03)	02 (.04)	03 (.03)	02 (.03)	.01 (.03)
Utility value (UV)	.05 (.03)	.05 (.04)	.05 (.03)	.05 (.03)	06 (.03)
Low cost (LC)	.09 (.04)*	.09 (.04)*	.09 (.04)*	.09 (.04)*	.13 (.04)*
Global value (GV)	03 (.06)	03 (.07)	02 (.05)	03 (.05)	01 (.05)
$SC \times IV$		02 (.08)			
$SC \times AV$			04 (.02)		
$SC \times UV$				01 (.02)	
$SC \times LC$.10 (.03)**
$SC \times GV$.15 (.02)***	.15 (.03)***	.15 (.02)***	.15 (.02)***	.13 (.02)***
Self-reported effort					
SC	.03 (.12)	.05 (.14)	04 (.12)	.04 (.12)	.02 (.11)
IV	.25 (.07)***	.26 (.08)***	.25 (.07)***	.25 (.07)***	.23 (.07)***
AV	.57 (.04)***	.57 (.04)***	.58 (.04)***	.57 (.04)***	.57 (.04)***
UV	.04 (.03)	.04 (.03)	.04 (.03)	.04 (.03)	.03 (.03)
LC	.10 (.05)*	.10 (.05)*	.10 (.05)*	.10 (.05)*	.08 (.05) †
GV	.29 (.12)*	.28 (.13)*	.29 (.11)**	.29 (.11)**	.30 (.10)**
$SC \times IV$		02 (.06)			
$SC \times AV$.03 (.03)		
$SC \times UV$.03 (.03)	
$SC \times LC$.06 (.04)
$SC \times GV$.10 (.03)***	.11 (.03)***	.10 (.03)***	.10 (.03)***	.11 (.03)***
Teacher-rated engagement					
SC	.31 (.10)*	.32 (.11)**	.31 (.10)**	.31 (.10)**	.30 (.10)***
IV	.16 (.07)*	.16 (.07)*	.15 (.06)*	.16 (.06)*	.17 (.07)*
AV	.21 (.04)***	.21 (.04)***	.21 (.04)***	.21 (.04)***	.22 (.04)***
UV	.01 (.04)	.01 (.04)	.01 (.03)	.01 (.04)	.01 (.04)
LC	.12 (.05)*	.12 (.06)*	.12 (.05)*	.12 (.05)*	.13 (.05)*
GV	01 (.09)	02 (.09)	01 (.08)	01 (.08)	01 (.08)
$SC \times IV$.01 (.05)			
$SC \times AV$			02 (.03)		
SC imes UV				.01 (.03)	
$SC \times LC$.02 (.03)
$SC \times GV$.05 (.02)*	.05 (.02)*	.05 (.02)*	.05 (.02)*	.05 (.02)*

 $\label{eq:posterior} \begin{tabular}{ll} & & & \\ \end{tabular} p < .05. \end{tabular} *p < .01. \end{tabular} *p < .001. \end{tabular}$

In summary, self-concept was more predictive of achievement, whereas value beliefs were more predictive of selfrated effort. However, self-concept and value beliefs had similar predictive effects on teacher-rated engagement. More importantly, after partialing out the global value, the findings showed differential patterns of predictive relations to the three outcomes for the different value components. Math achievement was more associated with low cost, whereas self-rated effort was more associated with attainment value. Intrinsic value, attainment value, and low cost had uniquely predictive power on teacher-reported engagement. However, utility value did not make a unique contribution in predicting the three outcomes.

Predictive Effects of Self-Concept and Value Beliefs

To probe the interactive roles of self-concept and value beliefs, we first added the interaction between self-concept 1.0

0.0

-0.5

-1.0

Achievement (SD) 0.5

1.0 0.5 0.0 Outcome (SD) -0.5 -1.0 1.0



Self-reported effort (SU)

.5

FIGURE 2. Response surface displays for the multiplicative effect of self-concept and task value on the three outcomes.

and global value along with all the predictive effects of the four value components (see Model D1 in Table 5). We found that the interaction model provided lower AIC and BIC than that without interaction (Model D1 vs. Model C1; $\Delta AIC =$ 211; $\Delta BIC = 227$; $\Delta adjust-BIC = 218$). Both models showed similar patterns of path coefficients for the first-order effects. To enhance the presentation, we provide graphical depictions of the interaction effects (3-D response surface displays; Myers, Montgomery, & Anderson-Cook, 2009; see Figure 2) using the RSA package (Schönbrodt, 2015) in R (R Core Team, 2013). As is generally the case with interaction effects, researchers are encouraged to plot the interactions in order to better understand their nature. The type of 3-D plot presented here has the added advantage of showing a scatter plot, which allows researchers to evaluate the range of values under consideration. This is useful because the nature of the interaction might not be relevant for very extreme values outside of the range of values actually observed.

The results showed that the interaction between selfconcept and global value positively predicted achievement

12

 $(\beta = .15)$. The simple slope in Figure 2A shows that the effects of self-concept on achievement are positive for all levels of global value, whereas the sizes of this positive simple effect vary substantially as a function of attainment value. More specifically, two latent observations of each student are represented on the surface display as one point; the circle on the surface contains at most 50% of the data points. The color of the surface indicates the level of achievement (from dark red to dark green, indicating -1 SD to +1 SD achievement), which is useful to identify the gradient of the regression line. For instance, the regression line of self-concept is relatively flat at -1.5 SD global value, increasing in steepness with incremental global value, and very steep at +1.5 SD global value. In other words, the effect of self-concept is moderated by global value: weaker with low value and substantially stronger with high value. Figure 2A also demonstrates that the simple effects of global value varied as a function of self-concept. The higher the self-concept, the more the global value contributes to increasing achievement. This finding

supports a synergistic relationship between self-concept and value in predicting achievement. It should be noted that slightly negative slopes for the effect of global value on achievement are evident when self-concept is very low (e.g., -1.5 SD self-concept).

For self-reported effort, the interaction effect between self-concept and global value was statistically significant (β =.10). The positive multiplicative relation between self-concept and global value (Figure 2B) indicates that the simple slope for the effect of self-concept on effort is relatively small when global value is low (-1.5 *SD*) and becomes more positive when global value is high (+1.5 *SD*). Figure 2C reveals a similar pattern of interaction between self-concept and global value for teacher-rated engagement, but the pattern is somewhat smaller (β =.05) compared to that for achievement.

Subsequently, we added interactions between self-concept and each value component to predict the three outcomes. In this case, we examined only interaction effects between self-concept and one value component at a time, in addition to self-concept-by-global value interaction (Models D2 through D5). However, only path coefficients from interactions between self-concept and low cost to achievement were statistically significant ($\beta = .10$; see Figure 2D). The inclusion of additional interaction between self-concept and specific value components did not alter the pattern of results (see Table 5).

In summary, the interactions between self-concept and global value were consistently found to be significant and positive, thus providing support for synergistic relationships in predicting the three outcomes. However, controlling for interaction between self-concept and global value, interaction between self-concept and specific value components did not have additional predictive power except for self-concept-by-low cost interaction on achievement.

Discussion

The current study is the first to evaluate the unique contributions of self-concept and the four math value components on academic achievement, self-rated effort, and teacherreported engagement. In line with a priori predictions, math self-concept proved to be a relatively important predictor of math achievement, whereas value components were more strongly associated with self-reported effort. We extended past research on the application of modern EVT by linking motivation beliefs to teacher-reported outcomes, and the findings indicate that self-concept and value beliefs emerged as equally important predictors of academic engagement assessed by teacher. More importantly, as expected, different value components have differential contributions to the prediction of the outcomes, particularly for effort and engagement, over and above the global value factor. Furthermore, we provided empirical evidence supporting synergistic

Expectancy-Value Interaction and Unique Prediction

interactions between self-concept and value in predicting the achievement-related outcomes; this is consistent with modern EVT.

Unique Contributions of the Four Value Components and Self-Concept

Controlling for self-concept and the global value factor, only one of the specific value beliefs-low cost-significantly predicted math achievement. For self-reported effort and teacher-rated engagement, the predictive effects of the four value factors differed substantially, thus supporting their discriminant validity. Consistent with our expectations. intrinsic value and low cost made unique contributions in predicting engagement and effort. Interestingly, attainment value plays a more important role in promoting students' effort, over and above the global value factor. Indeed, modern EVT places great emphasis on the roles of both personal and social identities that underlie attainment value over the last decade (Eccles, 2009, 2011). Attainment value, relating to how well the task helps students manifest their personal needs and both their personal and their social identities, becomes more salient for engagement by older students, who have better-articulated identities (Eccles & Wang, 2012). However, utility value did not have unique predictive power on the three outcomes. One potential explanation is that utility value, referring to how useful a task is for fulfilling students' various short- and long-term goals, may be more directly related to course work choices and enrollment intentions (Eccles et al., 1999; Eccles, Vida, & Barber, 2004; Guo, Parker, et al., 2015) as well as educational and career aspirations (Durik et al., 2006; Watt et al., 2006, 2012). These distinct patterns of results provide strong support for the conceptual differentiation of task value components.

In contrast to self-rated effort, self-concept makes a significant contribution to the prediction of teacher-reported engagement, controlling for task values. One reason might be that teacher-rated behavioral engagement is inherently confounded by the teachers' knowledge of students' achievement, which is in turn highly associated with students' selfconcept. Indeed, previous research has demonstrated that teachers appear to use students' performance- and abilitybased information to inform their inferences of engagement (Givvin, Stipek, Salmon, & MacGyvers, 2001; Lee & Reeve, 2012; Skinner et al., 2008). However, it is important to keep in mind that students' prior achievement most likely also affects students' perceptions and, consequently, their behavior. Thus, these possible confounding effects should be further investigated in future research.

The Nature of the Multiplicative Relation

In this section we more carefully evaluate what constitutes support for EVT when there is an expectancy-by-value



FIGURE 3. Response surface display for synergistic and compensatory relations between academic self-concept and task value, based on the hypothetical results. In regression equations containing an interaction term, simple slopes of simple regression equations, and the status and interpretation of interaction (ordinal vs. disordinal), are unaffected by additive scales transformation. Thus, the hypothetical plots presented in this section were independent of scaling (uncentered vs. centered; see Appendix E in the supplemental materials for more discussion); it is important to note that the interactions in which two predictors (i.e., academic self-concept and task value) and the outcome variable (i.e., achievement-related performance and choices) are considered as continuous latent variables. Only the linear effects of both predictors are included in the hypothetical regression equations. ASC = academic self-concept.

interaction, clarify some apparent misconceptions in the recent literature, and address these clarifications in relation to the results of the present investigation. To do this, we provide a series of graphs of paradigmatic outcomes based on hypothetical results—purely synergistic or compensatory interactions with no first-order effects, or combinations of positive first-order effects and various forms of expectancy-by-value interactions (see Figure 3). These graphs and their interpretation in relation to EVT express certain complexities apparently not identified in previous research.

Even with relatively simple models, the interaction effects can be substantially different. Typically, synergistic and compensatory relations predict the interaction between two independent variables. The "pure" synergistic model (i.e., positive interaction effect) with no first-order effects indicates that individuals tend to choose and pursue a task only when both academic self-concept and task value are either high or low (Figure 3A). Conversely, the "pure" compensatory model (i.e., negative interaction effect) with no first-order effects indicates that to gain high achievementrelated outcomes, individuals need either high self-concept coupled with low task value or vice versa (Figure 3E). Likewise, synergistic and compensatory models with substantially smaller positive first-order effects are similar to the "pure" models, in that the simple effects of self-concept (and task value) are negative for some levels of task value (and self-concept; Figures 3B and 3F). We argue that these forms of interaction would not be in line with modern EVT. In particular, in contrast to suggestions by Nagengast et al. (2011) and Trautwein et al. (2012), neither a purely synergistic interaction (with no first-order effects) nor a result dominated by a synergistic interaction is consistent with EVT predictions. Nevertheless, it should be borne in mind that in empirical settings, interaction effects are typically small to moderate in size, resulting from the sparsity of cases in extreme conditions (e.g., high self-concept coupled with extremely low task value).

When the positive first-order effects are similar in size to or stronger than the interaction effect, the synergistic model shows that the outcome is especially high if individuals have high self-concept and task value. These findings align with modern EVT (see Figures 3C and 3D). Equivalently, this finding indicates that the simple effect of self-concept is stronger for individuals with higher task value and that the simple effect of self-concept is substantially weak when task value is extremely low and vice versa. In contrast, the corresponding compensatory model indicates that self-concept has a stronger positive simple effect of self-concept is substantially weaker when task value is extremely high and vice versa (see Figures 3G and 3H). In other words, this finding suggests that high self-concept can only partially compensate for low task value to achieve the outcome (and vice versa), particularly when the first-order effects are substantially larger than the interaction effect. These forms of compensatory interaction are also consistent with modern EVT. In sum, when the size of the first-order effects is similar to (or substantially stronger than) the interaction effect, both synergistic and compensatory interactions support modern EVT.

One of the central contributions of this study is its examination of the interaction effects of self-concept and task values in relation to the modern EVT model (Eccles, 2009). The results show the synergistic interaction between self-concept and global value, with stronger first-order effects on the three outcomes. These findings provide clear evidence for modern EVT predictions, suggesting that students tend to gain high math achievement, to exert great effort, and to be highly engaged only when both self-concept and task value are relatively high. Interestingly, in addition to self-conceptby-global-value interaction, a synergistic interaction is evident between self-concept and low cost for math achievement. This suggests that students with high math self-concept are unlikely to achieve academically if they ascribe a high level of task cost to math in terms of time, effort, and energy. This finding is in line with more recent empirical work on cost, which suggests that cost is better conceived of as a moderator variable for the relations between expectancy and achievement-related behaviors, compared to other value components (Barron & Hulleman, 2015; Flake et al., 2015).

In sum, the multiplicative relations between self-concept and task value for all three outcomes are consistent with our expectations and with modern EVT predictions, highlighting the importance of taking expectancy-by-value interaction into account in future EVT studies.²

Limitations, Strengths, and Implications

Some limitations should be considered when interpreting the results. First, we focused only on self-concept and task value in the domain of math in the present study. Further examination of the associations between motivation beliefs and achievement-related outcomes in other domains, across diverse national/international samples, would be useful for clarifying whether the current findings are replicable and reflect a generalizable EVT prediction, particularly for the multiplicative relation between self-concept and task values.

Second, teacher-rated engagement was measured by two items in this study: behavioral engagement in math lessons and homework. However, academic engagement has been assumed to be a multidimensional construct and in prior studies was usually assessed by multiple items (Wang, Willett, & Eccles, 2011). For example, engagement was conceptualized by three features: behavioral, emotional, and cognitive (Skinner et al., 2008; Wang & Eccles, 2013). Hence, further use of multidimensional measures of engagement would provide a more nuanced understanding of associations between motivational beliefs and these outcomes.

Third, as with previous studies (Nagengast et al., 2011; Trautwein et al., 2012), we used the measure of self-concept to address this substantive issue—expectancy-by-value interaction—with theoretical and practical implications. A worthwhile further study would be to tackle this issue on the basis of the measure of expectancies of success.

Fourth, to keep the length of the questionnaire in balance, only two items were used to measure two value facets: utility for school and utility for job. This resulted in low reliability (α = .52 and α = .68). Indeed, using short scales can undermine reliability as well as validity (see further discussion in Gaspard et al., 2015). However, in this study, we mainly focus on the major value components posited in modern EVT. If the focus of subsequent research were on the value facets, then the development of a more extensive instrument with more refined items measuring different value facets would be desirable.

Fifth, to evaluate the temporal ordering of the EVT constructs in relation to the achievement-related outcomes implicit in the present investigation, there is a need for carefully constructed longitudinal panel studies and, perhaps, for experimental interventions to better understand the causal mechanisms. Additionally, because the study was based on responses by Year 9 students in German academic-track schools, future studies evaluating the generalizability of the results to students who are younger, less able, in different school types, and from other countries are warranted. For example, it might be that younger, less able students in untracked systems have less well-defined and less differentiated values in relation to mathematics.

Finally, although the global value factor and the specific value factors (i.e., the four value components) are well defined in the second-order bi-factor model, the factor loadings of some value items on the global value are substantially higher than those on the specific value facets. This indicates that the global, overarching value factor may capture the essence of specific value facets, which would lead to the value components losing predictive power on educational outcomes. Thus, it is important to replicate and extend future research to evaluate factor structure of value beliefs using bi-factor models.

Despite these limitations, this study makes significant contributions to the existing research in a number of ways. First, this study expands our understanding of the interplay between self-concept and value beliefs in predicting academic behaviors and provides a heuristic guide for future research and for intervention design. This finding of a synergistic relation between self-concept and value beliefs implies that isolated interventions that aim at strengthening one component would be less effective at promoting academic

Guo et al.

performance, effort, and engagement. Rather, interventions targeting the promotion of educational outcomes should seek to enhance both self-concept and value beliefs. Second, examining the unique contribution of each value component advances our understanding of what value components lead to gains in achievement, effort, and engagement. Importantly, the distinctive patterns of value components in relation to academic outcomes provide more specific suggestions for intervention strategies. For example, perceived math attainment was more highly associated with students' effort, compared to other value components. Our findings also have the potential to contribute to the design of more specifically targeted and nuanced student engagement programs. Furthermore, the inclusion and distinguishing of selfreported and teacher-rated effort enabled us to identify differences in the pattern of predictions for these two outcomes. Different patterns of results for student-rated effort and teacher-reported engagement in our study also suggest the importance of assessing both student and teacher perceptions to better understand actual levels of student academic effort and engagement. In conclusion, we have provided a comprehensive picture illuminating the differential roles of motivational beliefs and their interaction with self-concept in predicting achievement-related behaviors. The findings underscore the importance of assessing the unique contribution of value beliefs and self-concept-by-value interaction, which was much less emphasized in modern EVT.

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Notes

1. The first-order bi-factor confirmatory factor analysis model (FO-B-4V), in which the factors represented one global value and four first-order value components while ignoring the value facets level, did not yield a satisfactory fit (e.g., comparative fit index = .895; Tucker-Lewis index = .880). The results again support the differentiation of value components into distinct facets.

2. We note that inspection of Figure 2A suggests that global value has a negative simple effect on achievement when self-concept is very low. However, the simple slope test (Aiken & West, 1991; Cohen, Cohen, West, & Aiken, 2003) indicates that the simple effect of global value on achievement was not statistically significant for self-concept of -1.5 SD below the mean ($\beta = -.166$, SE = .121, p > .05). Thus, the plot of self-concept-by-global-value interaction on achievement (Figure 2A) is a special case of the hypothetical model (Figure 3D), in which self-concept is a dominant predictor.

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Guo et al.

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For the last three decades, research based on expectancy-value theory (EVT) has been successful in explaining how expectancies and task values influence diverse achievement-related outcomes, such as performance and choices in different subject domains (Eccles, 2009; Eccles & Wigfield, 2002). Despite the fact that research on task values has increased, it still lags far behind research on expectancy-related beliefs (e.g., academic self-concept [ASC]) (Wigfield et al., 2009). The aim of this thesis was to provide a comprehensive test of EVT and its integration with ASC theory, particularly testing the combined effects of ASC, value beliefs and their interactions on diverse achievement-related outcomes. To this end, five empirical studies (see Table 9.1) using combinations of cross-sectional and longitudinal data based on nationally representative samples were conducted as part of this thesis. First, the findings of the five empirical studies were summarised and discussed within the EVT broader research context. Second, some strengths, limitations and directions for future research were addressed. Finally, implications for educational policy and practice were elaborated. **Summary of Findings: Studies 1 to 5**

Study 1. Study 1 examined the relations among student background variables (SES and gender), maths motivation (ASC and value), and maths achievement and aspirations relying on three cohorts (1999, 2003, and 2007) from Hong Kong's TIMSS dataset. The results revealed that: (a) compensatory ASC-by-value interactions in which ASC was more important for students with lower utility values in predicting the outcomes; (b) motivational beliefs substantially mediated the relations between background variables and the outcomes; (c) the relationships among SES, motivational beliefs, and the outcomes were not substantially moderated by gender.

Study 2. Study 2 examined the directionality of the associations among cognitive assets (IQ, academic achievement), motivational beliefs (academic ASC, intrinsic value, and utility value), and educational and occupational aspirations over time from late adolescence (Grade 10) into early adulthood (five years post-high school) based on a nationally representative sample of U.S. boys (N = 2,213). The results revealed that: (a) ASC was a stronger predictor of achievement and aspirations than task values; (b) by integrating REM into EVT, ASC and intrinsic value had reciprocal effects with academic achievement, and significantly predicted educational attainment; (c) ASC in high school had stronger long-term indirect effects on future occupational aspirations and educational attainment than did task values and IQ; (d) motivational beliefs partially mediated the associations between prior

Study 3. Study 3 explored individual and gender differences in maths motivational beliefs as well as subsequent post-secondary choices based on a nationally representative sample of 15-year-old Australian youths (N = 10,370). The results revealed that: (a) both maths ASC and intrinsic value synergistically interacted in the prediction of advanced maths course selection, matriculation results, entrance into university, and the selection of STEM fields of study; (b) by integrating the I/E model into EVT, prior reading achievement had negative effects on advanced maths course selection and STEM fields of study that were mediated through maths-related motivational beliefs; and (c) gender differences in educational outcomes were mediated by gender differences in motivational beliefs and prior academic achievement, whereas the processes underlying choice of educational pathways were similar for males and females.

Study 4. Study 4 tested new predictions about how ASC and task value (intrinsic value and utility value) were related to students' achievement and coursework aspirations in relation to four science domains (physics, chemistry, earth science, and biology) based on nationally representative samples of 18,047 Grade 8 students from four OECD countries. The results revealed that: (a) ASC was a stronger predictor of achievement in the matching domain than value beliefs, whereas intrinsic value was a stronger predictor of aspirations than ASC; (b) the effects of achievement in one domain on ASC and intrinsic value were found to be highly domain specific, whereas those based on utility value were less domain specific (i.e., more highly correlated across multiple science domains); (c) by integrating DCT into EVT, achievement in each domain had a positive effect on ASC in the matching domain (e.g., paths from physics achievement to physics ASC), but a negative effect in contrasting domains (e.g., paths from physics achievement to biology ASC); (d) a similar pattern of results was found for the effects of ASC and intrinsic value on coursework aspirations (i.e., positive effects in matching domains, negative effects in contrasting domains); (e) distinctive, synergistic ASCby-value interactions contributed to the prediction of coursework aspirations across the four science domains; and (f) the results were consistent across the four OECD countries. providing support for the robustness and generalisability of the findings.

Study 5. Study 5 examined the unique contributions of the four major value beliefs and ASC on achievement, self-reported effort, and teacher-rated behavioural engagement in maths based on a nationally representative sample of German 9th grade students (N = 1,978).

¹ It should be noted that latent interactions between ASC and value were not included in the above paper (study 2), given that the journal editors and reviewers suggested that this issue would bring another complication to an already complex article. These additional results are reported in Appendix 2-F of the supplemental materials related to study 2.

Data analyses relied on a higher-order structure model of value beliefs using a newly developed multifaceted instrument. The results revealed that: (a) ASC was more predictive of achievement, whereas value beliefs were more predictive of self-rated efforts; (b) ASC and value beliefs were equally important predictors of teacher-reported engagement; (c) among the four value beliefs, achievement was more related to low cost, whereas effort was more related to attainment value; and (d) latent interactions between ASC and value beliefs synergistically predicted the three outcomes.

These five empirical studies are based on secondary data analyses of large scale nationally representative samples. Secondary data analysis is defined as re-using and repurposing initial datasets for solving new research questions and offering new insights into theory (e.g., Kum & Ahalt, 2013). Although the items used in the five studies might be initially designed to measure different motivational constructs, the analyses of these items allowed for the development of reliable and valid measures of ASC and value beliefs. In doing so, the generalisability of the results across countries and student cohorts, particularly for the unique and combined effects of ASC and value beliefs, could be clearly assessed and established. However, when comparing and contrasting the results across the five studies, it should be borne in mind that in different studies ASC and value beliefs were assessed by somewhat different items, even though they all possessed strong psychometric properties.

Discussion of General Findings

Unique predictions of ASC and value beliefs. Of particular importance in the thesis was that the five empirical studies considered multiple value components together with ASC to explore their unique contributions to the prediction of achievement-related outcomes (See Table 9.1 for the overview of the five studies). In particular, study 5 was the first to evaluate the unique roles that ASC and the four value components (intrinsic value, utility value, attainment value, and cost) played in predicting educational outcomes. Note that study 2 focused on the effects of general ASC and value beliefs on general academic outcomes, such as educational attainment and aspirations, whereas the other four studies drew on domain-specific ASC and value beliefs across multiple subject domains. In this section, therefore, I begin with a discussion of the findings in relation to domain-specific ASC and value beliefs, followed by those based on general academic motivation beliefs in study 2.

TIMSS (2007)

Moma (2014)

Study

1

2

3

4

5

	1						
Datasets (Date)	Participants	Subject	Value components	Outcomes	Covariates	Approach for interaction	Unique features
TIMSS (1999, 2003, 2007)	Hong Kong G8 (N = 13621)	Maths	Intrinsic (IV) Utility (UV)	Achievement General educational aspirations	Gender SES	LMS	a. Mediating role of motivation b. Gender and SES effects
YIT (1966–1974; post-high school transition)	U.S. boys (N = 2,213)	General	Intrinsic (IV) Utility (UV)	Achievement Educational aspirations Occupational aspirations Educational attainment	N/A	Unconstrained approach	a. Integration of REM into EVT b. Long-term indirect effects
LSAY (2003– 2013; post-high school transition)	Australian 15-year-olds (N = 10,370)	Maths	Intrinsic (IV) Utility (UV)	Tertiary Entrance Rank Maths course selection University entry STEM major selection	Gender SES School year	LMS	a. Integration of the I/E model and DCT into EVT b. Gender and SES effects

Achievement

N/A

Unconstrained

approach

LMS

Coursework aspirations

Maths achievement

Self-reported effort

Teacher-rated

engagement

Table 9.1 An overview of the five empirical studies conducted in this thesis

Physics,

Maths

chemistry,

earth science, biology

4 OECD countries

(N = 18,047)

German G9

(N = 1.978)

G8

Note. SES = socioeconomic status; LMS = the latent moderated structural equation approach; DCT = dimensional comparison theory; EVT = expectancyvalue theory; REM = reciprocal effects model; I/E model: internal/external frame-of-references model; TIMSS = Trends in International Mathematics and Science Study; YIT = Youth in Transition study; LSAY = Longitudinal Study of Australian Youth; Moma = Motivation in Mathematics project.

Intrinsic (IV)

Utility (UV)

components

4 value

a. Domain specificity for

power for the four values

b. Innovative bi-factor

model (based on multifaceted value instrument)

b. Integration of DCT

a. Unique predictive

ASC and value

into EVT

Domain-specific ASC and value beliefs. Consistent with a priori predictions, domainspecific ASCs considered in all but study 2 were consistently found to be stronger predictors of domain specific academic achievement, whereas value beliefs were more predictive of educational and coursework aspirations (studies 1, 3, 4 and 5, see Table 9.1). However, domain-specific ASC and value beliefs contributed equally to the prediction of academic choices, such as senior high school maths course selections, university entry, and postsecondary STEM major selections over and above prior achievement in terms of total effects, even though value beliefs were more directly associated with these choices (study 3). Another unique feature of the thesis was the juxtaposition of teacher-rated and self-reported outcomes in study 5. The results demonstrated that value beliefs were stronger predictors of selfreported academic effort, whereas ASC and value beliefs emerged as equally important predictors of academic behavioural engagement as assessed by teachers. Therefore, the thesis provided substantial evidence attesting that both ASC and value beliefs represent key determinants of achievement-related outcomes.

Unique predictions of domain-specific value beliefs. In accordance with modern EVT, different domain-specific value components played differential roles in predicting students' achievement-related behaviours. The results showed that intrinsic value was more directly associated with academic effort and engagement, whereas utility value was more directly associated with post-secondary academic choices, such as university entry and STEM major selection (studies 3 and 5). However, study 1 showed that utility value was more predictive of general educational aspirations than intrinsic value, whereas in study 4 intrinsic value was more predictive of coursework aspirations in a particular domain than utility value. Theoretically, utility value refers to how useful a task is for facilitating an individual's long-range goals and helping an individual obtain long-range external rewards. High levels of educational aspirations are closely linked to adolescents' future occupation, later income, and life quality, which seem to be more highly associated with utility value than with intrinsic value. This finding was also in line with previous research (e.g., Watt et al., 2012).

Study 5 extended prior EVT research by capturing the multidimensional and hierarchical nature of value beliefs (e.g., utility value was formed by three facets: utility for school, daily life, and social life), which made it possible to extricate the unique contribution of the four major value components (intrinsic value, utility value, attainment value, and cost) to the prediction of achievement-related outcomes. More specifically, in study 5 an innovative approach (i.e., bi-factor second-order measurement model) was applied to separate a global (general) value from each of the four value components. The global value presented an overall sense of value students attach to different academic tasks, which might lead to high correlations among the four value components (see subsequent discussion regarding methodological contributions of the thesis).



Figure 9.1 Effect sizes of path coefficients for self-concept and value beliefs in predicting achievement-related outcomes across the five studies

Note. SC = self-concept; IV = intrinsic value; ACH = Achievement; Asp = Aspirations; Att = Attainment; Edu = Educational; TER = Tertiary Entrance Rank. Vertical dash lines indicate the value zero on the x-axis. Given that the effects of motivational beliefs on educational outcomes (e.g., educational achievement and career aspirations) are similar across waves in study 2, the effect sizes presented in this figure are based on averaged standardised path coefficients.

Given that attainment value has often been combined with utility value (also called importance value) (Simpkins et al, 2006; Watt et al., 2012) or with intrinsic value (Battle & Wigfield, 2003) in previous EVT research, study 5 was one of the first to consider attainment value along with other value components to explore their unique predictive power. The results indicated that attainment value was an important predictor of students' academic engagement and, in particular, effort exertion (see Figure 9.1). Attainment value relates to how a given task or activity fits with one's personal identity (Eccles, 2009), and appeared to play a more salient role in students' engagement in secondary school, potentially because the emergence of more well-articulated personal identities would guide students to explore activities which were more directly linked to their identities (Eccles & Wang, 2012).

Cost, as the least researched value component (Wigfield & Cambria, 2010), has attracted growing attention in recent research literature (Barron & Hulleman, 2015; Perez et al., 2014). Consistent with this recent work, study 5 found cost to be a negative predictor of academic achievement and engagement while controlling for ASC and other value components. This provided empirical evidence that cost captured motivational dynamics that complemented competence beliefs and the positive valanced value components. Thus, for example, these negative psychological costs may lead the students to not devote their time and energy to a specific science subject, even when they have relatively high ASC and value beliefs in the specific science subject.

Given three out of the five empirical studies conducted in this thesis focused on domain-specific intrinsic value and utility value (studies 1, 3, and 4, see Table 9.1), it is interesting to compare these studies with study 5 where all four value components are considered. As noted earlier, utility value was found to be a significant predictor of all educational outcomes, particularly for coursework and major choices and educational aspirations, controlling for intrinsic value in studies 1, 3, and 4. However, utility value lost its predictive power when attainment value and cost were also taken into account in study 5. One possible theoretical explanation is that utility value, referring to how useful a task is for fulfilling students' various short- and long-term goals, is indeed more closely tied to educational choices, intentions, and aspirations than academic engagement and effort exertion (e.g., Eccles et al., 1999, 2004). More importantly, these findings suggest the need for caution in interpreting the findings of the EVT empirical studies while only considering one or two value components. It is imperative to include and differentiate all value components along with ASC in one single predictive model to disentangle relationships between each motivational belief (ASC and value beliefs) and achievement-related outcomes.

Unique predictions of general ASC and value beliefs. Study 2 examined the temporal process linking general academic motivational beliefs with educational and occupational outcomes, such as educational achievement, attainment, and aspirations, across the transition into early adulthood. This study extended previous ASC research (Marsh & O'Mara, 2008, 2010), and showed that ASC was a key determinant of educational achievement and attainment, even after controlling for IQ, prior achievement, and value beliefs. However, contrary to the findings based on domain-specific ASC and value beliefs, general ASC was also a stronger predictor of educational and occupational aspirations than value beliefs over time. It should be borne in mind that in study 2 the measure of general academic value beliefs was substantially different from the measures of domain-specific value beliefs used in the other studies. For instance, general academic intrinsic value was measured by multiple items

in relation to how interesting and enjoyable learning at school was and how satisfied students were with school in general, whereas domain-specific intrinsic value refers to the enjoyment students gain in a specific subject domain. General academic value beliefs may not play such a large role, as many youth know the importance of high attainment and high prestige occupations for their later income and life quality (to be productive citizens) and are more likely to have high educational and occupational aspirations when they expect to do well in specific school subjects.

Furthermore, study 2 was one of the few studies to explore the long-term indirect effects of cognitive and non-cognitive assets on educational attainment over an eight-year span. Given the remarkable stability of ASC during the post-high school transition, ASC coupled with high school achievement accounted for almost all of the association between IQ and educational attainment.

In summary, this thesis provided strong support for the proposition of modern EVT that different value components had differential predictive effects on achievement-related outcomes, by taking into account a broader range of outcome variables and multiple value components. The thesis also extended prior ASC research and demonstrated that ASC, in particular general ASC, played an important role in influencing not only educational achievement and long-term attainment but also choice behaviours, such as coursework selection and academic engagement.

Multiplicative relation between ASC and value beliefs. One of the central contributions of the thesis was the examination of the multiplicative relation between ASC and task value, which was the core proposition of classic EVT (Atkinson, 1957). More specifically, the thesis extended relatively few empirical studies on the ASC-by-value interaction (i.e., Trautwein et al., 2012; Nagengast et al., 2011) in several ways.

First, the thesis incorporated multiple value components when testing their interactive relations with ASC. When one ASC-by-value interaction (e.g., ASC-by-intrinsic value interaction or ASC-by-utility value interaction) was considered along with multiple domain-specific value components and ASC, the results consistently revealed that the interactions between ASC and task value significantly predicted achievement-related outcomes. It is worth noting that study 4, incorporating a more multidimensional perspective, tested ASC-by-value interactions for multiple science domains within the same model. Again, significant interaction effects between ASC and task value were consistently found across domains.

However, when domain-specific ASC-by-intrinsic value interaction and ASC-byutility value interaction were considered simultaneously, one of the two interactions lost predictive power on the outcomes (see Table 9.1). In contrast, the more parsimonious model

(in which the paths leading from both types of interactions to the outcome were constrained to be equal) was able to fit the data as well with a notable reduction in the size of the standard errors. This was further indicative of multicollinearity when the two interaction terms were considered as separate predictors (Marsh, Dowson, Pietsch, & Walker, 2004) (see further discussion in study 4). The results for this model indicated that both types of latent interaction positively predicted matching measures of aspirations, suggesting that they might make similar contributions to the prediction of the achievement-related outcomes.

These finding were also in line with study 5, in which specific value components did not significantly interact with ASC in predicting the outcomes (except for cost), while controlling for the ASC-by-global value interaction. These results indicated that the ASC-byvalue interaction might be characterised by an interactive relation based on the *overall* sense of value students attached to domain-specific tasks and ASC. Interestingly, in addition to ASC-by-global value interaction, a significant interaction was evident between ASC and cost. These results apparently reflect the fact that cost is the most distinctive of the various value components. This finding was also consistent with more recent empirical work on cost, which indicated that cost was better conceived as a moderator of the relations between ASC and educational outcomes compared to other value components (Barron & Hulleman, 2015; Flake et al., 2015).

Second, this thesis examined the longitudinal contributions of domain-specific ASCby-value to the predictions of long-term attainment and critical education choices during posthigh school transition. Study 3 provided longitudinal and strong evidence for the ASC-byvalue interactions in predicting the outcomes. In particular, the interaction effects of ASC and value beliefs on post-secondary educational choices (i.e., STEM major selections and university entry) were fully mediated through maths course selection and TER. In other words, the indirect effect of maths ASC on university entry and STEM major selection, via TER and maths course selection respectively, varied with the level of value beliefs.

Third, the thesis provided a more complete evaluation of the nature of expectancy-byvalue interactions in support of EVT, by juxtaposing the results of the five empirical studies and recent literature. Consistent with recent studies of ASC-by-value interactions (Nagengast et al., 2011; Trautwein et al., 2012), studies 3, 4, and 5 found a synergistic interaction between domain-specific ASC and value beliefs, coupled with strong and positive main effects, in predicting all achievement-related outcomes (see Table 9.1). This indicated that high performance and choices of coursework or a major in a particular subject domain was more likely to occur when students thought they exceled in the domain and valued it relatively highly. This empirical evidence was consistent with modern EVT. In contrast, study

1 showed a negative, compensatory relation between maths ASC and value beliefs in predicting maths achievement and educational aspirations. More specifically, the compensatory model indicated that task value had a stronger positive simple effect on the outcomes when ASC was lower; the simple effect of task value became weaker when ASC was extremely high and vice versa. In other words, ASC was more important for students with lower utility values in predicting the outcomes. However, it was noteworthy that both high ASC and high task value still led to higher outcomes, suggesting that high task value could only partially compensate for low ASC to achieve the outcomes. Thus, this form of compensatory interaction was also consistent with modern EVT. These findings imply that whether the ASC-by-value interactions supports modern EVT cannot be summarised by simply showing synergistic/compensatory interaction effects should always be based on a graph of the results. The thesis provides empirical and theoretical evidence that compensatory interactions are not necessarily inconsistent with EVT predictions (see study 5 for more details).

The results with respect to latent interaction based on domain-specific motivational beliefs were inconsistent with those based on general academic motivational beliefs. Study 2 found that general ASC did not significantly interact with either intrinsic value or utility value to predict general academic outcomes during post-high school transition, when two sets of product variables were included simultaneously (ASC-by-intrinsic value and ASC-by-utility value interactions). Nevertheless, supplemental analyses showed that when only the selfconcept-by-intrinsic value interaction was included, it positively predicted educational achievement and aspirations across time (averaged effects; M = .091 and .060 respectively, see Appendix 2-F in the supplementary materials), whereas the effects of this interaction on educational attainment and occupational aspirations were non-significant. However, none of the interaction effects was significant even when only ASC-by-utility value interactions were considered along with the main effects of ASC and value. These findings indicated relatively weak support for ASC-by-value interactions based on general academic motivational beliefs. The reason might be that students had more stable perceptions of their academic ability during late adolescence into early adulthood, and ASC was a predominant predictor of long-term educational and occupational outcomes. In contrast, general academic task value was less stable (averaged test-retest correlation: .375 for intrinsic value, .402 for utility value, and .779 for ASC) and played a smaller role in influencing long-term outcomes. This led to the loss of predictive power for the ASC-by-value interactions on the outcomes during post-high school transition.

In summary, the thesis provided cross-sectional and longitudinal evidence that domain-specific ASC and task value consistently interacted with each other to predict educational outcomes. Both the synergistic and compensatory interactions revealed in this thesis supported the modern EVT.

Integration of EVT and ASC theory. This thesis integrated three of the main theoretical models of ASC (domain specificity, REM, I/E model) into EVT, and examined how these models generalise to different components of task value with various achievement-related outcomes.

Domain specificity. Compared to ASC, the factor structure of task value had not been fully evaluated in relation to multiple dimensions and different subject domains, in particular within science domains. In this thesis, evidence was found for the high domain specificity of ASC and intrinsic value across maths, reading, and general science (in study 3) as well as across four science subjects (physics, chemistry, earth science, and biology, in study 4). The support for the domain specificity of utility value was much weaker, particularly across the four science disciplines. These findings indicated that students were able to differentiate different levels of ASC and interest across different academic subjects, whereas they were less likely able to distinguish clearly between the usefulness of subject domains. Indeed, utility or usefulness refers to how an activity relates to other plans the individual has, such as taking an advanced physics course in order to get a job in a physics-intensive field. Studies 3 and 4 focused on Grade 8, or 15-year-old students, whose initial sense of exactly what skills they will need later on in life in all likelihood is murky, particularly among the science domains (Wigfield et al., 2009). Hence, the utility value of the different science domains might be better differentiated among university students — particularly those majoring in different science subjects.

Reciprocal effect model (REM). Consistent with a priori expectations, the significant reciprocal effects between ASC and academic achievement were evident during post-high school transition (study 2). Although the reciprocal association between intrinsic motivation and academic achievement has been examined in the literature (e.g., Garon-Carrier et al., 2015; Marsh et al., 2005; Pinxten et al., 2014), these studies drew on either a short time period with only two time points or students in elementary school or early secondary school (i.e., Grade 7). These studies found relatively weak reciprocal effects between intrinsic value and achievement, but this pattern of results disappeared when ASC was included.

Study 2 was among the first to test the reciprocal effects between task value and achievement over a longer time span (eight years) during the critical transition into adulthood. Study 2 provided strong evidence for reciprocal effects between intrinsic value and
achievement, even controlling for ASC, utility value, and aspirations. The reason for these apparent differences across studies may be that in the early school years, the learning environment is highly structured and driven by school contingencies, such as mandatory schedules and learning exercises. This may lead to an unfavourable context for intrinsic value to influence subsequent learning behaviours. In contrast, intrinsic value may play a more important role in later school years when the learning environment becomes less structured (Köller et al., 2001).

However, there was no empirical evidence for reciprocal effects between utility value and achievement, controlling for the positive effects of ASC and intrinsic value. It is interesting to note that the supplemental analyses showed significant but relatively weak reciprocal effects for utility value and achievement when ASC and intrinsic value were not taken into account. One reason for the weak support for the REM in relation to utility value might be that, although high utility value could lead to high achievement and high achievement could lead to high utility value to some extent, students might become extrinsically motivated when receiving poor marks because teachers or parents introduce incentives, punishments, or other extrinsic contingencies in order to encourage better performance (Corpus, McClintic-Gilbert & Hayenga, 2009). Thus, this thesis provides good support for the REM in relation to ASC and intrinsic value, but not utility value.

I/E model and DCT. Modern EVT assumes that achievement-related choices are influenced by intraindividual hierarchies of expectancies and task value, and emphasises that it is important to examine the processes through which these intraindividual hierarchies develop across different subjects (Eccles, 2009). Studies 3 and 4 integrated the I/E model with its extension to DCT into modern EVT, and explored dimensional intra-individual comparisons (internal frame of reference) in relation to ASC, intrinsic value, and utility value.

Consistent with a priori predictions, our findings provided clear support for DCT, in that the paths from achievement to matching domain of ASC were substantially stronger than the cross-paths from achievement to non-matching domains of ASC. More specifically, in accordance with a priori verbal-mathematical continuum of academic domains, the contrast effects were evident between maths and reading (i.e., negative effects of achievement in reading on ASC in maths), whereas the assimilation effects were evident between maths and science in study 2 (i.e., positive effects of achievement in science on ASC in maths). When a narrower spectrum of the verbal-mathematical continuum that included only science subject domains was investigated (study 5), the contrast effects were evident between physics and biology which were separated by the greatest distance on the continuum. In addition, the assimilation effects were evident between chemistry

and biology. Furthermore, study 4 was the first to incorporate earth science into DCT and explore its location in the verbal-mathematical continuum. The assimilation effects between earth science and other science subjects suggest that earth science should be located between physics/chemistry and biology. Thus, these results provided new theoretical and substantive support to the I/E model and DCT.

With respect to value beliefs, the pattern of results in support of the I/E and DCT models was similar for ASC and intrinsic value. This finding indicated that when students perceived school subjects to be similar (e.g., physics vs. chemistry), intrinsic motivation in one domain was likely to generalise to the other domain, whereas when they perceived those subjects to be distinct (maths vs. reading and physics vs. biology), high achievement in one domain would lead to the waning of intrinsic value in the other domain. However, support for the a priori predictions posited in DCT in relation to utility value was relatively weak. The reason might be due to low domain specificity of utility value across academic domains, which have been found to be associated with weak support for the I/E model (Xu, 2010).

DCT and achievement-related behaviours. Consistent with previous research (e.g., Nagy et al., 2006; Parker et al, 2012; Parker, Nagy et al., 2014), intraindividual cross-domain comparisons proposed in DCT were useful for predicting achievement-related choices and aspirations. For instance, study 4 showed that high ASC and intrinsic value in the physics domain led to low coursework aspirations in biology, after controlling for physics ASC and ability. Students who had high confidence and interest in physics were less likely to aspire to engage in physics if they had even higher confidence and interest in biology. This suggests that choices and aspirations in one academic domain depend not only on abilities, ASC, and value beliefs in that domain, but also on relative abilities and motivation in other domains.

In summary, the thesis provided strong support for domain specificity, REM, and the I/E model with its extension to DCT in relation to ASC. The results generalised well to intrinsic value but relatively weakly to utility value.

Gender and family background (SES). The thesis investigated how gender and SES influence achievement-related outcomes through motivational beliefs, but also mapped how they moderated the relationships between EVT predictors and outcomes. Studies 1 and 3 provided a holistic view in order to accurately capture the influences of gender and family posited in modern EVT.

Gender. Consistent with a priori predictions, males reported higher levels of maths ASC, intrinsic value, and utility value. These gender differences in maths motivational beliefs partially mediated gender imbalance in maths-related behaviours, such as the selection of advanced maths course and STEM major (study 3). Similar indirect effects of gender through

motivational beliefs were also found in study 1. These findings suggest that boys are likely to have higher maths ASC and value beliefs, which leads to higher maths performance and a greater likelihood of enrolling in maths-related courses and majors. However, it was interesting to note that in study 1 girls tended to have higher maths achievement when girls and boys have similar levels of motivational beliefs (the direct path from gender to maths achievement controlling for movational beliefs). These direct effects were largely off-set by the corresponding indirect effects. Taken together therefore, there was no gender difference in maths achievement in terms of total effect.

With respect to the role of gender as a possible moderator, this thesis found that SES was more strongly linked to educational aspirations for males in study 1, and academic achievement was also more strongly associated with utility value for males in study 3. However, all other relations based on the hypothesised model did not vary as a function of gender. Given the relatively large sample size of both studies, the marginal effect sizes of gender-differentiated patterns indicated little evidence that any of the effects were substantially moderated by gender.

Despite maths-related motivation and choice behaviours in maths favouring males, females were favoured in terms of general educational aspirations at high school and of subsequent university enrolment (see study 1 and 3 for more details). These findings suggest that future research covering motivational beliefs in the range of the academic continuum and not just the maths-science end of it are needed.

SES. Consistent with a priori predictions and previous studies, SES positively predicted achievement-related outcomes partially through its positive association with ASC and value beliefs (Parker et al., 2012; Schoon & Polek, 2011). These results suggested that children from a socially and economically disadvantaged background tend to have low academic motivational beliefs, especially for maths and science, which in turn influences subsequent educational choices (Eccles, 2009).

In summary, aligning with modern EVT, ASC and value beliefs played important mediating roles between gender and SES, and achievement-related outcomes. Despite gender differences in the mean level of maths motivational beliefs and educational outcomes, gender did not largely moderate the relations between these factors.

The effects of gender and SES: From a cross-cultural perspective. EVT theorists (Wigfield & Eccles, 2002; Wigfield et al., 2009) claimed that the modern EVT was originally designed to explain a sociocultural phenomenon, in which cultural differences not only shape the way education is valued but also the way in which self-beliefs are constructed and encouraged. Thus, it is believed that the EVT model is particularly suited to a cultural

analysis of motivation and activity choices. However, in extant EVT research, the role of culture in students' motivational dynamics has often been neglected. Drawing on different cultural groups (Hong Kong, U. S., Australia, Germany, and four OECD European countries [Czech Republic, Hungary, Slovenia, and Sweden]), the results in this thesis provide strong support of the cross-cultural validity of the expectancy-value models. Positive ASC and high value beliefs were universally and positively associated with different kinds of academic engagement, choices, and achievement. These positive ASC and value beliefs played important mediation roles between gender and SES, and achievement-related outcomes.

However, several cross-cultural differences in the effects of gender and SES were evident between Hong Kong and Australia. It was interesting to note that SES was more substantially related to math utility value than intrinsic value based on Hong Kong students (study 1), whereas the relations to SES were similar for math intrinsic value and utility value based on Australian students (in study 3). A possible explanation might be that in cultures characterized as collective (e.g., Hong Kong) utility value may reflect not just the usefulness of the activity to the individual but also to one's larger social group (Wigfield, Tonks, & Eccles, 2004). And students tend to seek to maintain their parents' class status (avoid downward social mobility, Akerlof and Kranton, 2000). Thus, the Hong Kong students from affluent families are more likely to place greater importance on educational success that helps them fit into and contribute to their social group. Another possible explanation might be that in Hong Kong, an extremely competitive society, the parents from affluent family may have a deeper understanding of how important of educational success to achieve certain career goals. They therefore are likely to communicate these beliefs to their children.

In addition, the results showed that Australian girls had lower math utility value than boys while math was perceived as equally useful for boys and girls in Hong Kong. This may be due to different educational systems. In Hong Kong, math is a compulsory subject for students across secondary school and one of the main subjects in university entry examination, whereas in Australia, math is not so and most students choose to study math because it was prerequisite to certain university courses. Such differences would lead to Hong Kong girls valuing math heavily even though they were, on average, less interested in math than boys. These cross-cultural variations in socialization and gender-role processes underlying choice of educational pathways indicate that more comparative studies in more diverse setting are needed to advance our understanding of students' choice behaviours.

Strengths of This Thesis

This thesis made theoretical and methodological contributions to the existing research in a number of ways.

Theoretical contributions. First, drawing on a multidimensional perspective of value beliefs, the thesis provided new and additional support to modern EVT stating that different value components along with ASC uniquely contributed to the prediction of achievement-related outcomes. These results allow the gaining of novel insights about which aspects of value beliefs are most salient, and thus potentially most effective, in enhancing the different types of choices behaviours, particularly during crucial transition periods.

Second, the thesis probed multiplicative relations between ASC and value beliefs in predicting achievement-related outcomes, which was the core proposition of classic EVT but had rarely been addressed in empirical EVT research. Specifically, this thesis juxtaposed the ASC-by-value interaction and critical features posited in modern EVT, such as multiple value components, longitudinal predictions, and a large set of choice behaviours (see earlier discussion). The consistency of the significant multiplicative effects between domain-specific ASC and value beliefs across both cross-sectional and longitudinal studies considered in this thesis added further support for the robustness of the expectancy-by-value interaction and underscored the importance of taking it into account in future EVT studies.

Third, this thesis helped bridge gaps between large bodies of ASC and EVT research by integrating three of the main theoretical models of ASC (domain specificity, REM, I/E model) into EVT, providing new perspectives on each. Separately, constructs from each area have been shown to be important predictors of educational outcomes, in concert they hold the promise of providing a powerful and nuanced account of achievement-related outcomes. Specifically, the thesis extended the theoretical models to school subject domains including maths, reading, and science domains. In particular, the thesis included multiple science domains — such as physics, chemistry, earth science, and biology — which have been seldom included in previous ASC and EVT research. High domain specificity of motivational beliefs as well as their distinctive relationship with achievement-related outcomes contributed to evidence about the importance of differentiating and incorporating motivational beliefs across academic domains.

Multiple domain-specific motivational beliefs and educational outcomes also allow extending traditional tests of the I/E model and exploring theoretical predictions based on DCT. Our findings supported the I/E model to confirm that students receive information from two main sources to form their ASC: students systematically evaluate their abilities by comparing difference subject domains (internal/dimensional comparison process), and they

engage in social comparison with others as a way to judge their own abilities (external comparison process). More importantly, our findings supported the crucial assumption of DCT that student tend to make assimilating or contrasting dimensional comparisons, which varies contingent upon how they perceive similarity of two or more domains. By integrating the I/E model and DCT into EVT, the results suggested that the two main sources involving achievement/ability comparison also significantly influence the development of students' intrinsic value. However, the pattern of results for utility value was somewhat weaker. This finding indicates that the formation of utility value may rely on other sources, for example, cultural and parent subjective norms (Wigfield, Tonks, & Klauda, 2016). Put simply, parents who value math are likely to communicate these beliefs to children as a way for children to understand that math is important and useful, which can influence students' own valuing of math.

In addition, the thesis extended previous REM research and tested the reciprocal effects of motivational beliefs and achievement over critical development periods. The findings provided a better understanding of how to produce positive changes in achievement and motivational beliefs across the secondary–post-secondary nexus.

Methodological contributions. This thesis also possesses methodological strengths by using appropriate state-of-the-art statistical methodology. First, the thesis employed new SEM techniques, such as the LMS approach (Klein & Moosbrugger, 2000) and the unconstrained product indicator approach (Marsh et al., 2004), to model ASC-by-value interactions based on large samples. In both approaches the measurement error of the latent predictors is corrected and substantially reduced. This thesis also created more appropriate tests of indirect effects of continuous and dichotomous variable for interaction effects (i.e., mediated interaction effects). Thus, this thesis provided a series of reliable tests on ASC-byvalue interaction, which had only been sparsely addressed in the EVT literature due mainly to methodological limitations (e.g., Nagengast et al., 2011).

Second, all motivational constructs were measured by multiple items and possessed strong psychometric properties. In order to properly model common measurement variance controlling for item wording, the a priori correlated uniquenesses in relation to parallel and negatively worded items were also included.

In particular, a newly developed multifaceted instrument was utilised to capture the multidimensional and hierarchical nature of value beliefs in study 5. In this study, the very high correlations among the four value constructs led to issues of multicollinearity that have plagued previous research. In order to address this issue, an innovative higher-order bi-factor model was applied. In this model, the total covariance was partitioned into a global (general)

factor that reflected an overall sense of value task as well as four specific factors that reflected major value components. Of particular importance was that in the bi-factor model the four value components are specified as uncorrelated (orthogonal) to one another and with global value. This made the bi-factor model uniquely suited to addressing the challenge of detecting unique predictions of each value component and expectancy-by-value interaction, given moderate and high correlations among the four value components.

In summary, this thesis reintroduced a long-standing, substantively important issue — the omission of multiplicative relationships between expectancy and task value — and extended the integration of substantive theories in ASC research to EVT. The state-of-the-art research methods were used to tackle these complex issues. Therefore, this thesis represents substantive-methodological synergy, applying new and evolving methodology to address substantively important issues with theoretical and policy-practice implications for researchers in achievement motivation.

Limitations and Directions for Future Research

Several limitations to this thesis, and some caveats, must be noted. First, this thesis successfully integrated multiple theoretical models of ASC research into EVT and illustrate that these ASC models generalized well to intrinsic value, and a less extent, to utility value. However, the actual integration of ASC and EVT has yet to be fully tested. For example, bigfish-little-pond-effect [BFLPE] model, another critical theoretical model of ASC, posited the influence of social comparisons with students' scholastic reference group. It indicates that students within high achieving schools or classes develop a lower self-concept compared to equally achieving students who compare their individual achievement with a low achieving reference group. Parker et al. (2013) integrated the I/E model and BFLPE model and showed that social and dimensional comparisons influenced students' ASC independently of each other, indicating both comparisons served different sources of information upon which students can form their ASC. Relatively little empirical work, however, has examined BFLPE in relation to value beliefs, particularly across multiple domains in addition to math and verbal subjects (Trautwein, Lüdtke, Marsh, Köller, & Baumert, 2006; Schurtz, Pfost, Nagengast, & Artelt, 2014). Although beyond the scope of this thesis, a fuller integration of EVT and the BFLPE is clearly warranted.

Second, the formation of intraindividual hierarchies of ASCs and task values, which was one of the key elements of EVT and of the I/E model with its extension to DCT, was addressed in studies 3 and 4. However, neither of these studies additionally examined the influence of internal comparison processes in the development of students' motivational

beliefs. Although study 3 was based on longitudinal data, all achievement and motivational beliefs were based on a single wave of data. In particular, individual achievement and motivational belief from the same wave of data would potentially confound the temporal ordering of these variables (e.g., REM) and preclude tests of the stability of cross subject paths over time. Indeed, how students contrast different subjects is likely to vary as a function of age and year in school. For instance, university students, particularly for those majoring in science, would be more capable of distinguishing physical and biological sciences in terms of ASC and value beliefs than those in secondary school. Although beyond the scope of this thesis, it might be anticipated that domain specificity and support for the internal comparison (contrast) effects would increase with age and the extent to which the science courses are taught as separate subjects. However, longitudinal research with multiple points of measurement in relation to motivational beliefs, covering multiple age groups, school subjects and schooling systems would be useful to clarify this issue.

Third, although this thesis employed longitudinal data in study 3, and particularly in study 2 that allowed examining the temporal ordering of ASC and value beliefs in relation to the outcome variables theorised by EVT, it was still not possible to systematically assess whether the observed relations were causal in nature. There is a need for carefully constructed longitudinal panel studies and, perhaps, for experimental interventions to better understand the causal mechanisms underlying the associations between motivational beliefs and achievement-related outcomes, particularly for ASC-by-value interaction.

Fourth, this thesis took variable-centred approaches to study motivational beliefs in predicting achievement-related outcomes. Future studies could employ person-centred approaches (e.g., latent profile analysis) (Vermunt & Magidson, 2002) to examine how profiles of multidimensional motivational constructs influence students' educational pathways leading to different fields of study. Specifically, such techniques classify students into homogenous groups with similar profiles across motivational beliefs and subject domains, then relations between different established profiles and educational outcomes can be examined. For example, having high levels of ASC in physics, chemistry and biology, and ascribing a high value to them, could have a different impact on educational outcomes than high physics and chemistry ASC and value, coupled with a low level of biology motivation (Chow et al., 2012; Eccles, 2011). Relatedly, there is an implicit assumption in the extension of the I/E model to DCT that the underlying maths-verbal continuum posited by Marsh (1990) is consistent across all students — a variable-centred rationale. However, it is possible that the placement of different academic domains might vary from student to student, more consistent with the person-centred approach. Although beyond the scope of this thesis, there is need for

more research evaluating the extent to which the placement of academic domains along the continuum is consistent across students and how this influences tests of DCT (Marsh, Parker, & Craven, 2015; Möller, Streblow, & Pholmann, 2006).

Fifth, the thesis mainly focused on two value components (intrinsic value and utility value) out of the four value components (except for study 5). Given that different value components play differential roles in predicting achievement-related behaviors (Eccles, 2009) (also see study 5), future studies evaluating the generalisability of results across the four value components are warranted.

In addition, the motivational beliefs were only measured by student self-reports in this thesis. Although self-reports are an adequate means to assess students' subjective value beliefs (Wigfield & Cambria, 2010), future studies would benefit from considering alternative measures of the four value components, such as teacher reports, observation measures or student diary studies. The fine-grain analyses of the four value components would provide a more nuanced understanding of the relationships between motivational beliefs and achievement-related outcomes.

Finally, although domain-specific expectancy-by-value interactions have been consistently demonstrated across the empirical studies included in this thesis, different forms of interactions (synergistic vs. compensatory) were evident in different studies. Therefore, it is important to replicate and extend future research, to evaluate the generalisability of the results to students from different age groups, school types and countries. Relatedly, another avenue for future research is to explore unique contributions of ASC, value beliefs and their interactions on more distal outcomes in addition to achievement and choices, such as self-regulated learning strategies (Chueng & Pomerantz, 2015) and achievement goals (Goetz, Sticca, Pekrun, Kou, & Elliot, 2016).

Implications for Educational Policy and Practice

This thesis expanded previous research on EVT and ASC and provided a comprehensive examination of both theories and a heuristic guide for future research and intervention designs.

First, this thesis demonstrated distinctive patterns of relations between ASC and value components, and a variety of achievement-related outcomes. These findings provided more specific suggestions for intervention strategies. For instance, intrinsic value was more directly associated with academic effort and engagement, whereas utility value was more directly associated with post-secondary choices, such as STEM major selection and university entry. This information potentially contributes to design more specifically targeted and nuanced intervention on STEM retention.

More importantly, the significant multiplicative effects between ASC and value beliefs suggests that isolated interventions that aim at boosting either ASC or value beliefs would be less effective at promoting education outcomes. Rather, interventions should seek to enhance both ASC and value beliefs simultaneously. There were multidimensional education interventions, such as the Concept-Oriented Reading Instruction (CORI) intervention by Guthrie et al. (2000), the Motivation and Engagement Wheel by Martin (2008), and the Emotional and Cognitive Aspects of Learning intervention (ECOLE) by Gläser-Zikuda et al. (2005). These interventions targeted multiple aspects of the motivational processes, including self-efficacy and competence (ASC), and value beliefs. For example, the CORI intervention study helped to enable all students to experience success and enjoyment, and offered personalised reading activities that also promote students' attainment value in reading (Guthrie, Wigfield, & VonSecker, 2000). More specifically, the observed synergistic ASCby-value interactions in studies 2 to 5 suggest that both dimensions of ASC and value beliefs should be treated as equally important when the multidimensional intervention is applied. However, the compensatory interaction revealed in study 1 suggests that more attention is needed on strengthening ASC for students with a lower utility value.

Third, this thesis showed a high level of domain specificity for ASC and intrinsic value, but also, to a lesser extent, for utility value. Of particular relevance was that high domain specificity was evident for four science disciplines (i.e., physics, chemistry, earth science, and biology). These findings suggest that interventions targeting general academic, or even a general science, ASC and intrinsic value, might not be beneficial in promoting students' motivation in STEM areas. Indeed, students who have high overall intrinsic value might still have very low intrinsic value in a particular domain, which would lead to poor performance and opting out of that particular domain. Rather, intervention targeting domain-specific motivational beliefs has been shown to be more effective to enhance students' ASC and value beliefs (Hulleman & Harackiewicz, 2009; also see Harackiewicz et al., 2014, for a review), which is also in line with the results from this thesis.

Fourth, the REM in relation to ASC and intrinsic value implies that academic achievement, ASC, and intrinsic value are reciprocally related and mutually reinforcing. Improved ASC and intrinsic value would lead to higher achievement (a self-enhancement model), and improved achievement would lead to high ASC and intrinsic value (a skill development model). For example, interventions targeting a specific ASC domain, with the integration of self-enhancement and skill development, have been found to effectively promote ASC in that domain (O'Mara, Marsh, Craven, & Debus, 2006). However, if teachers boost students' ASC and intrinsic value without simultaneously promoting their academic

achievement in the same domain, then observed growth in ASC and intrinsic value might be ephemeral. Likewise, if teachers boost students' achievement without improving ASC and intrinsic value, the observed increase in achievement might not be longstanding. Thus, the reciprocal effects of ASC and intrinsic value with academic achievement shown in the results suggest that one of the most effective strategies is to improve both ASC and intrinsic value along with achievement simultaneously. However, teachers are not particularly effective at enhancing ASCs, particularly at the secondary level, where an increasing emphasis on getting good marks on standardised tests might not be supportive of positive ASCs (Marsh et al., in review).

Fifth, the thesis revealed contrasting relationships between maths and verbal domain as well as physics and biology for ASC and intrinsic value. It suggests that an intervention targeting ASC and interest in maths might lower ASC or interest in verbal domains. Such negative side effects have been found in a recent intervention study focusing on task value (Gaspard et al., 2015). Based on a large sample of German Grade 9 students, Gaspard et al. (2015b) showed that a maths intervention on utility value effectively promoted students' intrinsic value, attainment value, and utility value in maths, but it had a negative effect on values in German.

One way to resolve this dilemma might be to build connections between school subjects in curriculum development. It would help to foster and reinforce students' general ASC and motivation in learning across all academic subjects, rather than only in the few subjects in which they perform better (see Woolley, Rose, Orthner, Akos, & Jones-Sanpei, 2013). Furthermore, teachers and parents appear to perceive students' ASCs as domain-transcending, and believe that ASCs in different domains primarily depend on external comparison processes rather than on internal comparison processes (Marsh, 1993). More simply, if students are good at maths, they are also likely to be perceived as good in the verbal domain by teachers and parents. Thus, teachers and parents should be aware of the formation of ASC and value beliefs in relation to the process posited in the I/E model and DCT, and reinforce the complementarity of different subjects to undermine the negative contrast effects.

Conversely, the contrasting comparison between maths and reading as well as between physics and biology may be one of the critical factors contributing to substantial underrepresentation of women in the fields of physics, science, mathematics, engineering, and computer technology (hereafter PME) but not biological and medical sciences. Thus, if the ultimate goal is to engage females to pursue careers in the fields of PME, intervention targeting physics ASCs and intrinsic value would be beneficial for females. The assimilation effects on physics motivation as well as the contrast effects on biology affect intraindividual

comparison between physics and biology, which would help push students into PME fields (Eccles & Wang, 2015; Parker et al., 2012; Parker, Nagy et al., 2014).

Conclusion

In conclusion, this thesis offers five empirical studies to provide a rather comprehensive picture and to expand understanding of how ASC interact with task value to influence achievement-related outcomes. One important conclusion of this study is that to achieve high academic performance and pursue coursework in a particular subject domain, both ASC and value beliefs need to be relatively high in that domain. In addition, the thesis provided strong support for the theoretical claim that different value components and ASC have differential predictive effects on diverse achievement-related outcomes. In addition, by integration of ASC and EVT research, our findings contribute to evidence about the importance of differentiating and incorporating motivational beliefs across academic domains, and shed further light on the critical roles played by reciprocal effects and internal comparison processes in shaping education pathways to different fields of study.

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Supplemental Materials: Study 1

Appendix 1-A Hong Kong context

In Hong Kong, as a former British colony, schools have long adopted English as the medium of instruction (MOI). However, after the political handover, the Instruction Guidance for Secondary Schools policy was implemented in 1998 and imposed that all secondary schools adopt Chinese as the MOI. Although the Guidance allowed individual schools to apply for using English as MOI if they could get through the assessment of instructional efficacy, the numbers of English-MOI schools substantially decreased from around ninety percent to only a quarter of secondary schools (Tsang, 2004). Marsh and colleagues (Marsh, Hau, & Kong, 2000; 2002) demonstrated that the effects of using a second language MOI (English rather than Chinese) were somewhat positive on English proficiency but negative for academic achievement and self-concept relating other school subjects based on a large Hong Kong sample. However, these two studies were carried out before the change of sovereignty when schools could freely choose English or Chinese as MOI. Recent qualitative studies reported that in science lessons using a Chinese-MOI, abstract scientific concepts were easier to connect to real-life examples for teachers, which in turn had a positive influence on students' self-concept and enjoyment in science (Ng, Tsui, & Marton, 2001; Yip, Coyle, & Tsang, 2007).

Further, before the handover of sovereignty, the maths curriculum was a product of the late 70s, and there were no fundamental changes to the maths curriculum development until the Target Oriented Curriculum (TOC) was put on the agenda in 1998 (Wong & Tang, 2012). Based on TOC, new syllabuses for secondary maths were implemented in 1999 (Curriculum Development Council, 1999). Due to the influence of the Confucian Heritage Culture (CHC) and the achievement orientation of the Chinese culture, Hong Kong students' intrinsic motivation was dominated by extrinsic themes (e.g., studying hard to meet the expectations of their parents; Leung, 2006). As a result, rote memorization and meaningless over-drilling are often used in maths learning and even teaching (Wong, 1994). In the new maths curriculum, students' affect and confidence and high-order thinking abilities were the major concern through the application of new technologies, the enhancement of ability rather than skill, more attention to individual differences, etc. (for more discussion see Education Commission, 2000; Curriculum Development Council, 2001). In addition, a new information technology curriculum was applied in 1999. This new curriculum assumed that flexible modes of organizing study content might promote student positive attitude toward maths (Curriculum Development Council, 2001). Overall, the education environment was dramatically changed in

Supplemental Materials: Study 1

terms of implementation of new educational policies and curricula. These two substantially different education environments between before and after the handover of sovereignty provide an opportunity to test the robustness of the effects of expectancy and value on education outcomes.

With regard to gender differences in maths, a 2010 meta-analysis based on two major international datasets, the TIMSS 2003 and the PISA 2003, found that gender differences in maths achievement in Hong Kong students of 14-16 years of age were very small ($d = -0.03^2$ in TIMSS; d = 0.04 in PISA; (Else-Quest, et al., 2010). Nonetheless, boys reported more positive maths self-concept and affect in both datasets (d = 0.43 in TIMSS, d = 0.24 in PISA for self-concept; d = 0.19 in TIMSS, d = 0.12 in PISA for affect; (Else-Quest, et al., 2010). In addition, gender differences in educational attainment have substantially changed from 1997 to 2007. The percentage of girls enrolled in higher education programs at undergraduate level has steadily increased from 49.6% in 1997 to 53.0% in 2007 (Census and Statistics Department, 2007). Similarly, the proportion of girls enrolled in research postgraduate study underwent a notable increase—from 29.5% to 42.2%. Thus, by 2007, significantly more girls than boys were enrolled in university study (54.1% vs. 45.9%; Census and Statistics Department, 2007); this is in line with studies conducted in Western countries (OECD, 2007; Goldin, Katz, & Kuziemko, 2006). However, these crucial changes have received little attention in research of students' educational outcomes and aspiration.

²Positive values for*d* represent higher scores for males than females, whereas negative values represent higher scores for females.

Appendix 1-B

The result of Confirmatory Factor Analysis

Model	χ^2	df	RMSEA	CFI	TLI
2007:CFA	1526.877	283	.050	.969	.962
2003:CFA	1911.819	254	.051	.978	.974
1999:CFA	3193.741	499	.050	.927	.917

Table B1 Model Fit Statistics for the total-group CFA Models

Latent Variable	Factor loading	Item wording (Code)	Response code	Reliability
Mathematics	.881	I enjoy learning maths (MIV1)	1 (disagree a lot) to	
intrinsic value	.676	Maths is boring(MIVn2) ^a	4 (agree a lot)	.863
	.930	I like maths (MIV3)		
	.765	I usually do well in maths (MSC1)		
Maths self-	.531	Maths is more difficult for me than for other (MSCn2) ^a	1 (disagree a lot) to	.808
(MSC)	.639	Maths is not one of my strengths (MSCn3) ^a	4 (agree a lot)	
	.822	I learn things quickly in maths (MSC4)		
	.613	I think learning maths will help me in my daily life (MUV1)		
Maths utility value (MUV)	.614	I need to do well in maths to get into the university of my choice (MUV2)	1 (disagree a lot) to 4 (agree a lot)	.816
	.833	I need maths to learn other school subjects (MUV3)		
	.825	I need to do well in maths to get the job I want (MUV4)		
Family	.819	The highest level of education of your mother (SES1)	1 (noschool) to 7	
socioeconomic	.760	The highest level of education of your father (SES2)	(UIII)	.707
status (SES)	.580	About how many books were there in your home? (SES3)	(>200 books) to 5	
	.929	Algebra (BSMALG)		
Maths	.887	Data & Chance (BSMDAT)		058
achievement	.923	Number (BSMNUM)		.938
	.967	Geometry (BSMGEO)		
Educational aspirations (ASP)	.900	How far do you expect to go in school? (ASP1)	1 (finish <isced 3>);2 finish < ISCED 4 >;3 finish < ISCED 5b>; 4 finish < ISCED 5a, first degree>; 5 beyond < ISCED 5a, first degree>^b</isced 	.810

Table B2 A priori factor structure and reliability relating timss2007 items used in this study

Note.^aThese negatively worded items were reverse-scored. ^b ISCED 3: Upper secondary school; ISCED 4: Post-secondary non-tertiary education; ISCED 5: Tertiary education (first stage) includes tertiary programs with academic orientation (type A) or with an occupational orientation (type B).

Latent Variable	Factor loading	Item wording(Code)	Response code	Reliability
Maths intrinsic value (MIV)	.881	I enjoy learning maths (MIV1)	1 (disagree a lot) to 4 (agree a lot)	.776
	.743	I usually do well in maths (MSC1)		
Maths self-	.646	Maths is more difficult for me than for other (MSCn2) ^a	1 (disagree a lot) to 4	.786
concept (MSC)	.783	Maths is not one of my strengths (MSC3n) ^a	(agree a lot)	
	.803	I learn things quickly in maths (MSC4)		
	.621	I think learning maths will help me in my daily life (MUV1)		
Maths utility value (MUV)	.661	I need to do well in maths to get into the university of my choice (MUV2)	1 (disagree a lot) to 4 (agree a lot)	.772
	.721	I need maths to learn other school subjects (MUV3)		
	.707	I need to do well in maths to get the job I want (MUV4)		
Family	.786	The highest level of education of your mother (SES1)	1 (neached) to 7	
Socioeconomic	.772	The highest level of education of your father (SES2)	(Uni) : 1 (no books) to (Uni) : 1 (no books) to (S_{200})	.739
status (SES)	.555	About how many books were there in your home? (SES3)	5 (~200 000KS)	
	.918	Algebra (BSMALG)		
Matha	.856	Data & Probability (BSMDAT)		.958
achievement	.967	Fractions & Numbers (BSMNUM)		
	.919	Geometry (BSMGEO)		
	.946	Measurement (BSMMEA)		
Educational aspirations (ASP)	.900	How far do you expect to go in school? (ASP1)	1 (finish <isced 3>);2 finish < ISCED 4 >;3 finish < ISCED 5b>; 4 finish < ISCED 5a, first degree>; 5 beyond < ISCED 5a, first degree>^b</isced 	.810

Table B3 A priori factor structure and reliability relating timss2003 items used in this study

Note. ^aThese negatively worded items were reverse-scored. ^b ISCED 3: Upper secondary school; ISCED 4: Post-secondary non-tertiary education; ISCED 5: Tertiary education (first stage) includes tertiary programs with academic orientation (type A) or with an occupational orientation (type 5).

study

Latent Variable	Factor loading	Item wording(Code)	Response code	Reliability
	.829	I enjoy learning maths (MIV1)		
	.708	Maths is boring ^a (MIVn2)		
Maths intrinsic	.663	I like maths (MIV3)	1 (disagree a lot) to 1	.782
value (MIV)	.695	Maths is important to everyone's life (MIV4)	(agree a lot)	
	.667	I would like a job that involved using maths (MIV5)		
	.667	I would like maths much more if it were not so difficult ^a (MSCn1)		
Mothe solf	.740	Although I do my best, maths is more difficult for me than for others ^a (MSCn2)		
concept	.709	I am just not talented in maths ^a (MSCn3)	1 (disagree a lot) to 4 (agree a lot)	.772
(MSC)	.590	Sometimes when I do not understand a new topic initially, I know that I will never really understand it ^a (MSCn4)		
	.796	Maths is not one of my strengths ^a (MSCn5)		
	.680	I need to do well in maths to get the job I want (MUV1)		
Maths utility	.577	I need to do well in maths to please my parents (MUV2)	1 (disagree a lot) to 4	
value (MUV)	.792	I need to do well in maths to get into the school I prefer (MUV3)	(agree a lot)	.763
	.610	I need to do well in maths to please myself (MUV4)		
Family	.733	The highest level of education of your mother (SES1)	1 (noschool) to 7 (Uni):	
Socioeconomic status (SES)	.785	The highest level of education of your father (SES2)	1 (no books) to 5 (>200 books)	.740
status (SES)	.456	About how many books were there in your home (SES3)	oooks)	
	.769	Algebra (BSMALG)		
M = th =	.579	Data & Probability (BSMDAT)		
Maths	.826	Fraction & Number (BSMNUM)		.821
achievenient	.595	Geometry (BSMGEO)		
	.741	Measurement (BSMMEA)		
Educational aspirations (ASP)	.900	How far do you expect to go in school? (ASP1)	1 (finish <isced 3="">);2 finish < ISCED 4 >;3 finish < ISCED 5b>; 4 finish < ISCED 5a, first degree>; 5 beyond < ISCED 5a, first degree>^b</isced>	.810

Table B4 A priori factor structure and reliability relating timss1999 items used in this

Note.^aThese negatively worded items were reverse-scored. ^bISCED 3: Upper secondary school; ISCED 4: Post-secondary non-tertiary education; ISCED 5: Tertiary education (first stage), includes tertiary programs with academic orientation (type A) or with an occupational orientation (type 5).

Appendix 1-C

Calculation of effect size

The fixed-effects model was used to compute the weighted mean effect size and standard errors. Each effect size was weighted by the inverse variance of its standard error (see Hox, 2010; Lipsey & Wilson, 2001).

The inverse variance weight $w = 1/\text{standard error (SE)}^2$. Mean of effect size

$$\overline{ES} = \frac{\Sigma(w \times ES)}{\Sigma w}$$
. The standard error of the mean effect size $se_{\overline{ES}} = \sqrt{\frac{1}{\Sigma w}}$.

Appendix 1-D

Correlation matrix for the latent variables

Table D1 Estimated correlation matrix for the latent variables (mean effect size and standard error)

	MSC	MIV	MUV	SES	Gender	ACH	ASP
Motivati	on factors						
MSC	1.000						
MIV	0.772	1.000					
	(.019)						
MUV	0.361	0.435 (.021)	1.000				
	(.016)						
Backgro	und variables						
SES	0.095	0.068 (.015)	0.157 (.014)	1.000			
	(.016)						
gender	0.212	0.146 (.012)	0.040 (.013)	0.033 (.023)	1.000		
-	(.013)						
Outcom	e variables						
ACH	0.434	0.382 (.021)	0.205 (.018)	0.230 (.028)	022 (.023)	1.000	
	(.018)						
ASP	0.192	0.201 (.015)	0.358 (.016)	0.360 (.019)	086 (.017)	0.432 (.030)	1.000
	(.014)						

Note. Gender was coded 1 for female and 2 for male. All correlations greater than 0.04 or less than -0.04 are statistically significant (p<0.05).MSC = maths self-concept; MIV = maths intrinsic value; MUV = maths utility value; SES = socioeconomic status; ACH = maths achievement; ASP = educational aspiration.

	MSC	MIV	MUV	SES	gender	ACH	ASP
-			1999				
Motivation	n factors						
MSC	1.000						
MIV	0.762 (.044)	1.000					
MUV	0.358 (.021)	0.350 (.03)	1.000				
Backgrour	nd variables	. ,					
SES	0.087 (.027)	0.092 (.025)	0.173 (.023)	1.000			
Gender	0.149 (.024)	0.190 (.022)	0.032 (.020)	0.035 (.041)	1.000		
Outcome v	variables	× *		. ,			
ACH	0.474 (.049)	0.398 (0.04)	0.15 (0.025)	0.229 (.047)	.007 (.048)	1.000	
ASP	0.216 (.027)	0.209 (.026)	0.332 (.024)	0.354 (.031)	123 (.032)	0.480 (.058)	1.000
		· · ·	2003		· · · · · ·	· · · ·	
Motivation	n factors						
MSC	1.000						
MIV	0.782 (.026)	1.000					
MUV	0.355 (.031)	0.535 (.039)	1.000				
Backgrou	nd variables	~ /					
SES	0.083 (.024)	0.043 (.023)	0.138 (.02)	1.000			
Gender	0.238 (.022)	0.138 (.02)	0.049 (.023)	0.038 (.040)	1.000		
Outcome v	variables	× ,		× ,			
ACH	0.437 (.026)	0.368 (.033)	0.264 (.033)	0.207 (.047)	005 (.035)	1.000	
ASP	0.176 (.020)	0.199 (.024)	0.396 (.027)	0.343 (.033)	055 (.026)	0.395 (.050)	1.000
	~ ~ ~ ~	X /	2007	~ ~ /			
Motivation	n factors						
MSC	1.000						
MIV	0.768 (.034)	1.000					
MUV	0.377 (.038)	0.492 (.045)	1.000				
Backgrour	nd variables	× /					
SES	0.128 (.032)	0.079 (.033)	0.174 (.033)	1.000			
Gender	0.238 (.022)	0.109 (.023)	0.040 (.023)	0.027 (.041)	1.000		
Outcome v	variables	× /	、	、			
ACH	0.414 (.030)	0.387 (.037)	0.282 (.047)	0.257 (.05)	051 (.039)	1.000	
ASP	0.199 (.028)	0.195 (.027)	0.348 (.039)	0.390 (.038)	095 (.029)	0.432(.049)	1.000

Table D2 Estimated correlation matrix for the latent variables in different cohorts

Note. Gender was coded 1 for female and 2 for male. All correlations greater than 0.04 or less than -0.04 are statistically significant (p<0.05).MSC = maths self-concept; MIV = maths intrinsic value; MUV = maths utility value; SES = socioeconomic status; ACH = maths achievement; ASP = educational aspiration

Appendix 1-E

The link among background variables, motivational beliefs and outcome variable

As shown in Table E1 and E2, gender was a positive predictor of self-concept (M ES = .223, SE = .013), and intrinsic value (M ES = .138, SE = .013), while the direct path from gender to utility value was not statistically significant when SES was controlled. This finding indicates that boys tend to have high maths self-concept and intrinsic value rather than utility value, which is in line with previous studies in Western countries about gender stereotypes (Wigfield & Eccles, 2002; Watt et al., 2012). Align with prior research and EVT theory (Eccles, 2009; Nagy et al., 2006), gender had a predictive indirect effect on mathematic achievements through its influence on math self-concept and intrinsic value (see Table E1; M ES = .080, SE = .008). Interestingly however, this indirect path was largely off-set by the corresponding direct path (M ES = -.113, SE = .017). These findings suggest that boys are likely to have higher maths self-concept and intrinsic value —the direct path from gender. Taken together, there was no gender difference in math achievement in terms of total effect.

Similarly, the direct path from gender to aspirations was negative and significant (M ES = -.128, SE = .013), as opposed to a significantly positive, albeit weak, indirect path via both self-concept (M ES = .029, SE = .007) and utility value (M ES = .010, SE = .004). Nevertheless, the direct path favouring girls was only partially countered by the corresponding indirect path favouring boys. In total, educational aspirations favoured girls to a small extent. This finding is in line with our expectations and the recently observed change in gender difference on educational attainment, with the numbers of girls enrolled in university study exceeding that of boys (Census Statistics Department, 2007).

In addition, SES was a positive predictor of self-concept (M ES = .087, SE = .015), intrinsic value (M ES = .062, SE = .014) and especially utility value (M ES = .161, SE = .015), which indicates that students who lived in a high SES family were likely to have more positive motivation. More importantly, the indirect paths from SES to achievement and aspirations were also significant and positive, as positively mediated by both self-concept (M ES = .036, SE = .006 for achievement; M ES = .012, SE = .003 for aspiration) and utility value (M ES = .013, SE = .002 for achievement; M ES = .051, SE = .006 for aspiration), which was in line with our expectation. Also, our model showed that the direct path from SES to maths achievement (M ES = .178, SE = .021) and educational aspirations (M ES = .302, SE = .015) were moderate and positive. These findings support previous studies that SES positively predicts achievement-related behaviours, directly or indirectly by promoting self-

Supplemental Materials: Study 1

concept and subjective task values (Parker et al., 2012; Schoon & Polek, 2011). However, the relationships between gender, SES, and outcome variables were not mediated through intrinsic value, resulting from intrinsic value losing positively predictive power on achievement and aspiration.

Outcome variables		MSC	MIV	MUV	MSCxMIV	MSCxMUV
Math	1999	.454*(.070)	.029 (.066)	.083*(.031)	.012 (.017)	044*(.020)
achievement	2003	.433*(.044)	016 (.053)	.098*(.023)	.001 (.023)	061*(.024)
	2007	.316*(.043)	.101*(.044)	.074*(.032)	001 (.021)	062*(.022)
	Mean(SE)	.386*(.028)	.048 (.030)	.088*(.016)	.005 (.011)	055*(.013)
Educational	1999	.211*(.041)	094 (.059)	.313*(.027)	001 (.014)	084*(.023)
aspirations	2003	.112*(.046)	082 (.053)	.362*(.030)	.021 (.024)	035*(.012)
	2007	.113*(.044)	028 (.039)	.260*(.029)	.054*(.020)	074*(.024)
	Mean(SE)	.168*(.027)	055 (.029)	.311*(.017)	.018 (.010)	069*(.015)

Note. MSC = maths self-concept; MIV = maths intrinsic value; MUV = maths utility value; SES = socioeconomic status; ACH = maths achievement; ASP = educational aspiration. MSCxMIV = maths self-concept by intrinsic value interaction. MSCxMUV = maths self-concept by utility value interaction.

Predictor		MSC	MIV	MUV
Gender	1999 2003 2007 Mean(<i>SE</i>)	.144*(.037) .235*(.021) .235*(.020) .223*(.013)	.187*(.031) .137*(.019) .111*(.024) .138*(.013)	.025 (.019) .043*(.021) .035 (.021) .034 (.018)
Socioeconomic Status	1999 2003 2007 Mean(<i>SE</i>)	.083*(.026) .074*(.021) .123*(.032) .087*(.015)	.085* (.024) .038 (.021) .080*(.034) .062*(.014)	.172*(.024) .143*(.024) .174*(.032) .161*(0.015)

Table E2 The direct path from background variables to motivational beliefs

Note. MSC = maths self-concept; MIV = maths intrinsic value; MUV = maths utility value; SES = socioeconomic status; ACH = maths achievement; ASP = educational aspiration.

Appendix 1-F The moderation effect of gender

In order to test whether the relationships among SES, motivational beliefs and educational outcomes vary as a function of gender, we conducted multigroup analysis in which gender was treated as a grouping variable rather than a background covariate. As a precondition for comparing boys to girls, we first tested the invariance of the factor loadings in multigroup CFA models. After examining factor-loading invariance, every path was constrained to be equal in multigroup SEM models. In each cohort, the change in model fit between the unconstrained and loadings-invariant CFA model, as well as between the unconstrained (i.e., path-non-invariant) and path-invariant SEM model, were negligible (see Table F).

Nevertheless, given gender issue was of particular interest in this study, we conducted a series of post hoc analyses. We did find significant differences in the path from SES to educational aspirations. More specifically, SES was more strongly associated with aspirations for boys than for girls (gender differences in magnitude of the path coefficient: 2007 model: ES=.125, SE = .043; 2003 model: ES=.094, SE = .040; 1999 model: ES=.116, SE = .040). This finding indicates that family SES is more important for boys' educational aspiration. In family settings, parents provide boys and girls with different advice and information in regard to the importance of preparing to support their family (Eccles, 2011; Wiese & Freund, 2011). Although Hong Kong is seen to be influenced greatly by Western culture, it is more appropriately described as neo-Confucian (Lee, 1996), where parents and family are the basis of the cultural upbringing of Chinese children as emphasised by Confucian heritage (Phillipson & Phillipson, 2007). Typical of Confucian culture, males are likely to take more responsibility and have more commitment to providing financial support for their family. In other words, males who come from relatively disadvantaged backgrounds are more likely to leave school and devote to work early, which leads to having lower educational aspirations.

Taking together, we found one gender-differentiated pattern out of 11 cases. This finding indicates that boys have relatively higher math self-concept and intrinsic value, the relationships between these beliefs and maths achievement and educational aspirations were similar for both genders. In addition, SES plays a more important role for males in educational aspirations than females, while the relationships between SES and motivational beliefs did not significantly differ by gender.

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Model	χ^2	df	RMSEA	CFI	TLI
	2007	v			
CFA	1446.953	270	.050	.971	.962
CFA: factor loading invariance	1526.877	283	.050	.969	.962
SEM	1526.877	283	.050	.969	.962
SEM: path invariance	1533.002	294	.049	.969	.964
	2003				
CFA	1895.550	242	.052	.978	.972
CFA: factor loading invariance	1911.815	254	.051	.978	.974
SEM	1911.819	254	.051	.978	.974
SEM: path invariance	1924.453	265	.050	.978	.975
-	1999				
CFA	3154.944	432	.049	.927	.915
CFA: factor loading invariance	3182.586	449	.048	.927	.917
SEM	3193.741	449	.048	.927	.917
SEM: path invariance	3191.182	460	.048	.927	.920

Table F1 Model fit statistics for the multigroup CFA and SEM models

Appendix 1-H MPlus Syntax for Model

TITLE: SEM DATA: file is impute1.txt; TYPE = imputation; ! use multiple imputations to handle missing data

VARIABLE: NAME ARE IDSCHOOL IDCLASS GENDER SES1 SES2 SES3 MSC1 MSCn2 MSCn3 MSC4 MIV1 MIVn2 MIV3 MUV1 MUV2 MUV3 MUV4 HOUWGT BSMALG BSMDAT BSMNUM BSMGEO ASP1; MISSING=ALL(-9); !Missing value are identified by -9; WEIGHT = HOUWGT; !HOUWGT is the weighting variable in the TIMSS database CLUSTER=IDSCHOOL; !Observations are clustered within schools;

USEVARIABLES ARE GENDER SES1 SES2 SES3 MSC1 MSCn2 MSCn3 MSC4 MIV1 MIVn2 MIV3 MUV1 MUV2 MUV3 MUV4 BSMALG BSMDAT BSMNUM BSMGEO ASP1;

ANALYSIS: TYPE=COMPLEX RANDOM; !COMPLEX: Analysis takes nesting of students into schools into account; !RANDOM is necessary for the latent interaction effects modelled with LMS; ESTIMATOR=MLR; Algorithm = integration; !Integration statement is required for the LMS-analysis of latent interactions; processors = 2; DEFINE: standardise GENDER SES1 SES2 SES3 MSC1 MSCn2 MSCn3 MSC4 MIV1 MIVn2 MIV3 MUV1 MUV2 MUV3 MUV4 BSMALG BSMDAT BSMNUM BSMGEO ASP1; ! Standardise all of the variables we used

MODEL: ! definition of the measurement models ACH BY BSMALG@.929 BSMDAT BSMNUM BSMGEO; MIV BY MIV1@.749 MIVN2 MIV3; MSC BY MSC1@.611 MSCN2 MSCN3 MSC4; MUV BY MUV1@.450 MUV2-MUV4; ASP BY ASP1@.900; ASP1@.190; SES BY SES1@1.285 SES2-SES3; ! Fix factor variance to be 1. MSCN2 MSCN3 MIVN2 WITH MSCN2 MSCN3 MIVN2; ! Correlated uniquenesses for negatively worded items

MSCXMIV | MSC XWITH MIV; MSCXMUV | MSC XWITH MUV; ! Definition of the latent product variable using the XWITH-statement;

ACH ON MIV MSC MUV SES GENDER MSCXMIV MSCXMUV;

ASP ON MIV MSC MUV SES GENDER MSCXMIV MSCXMUV; MIV MSC MUV ON SES GENDER; ! Outcome is regressed on control variables, latent predictors and ! their latent interaction;

MIV MSC MUV WITH MIV MSC MUV; SES WITH GENDER; ACH WITH ASP; ! Control variables are free to correlate with latent predictors and with each other; OUTPUT: SAMPSTAT; ! Sample statistics are requested

Supplemental Materials: Study 2

Appendix 2-A

Latent Variable	Item number	Factor loading	Item wording(Code)	Response code
	T1V707	.677	How do you rate in school ability	
Academic self- concept	T1V1108	.789	How intelligent do you think you are, compared to others	1 (disagree a lot) to 4 (agree
(ASC1)	T1V1113	.514	How good a reader do you think you are, compared to others	a lot)
	T1V38	.692	Satisfied with school-learn what you want to know	1(not at all) to
Intrinsic value	T1V42	.571	Have an area of special interest in school	4(very much)
(INV1)	T1V43	.786	Enjoy school - learn interesting things	
	T1V585	.562	How interesting are most of your courses to you	1(very dull) to 5(very exciting)
	T1V313	.740	Is this a good thing to do: working hard to achieve academic honors	
Utility value (UV1)	T1V314	.742	Is this a good thing to do: striving to get the top grade-point average in the group	1(very bad) to 6 (very good)
(011)	T1V315	.792	Is this a good thing for people to do: studying hard to get good grades in school	(()) 2004)
A an domin solf	T2V635	.721	How do you rate in school ability compared to others	1 (discourses a
concept	T2V1097	.809	How intelligent do you think you are, compared to others	lot) to 4 (agree
(ASC2)	T2V1105	.548	How good a reader do you think you are, compared to others	a 101)
	T2V38	.692	Satisfied with school-learn what you want to know	1(not at all) to
Intrinsic value	T2V42	.605	Have an area of special interest in school	4(very much)
(INV2)	T2V43	.798	Enjoy school - learn interesting things	
	T2V504	.594	How interesting are most of your courses to you	1(very dull) to 5(very exciting)
	T2V313	.734	Is this a good thing to do: working hard to achieve academic honors	
Utility value (UV2)	T2V314	.712	Is this a good thing to do: striving to get the top grade-point average in the group	1(very bad) to 6 (very good)
	T2V315	.768	Is this a good thing to do: studying hard to get good grades in school	
Academic self- concept	T4V592	.716	How intelligent do you think you are, compared to others	1 (disagree a lot) to 4 (agree a lot)
(ASC4)	T4V600	.537	How good a reader do you think you are, compared to others	
Intrinsic value (INV4)	T4V394R		How interesting are most of your courses to you	1(very dull) to 5(very exciting)
	T4V313	.734	working hard to achieve academic honors	
Utility value (UV4)	T4V314	.712	striving to get the top grade-point average in the group	1(very bad) to 6 (very good)
	T4V315	.768	studying hard to get good grades in school	

 Table A1 Latent motivation construct and reliability relating youth in transition data used in

 this study

Appendix 2-B

Path Coefficients of Direct Effects and Standard Error from Three Models

	IQ	AchT1	ASC1	INV1	UV1	AchT2	ASC2	INV2	UV2	AchT3	ASC4	INV4	UV4	AttT4	R^2
Outcome															
ASC1	.338*	.488*													.393
(S.E.)	(.039)	(.037)													
INV1	066	.284*													.077
(S.E.)	(.035)	(.033)													
UV1	.113*	.286*													.113
(S.E.)	(.023)	(.030)													
AchT2	.005	.456*	.268*	.080*	.023										.500
(S.E.)	(.032)	(.034)	(.034)	(.026)	(.026)										
ASC2			.764 *			.174*									.747
(S.E.)			(.040)			(.032)									
INV2				.576 *		.145*									.500
(S.E.)				(.027)		(.024)									
UV2					.477*	.070*									.344
(S.E.)					(.032)	(.027)	0 (0.4	0.70*							100
Ach 13						.4/9*	$.260^{*}$	$.0/2^{*}$.020						.489
(S.E.)						(.031)	(.031)	(.028)	(.020)	001*					661
(SE)							(040)			(034)					.001
(\mathbf{D},\mathbf{L})							(.040)	228*		(.054)					308
(SE)								(044)		(026)					.308
UV4								()	517*	- 022					357
(S.E.)									(.034)	(.032)					.557
Λ ++Τ/									()	/08*					240
(S.E)										(.019)					.247
AttT5										()	217*	072*	- 036	647*	543
(S.E.)											(.029)	(.026)	(.028)	(.023)	.010

Table B1 Path coefficients of direct effects and standard error from the Model 1

Note. C.I. = 95% bootstrap percentile confidence interval All variables were given a label that identifies the Time (T1 to T5). IQ = intelligent test scores; ASC = academic self-concept; INV = intrinsic value; UV = utility value; Ach = educational achievement; Att = educational attainment; Oasp = occupational aspirations.

Outcome	IQ	ASC1	INV1	UV1	OaspT1	ASC2	INV2	UV2	OaspT2	EdaspT2	OaspT3	EdaspT3	ASC4	INV4	UV4	OaspT4	R^2
ASC1 (S.E.)	.310* (.034)																.098
INV1 (S.E.)	066 (.035)																.000
UV1 (S.E.)	.124* (.026)																.050
OaspT1 (S.E.)	.178* (.027)	.334* (.029)	.045 (.036)	.114* (.031)													.242
ASC2 (S.E.)		.752 * (.024)			.054 (.029)												.712
INV2 (S.E.)			.617 * (.026)		.057 (.027)												.460
UV2 (S.E.)				.505* (.044)	.037 (.027)												.339
OaspT2 (S.E.)					.522* (.027)	.265* (.024)	.048 (.028)	.029 (.031)									.437
EdaspT2 (S.E.)					.313* (.032)	.295* (.011)	.145* (.014)	.065* (.029)									.293
OaspT3 (S.E.)									.601* (.026)	.159* (.026)							.476
EdaspT3 (S.E.)									.306* (.021)	.460* (.018)							.451
ASC4 (S.E.)						.792* (.042)					020 (.039)	.049 (.043)					.652
INV4 (S.E.)							.342* (.048)				112* (.052)	.038 (.073)					.265
UV4 (S.E.)								.518* (.034)			080 (.045,)	065 (.041)					.356
OaspT4 (S.E.)											.468* (.036)	.215* (.034)	.116* (.031)	.027 (.040)	.040 (.025)		.488
OaspT5 (S.E.)																.331* (.026)	.107

Table B2 Path coefficients of direct effects and standard error from the Model 2

Note. S. E. = standard error. All variables were given a label that identifies the Time (T1 to T5). IQ = intelligent test scores; ASC = academic self-concept; INV = intrinsic value; UV = utility value; Ach = educational achievement; Att = educational attainment; Oasp = occupational aspirations; Eduasp = educational aspirations.

Outcome	IQ	AchT1	ASC1	INV1	UV1	OaspT1	AchT2	ASC2	INV2	UV2	OaspT2	EdaspT2	AchT3	OaspT3	EdaspT3	ASC4	INV4	UV4	AttT4	OaspT4	AttT5	R^2
ASC1 (SE)	.175*	.562*																				.394
INV1	066	.286*																				.077
(S.E.) UV1	(.038) .054*	(.028) .288*																				.113
(S.E.) AchT2	(.024) 051	(.025) 454*	270*	080*	102																	499
(S.E.)	(.032)	(.031)	(.034)	(.026)	(.026)																	
(S.E.)	.1/1* (.027)	.093* (.032)	.285* (.037)	.045 (.034)	(.031)																	.244
ASC2 (S.E.)			.756 * (.034)			.011 (.029)	.158* (.031)															.747
INV2 (SE)				.580 *		013 (026)	.150*															.505
UV2				(.020)	.467*	.010	.069*															.344
(S.E.) OaspT2					(.044)	(.028) .508*	(.028) .111*	.212*	.042	.028												.480
(S.E.) EdaspT2						(.025) 299*	(.031) 138*	(.030) 223*	(.030) 145*	(.027) 057*												361
(S.E.)						(.032)	(.032)	(.032)	(.034)	(.025)	0.6.4.*											470
(S.E.)							.4/6* (.031)	(.035)	(.029)	(.032)	(.031)	028 (.028)										.470
OaspT3 (S.E.)											.602* (.026)	.159* (.026)										.496
EdaspT3 (S.E.)											.311* (.029)	.460* (.030)										.470
ASC4 (SE)								.769* (042)					.056	010	.041							.671
INV4								()	.312*				.161*	133*	.024							.384
(S.E.) UV4									(.048)	.523*			022	080	058							.465
(S.E.) AttT4										(.034)			(.034) 271*	(.045,) 239*	(.040) .324*							431
(S.E.)													(.023)	(.029)	(.027)	110*	006	0.2.6	105*			
Oasp14 (S.E.)													.011 (.033)	.419* (.037)	.153* (.036)	.118* (.030)	.026 (.039)	.036 (.022)	.185* (.032)			.496
AttT5 (S.E.)																.182* (.034)	.062 (.051)	039 (.029)	.579* (.027)	.131* (.026)		.551
OaspT5 (S.E.)																				.162* (.030)	.294* (.027)	.161

Note. S. E. = standard error. All variables were given a label that identifies the Time (T1 to T5). IQ = intelligent test scores; ASC = academic self-concept; INV = intrinsic value; UV = utility value; Ach = educational achievement; Att = educational attainment; Oasp = occupational aspirations; Eduasp = educational aspirations.

		T : 0				TT' 1			T: 0	
		Time 0	1001	0.0.0		lime l	1.1.770	1000	Time2	
	IQ	Achill	ASCI	INVI	UVI	OaspT1	Ach12	ASC2	INV2	0V2
Outcome										
AchT2	.097 (.015) (.068, .126)	.180 (.019) (.141, .219)								
OaspT1	.085 (.016) (.056, .118)	.202 (.022) (.161, .243)								
ASC2	.279 (.020) (.240, .319)	.529 (.021) (.494, .564)	.046 (.012) (.023, .069)	.013 (.005) (.003, .023)	.005 (.006) (006, .015)					
INV2	027 (.022) (016, .016)	.258 (.023) (.218, .297)	.037 (.010) (.017, .057)	.011 (.004) (.003, .020)	.002 (.004) (008, .012)					
UV2	.063 (.014) (.038, .090)	.181 (.020) (.145, .217)	.021 (.010) (.003, .040)	.006 (.003) (.000, .012)	.003 (.003) (004, .009)					
OaspT2	.187 (.015) (.158, .216)	.342 (.018) (.310, .374)	.346(.028) (.296, .395)	.043(.026) (.001, .086)	.070 (.021) (.030, .110)	.003 (.007) (009, .014)	.038 (.009) (.021, .055)			
EdaspT2	.140 (.014) (.113, .167)	.341 (.016) (.312, .371)	.308 (.024) (.262, .353)	.113 (.023) (.073, .154)	.016 (.021) (.027, .196)	.001 (.009) (014, .016)	.061 (.011) (.041, .081)			
AchT3	.107 (.014) (.079, .125)	.454 (.021) (.419, .489)	.327 (.026) (.273, .380)	.077 (.022) (.034, .121)	.022 (.019) (015, .060)	.026 (.014) (003, .055)	.050 (.009) (.032, .069)	.007 (.007) (007, .021)	003 (.004) (012, .005)	.000 (.002) (004, .005)
OaspT3	.112 (.012) (.089, .135)	.260 (.014) (.233, .287)	.257 (.021) (.219, .295)	.044 (.018) (.014, .074)	.052 (.015) (.024, .080)	.355 (.020) (.316, .394)	.121 (.018) (.089, .153)	.163 (.021) (.122, .204)	.032 (.020) (003, .067)	.028 (.018) (006, .062)
EdaspT3	.130(.011) (.109, .151)	.263 (.016) (.237, .290)	.249 (.020) (.214, .284)	.066 (.016) (.037, .094)	.050 (.014) (.024, .076)	.297 (.021) (.260, .334)	.138 (.018) (.106, .170)	.168 (.021) (.128, .209)	.071 (.020) (.037, .105)	.036 (.017) (.002, .070)
ASC4	.224 (.019) (.187, .261)	.440 (.027) (.400, .480)	.643 (.035) (.583, .702)	.017 (.006) (.005, .029)	.006 (.006) (004, .017)	.019 (.026) (027, .064)	.156 (.030) (.101, .210)	.018 (.011) (005, .041)	.006 (.004) (002, .014)	.002 (.002) (003, .008)
INV4	007 (.012) (030, .016)	.125 (.024) (.074, .176)	.036 (.022) (012, .083)	.129 (.028) (.131, .254)	002 (.006) (014, .011)	040 (.028) (100, .021)	.119 (.023) (.073, .165)	.020 (.016) (014, .054)	.007 (.009) (009, .023)	.000 (.006) (012, .012)
UV4	.004 (.007) (013, .016)	.049 (.018) (.020, .077)	031 (.017) (052, .010)	006 (.004) (012, .000)	.238 (.026) (.193, .283)	041 (.025) (095, .013)	.007 (.023) (029, .042)	028 (.018) (063, .007)	008 (.006) (021, .005)	005 (.003) (011, .001)
AttT4	.082(.010) (.063, .101)	.270 (.014) (.243, .297)	.230 (.015) (.200, .261)	.053 (.012) (.030, .075)	.035 (.010) (.015, .055)	.118 (.014) (.162, .214)	.216 (.017) (.183, .249)	.157 (.015) (.127, .187)	.047 (.013) (.022, .072)	.023 (.013) (002, .049)
OaspT4	.091 (.011) (.070, .112)	.256 (.017) (.228, .285)	.264 (.022) (.223, .306)	.045 (.014) (.018, .072)	.045 (.012) (.022, .069)	.229 (.018) (.196, .261)	.134 (.014) (.108, .159)	.216 (.027) (.165, .266)	.04 (.019) (.006, .077)	.040 (.017) (.006, .075)
AttT5	.081 (.011) (.060, .102)	.276 (.016) (.245, .307)	.288 (.023) (.233, .333)	.052 (.014) (.026, .077)	.018(.011) (003, .039)	.141 (.014) (.116, .166)	.178 (.014) (.149, .207)	.264 (.028) (.210, .319)	.054 (.018) (.019, .089)	001 (.020) (037, .035)
OaspT5	.039 (.005) (.029, .048)	.123 (.010) (.104, .142)	.128 (.012) (.106, .150)	.023 (.006) (.012, .033)	.013 (.005) (.003, .022)	.079 (.009) (.063, .094)	.074 (.008) (.059, .089)	.113 (.013) (.089, .137)	.023 (.007) (.009, .036)	.006 (.008) (007, .020)

Appendix2-C Table C1 Path coefficients of indirect effects and standard error from Model 3

Outcome	OaspT2	EdaspT2	AchT3	OaspT3	EdaspT3	ASC4	INV4	UV4	AttT4	OaspT4
ASC4 (C. I.)	.010 (.023) (031, .015)	.016 (.017) (016, .048)								
INV4 (C. I.)	062 (.035) (139, .014)	015 (.041) (094, .065)								
UV4 (C. I.)	067 (.038) (139, .005)	039 (.021) (081, .004)								
AttT4 (C. I.)	.262 (.017) (.225, .298)	.179 (.020) (.142, .216)								
OaspT4 (C. I.)	.346 (.023) (.303, .389)	.170 (.020) (.133, .207)	.058 (.014) (.037, .084)	.037 (.010) (.015, .059)	.063 (.011) (.044, .087)					
AttT5 (C. I.)	.197 (.015) (.166, .229)	.129 (.015) (.101, .157)	.186 (.018) (.149, .223)	.191 (.021) (.148, .234)	.227 (.020) (.188, .266)	.015 (.005) (.006, .024)	.003 (.005) (008, .015)	.005 (.003) (002, .011)	.024 (.006) (.012, .036)	
OaspT5 (C. I.)	.114 (.011) (.093, .136)	.066 (.009) (.051, .081)	.065 (.008) (.048, .081)	.130 (.017) (.103, .158)	.102 (.011) (.082, .122)	.077 (.012) (.054, .100)	.024 (.014) (006, .035)	004 (.010) (023, .015)	.208 (.018) (.173, .242)	.039 (.008) (.021, .056)

Note. C.I. = 95% bootstrap percentile confidence interval All variables were given a label that identifies the Time (T1 to T5). IQ = intelligent test scores; ASC = academic self-concept; INV = intrinsic value; UV = utility value; Ach = educational achievement; Att = educational attainment; Oasp = occupational aspirations.

Appendix 2-D

Outcome	IQ	AchT1	ASC1	INV1	UV1	OaspT1	AchT2	ASC2	INV2	UV2
ASC1 (C. I.)	.175 (.026) (.165, .287)	.562 (.020) (.640, .795)								
INV1 (C. I.)	066 (.038) (120, .017)	.286 (.028) (.243, .353)								
UV1 (C.I.)	.054 (.024) (.003, .016)	.288 (.025) (.255, .350)								
AchT2 (C. I.)	.102 (.023) (.079, .148)	.635 (.022) (.597, .672)	.270 (.034) (.165, .262)	.080 (.026) (.024, .127)	.021 (.026) (031, .074)					
OaspT1 (C. I.)	.256 (.026) (.205, .308)	.295 (.025) (.254, .337)	.285 (.037) (.168, .271)	.045 (.034) (020, .098)	.102 (.031) (.038, .156)					
ASC2 (C. I.)	.279 (.020) (.240, .319)	.529 (.021) (.494, .564)	.802 (.026) (.757, .847)	.013 (.005) (.003, .023)	.005 (.006) (006, .015)	.011 (.029) (055, .082)	.158 (.031) (.134, .286)			
INV2 (C. I.)	027 (.022) (016, .016)	.258 (.023) (.218, .297)	.037 (.010) (.017, .057)	.591 (.027) (.539, .644)	.002 (.004) (008, .012)	013 (.026) (077, .045)	.150 (.026) (.104, .212)			
UV2 (C. I.)	.063 (.014) (.038, .090)	.181 (.020) (.145, .217)	.021 (.010) (.003, .040)	.006 (.003) (.000, .012)	.469 (.044) (.405, .533)	.010 (.028) (046, .064)	.069 (.028) (.020, .111)			
OaspT2	.187 (.015)	.342 (.018)	.346 (.028)	.043 (.026)	.070 (.021)	.511 (.025)	.149 (.027)	.212 (.030)	.042 (.030)	.028 (.027)
(C. I.)	(.158, .216)	(.310, .374)	(.296, .395)	(.001, .086)	(.030, .110)	(.465, .556)	(.102, .196)	(.115, .207)	(017, .101)	(.002, .081)
EdaspT2	.140 (.014)	.341 (.016)	.308 (.024)	.113 (.023)	.016 (.021)	.301 (.031)	.199 (.027)	.223 (.032)	.145 (.034)	.057 (.030)
(C. I.)	(.113, .167)	(.312, .374)	(.262, .353)	(.073, .154)	(.027, .096)	(.249, .352)	(.147, .250)	(.118, .215)	(.083, .195)	(.007, .117)
AchT3	.107 (.014)	.454 (.021)	.327 (.026)	.077 (.022)	.022 (.019)	.026 (.014)	.526 (.028)	.234 (.032)	.059 (.029)	.018 (.032)
(C. I.)	(.079, .125)	(.419, .489)	(.273, .380)	(.034, .121)	(015, .060)	(003, .055)	(.474, .579)	(.170, .299)	(.001, .117)	(039, .076)
OaspT3	.112 (.012)	.260 (.014)	.257 (.021)	.044 (.018)	.052 (.015)	.355 (.020)	.121 (.018)	.163 (.021)	.032 (.020)	.028 (.018)
(C. I.)	(.089, .135)	(.233, .287)	(.219, .295)	(.014, .074)	(.024, .080)	(.316, .394)	(.089, .153)	(.122, .204)	(003, .067)	(006, .062)
EdaspT3	.130(.011)	.263 (.016)	.249 (.020)	.066 (.016)	.050 (.014)	.297 (.021)	.138 (.018)	.168 (.021)	.071 (.020)	.036 (.017)
(C. I.)	(.109, .151)	(.237, .290)	(.214, .284)	(.037, .094)	(.024, .076)	(.260, .334)	(.106, .170)	(.128, .209)	(.037, .105)	(.002, .070)
ASC4	.224 (.019)	.440 (.027)	.643 (.035)	.017 (.006)	.006 (.006)	.019 (.026)	.156 (.030)	.787 (.035)	.006 (.004)	.002 (.002)
(C. I.)	(.187, .261)	(.400, .480)	(.583, .702)	(.005, .029)	(004, .017)	(027, .064)	(.101, .210)	(.721, .853)	(002, .014)	(003, .008)
INV4	007 (.012)	.125 (.024)	.036 (.022)	.129 (.028)	002 (.006)	040 (.028)	.119 (.023)	.020 (.016)	.318 (.045)	.000 (.006)
(C. I.)	(030, .016)	(.074, .176)	(012, .083)	(.131, .254)	(014, .011)	(100, .021)	(.074, .165)	(104, .054)	(.219, .418)	(012, .012)
UV4	.004 (.007)	.049 (.018)	031 (.017)	006 (.004)	.238 (.026)	041 (.025)	.007 (.023)	028 (.018)	008 (.006)	.518 (.034)
(C. I.)	(013, .016)	(.020, .077)	(040, .012)	(012, .000)	(.193, .283)	(095, .013)	(029, .042)	(063, .007)	(021, .005)	(.460,.576)
AttT4	.082(.010)	.270 (.014)	.230 (.015)	.053 (.012)	.035(.010)	.118 (.014)	.216 (.017)	.157 (.015)	.047 (.013)	.023 (.013)
(C. I.)	(.063, .101)	(.273, .297)	(.200, .261)	(.030, .071)	(.015, .055)	(.162, .214)	(.183, .249)	(.127, .187)	(.022, .072)	(002, .049)
OaspT4	.091 (.011)	.256 (.017)	.264 (.022)	.045 (.014)	.045 (.012)	.229 (.018)	.134 (.014)	.216 (.027)	.042 (.019)	.040 (.017)
(C. I.)	(.070, .112)	(.228, .285)	(.223, .306)	(.018, .072)	(.022, .067)	(.196, .261)	(.108, .159)	(.165, .266)	(.006, .077)	(.006, .075)
AttT5	.081 (.011)	.276 (.016)	.288 (.023)	.052 (.014)	.018 (.011)	.141 (.014)	.178 (.014)	.264 (.028)	.054 (.018)	001 (.020)
(C. I.)	(.060, .102)	(.246, .306)	(.045, .332)	(.026, .077)	(003, .039)	(.116, .166)	(.149, .207)	(.210, .319)	(.019, .089)	(037, .035)
OaspT5	.039 (.005)	.123 (.010)	.128 (.012)	.023 (.006)	.013 (.005)	.079 (.009)	.074 (.008)	.113 (.013)	.023 (.007)	.006 (.008)
(C. I.)	(.029, .048)	(.104, .142)	(.106, .150)	(.012, .033)	(.003, .022)	(.063, .094)	(.059, .089)	(.089, .137)	(.009, 0.36)	(007, .020)
Outcome	OaspT2	EdaspT2	AchT3 Oasp	DT3 EdaspT	3 ASC4	INV4	UV4	AttT4	OaspT4	AttT5

 Table D1 Path coefficients of total effect, standard error and confidence interval from Model 3

OaspT3 .602 (.026) .159 (.026)

Supplemental Materials: Study 2

(C.I.)	(.550, .655)	(.106, .216)									
EdaspT3 (C.I.)	.311 (.029) (.253, .360)	.460 (.030) (.409, .517)									
ASC4 (C.I.)	.010 (.023) (031, .015)	.016 (.017) (016, .048)	.056 (.039) (034, .146)	010 (.044) (093, .063)	.041 (.042) (033, .128)						
INV4 (C.I.)	062 (.035) (139, .014)	015 (.041) (094, .065)	.161 (.046) (.078, .273)	133 (.052) (259,015)	.024 (.086) (174, .211)						
UV4 (C. I.)	067 (.038) (139, .005)	039 (.021) (081, .004)	022 (.034) (078, .031)	080 (.045) (170,010)	058 (.040) (132, 023)						
AttT4 (C. I.)	262 (.017) (.225, .298)	.179 (.020) (.142, .216)	.271 (.023) (.227, .314)	.239 (.029) (.186, .291)	.324 (.027) (.261, .365)						
OaspT4 (C. I.)	.346 (.023) (.303, .389)	.170 (.020) (.133, .207)	.069 (.029) (.037, .084)	.456 (.035) (.395, .518)	.216 (.033) (.157, .276)	.118 (.030) (.054, .153)	.026 (.039) (053, .106)	.036 (.022) (013, .090)	.185 (.032) (.129, .234)		
AttT5 (C. I.)	.197 (.015) (.166, .229)	.129 (.015) (.101, .157)	.186 (.018) (.149, .223)	.191 (.021) (.148, .234)	.227 (.020) (.188, .266)	.197 (.034) (.113, .263)	.066 (.050) (026, .157)	034 (.029) (092, .024)	.604 (.025) (.558, .649)	.131 (.026) (.072, .179)	
OaspT5 (C. I.)	.114 (.011) (.093, .136)	.066 (.009) (.051, .081)	.065 (.008) (.048, .081)	.130 (.017) (.103, .158)	.102 (.011) (.082, .122)	.077 (.012) (.054, .100)	.024 (.014) (006, .053)	004 (.010) (023, .015)	.208 (.018) (.173, .242)	.201 (.035) (.147, .255)	.294 (.027) (.239, .360)

Note. C.I. = 95% bootstrap percentile confidence interval All variables were given a label that identifies the Time (T1 to T5). IQ = intelligent test scores; ASC = academic self-concept; INV = intrinsic value; UV = utility value; Ach = educational achievement; Att = educational attainment; Oasp = occupational aspirations.

Appendix 2-E

Addition analyses for mean comparison of motivational beliefs at T4.

According to EVT (Eccles, 2009), attending different programs of higher education, such as community colleges (i.e., 2-year colleges) and 4-year colleges would provide a different social context to students. Students' self-concept and task value would be shaped, in part, by their subjective interpretations of those experiences within their new educational context. For example, a student is likely to show greater interest when curriculum and instruction connect with personal goals and interests to actual classroom experiences (Wang

& Eccles, 2012). While community colleges have a vocational aspect to the learning

curriculum that may thus more directly reflect on students' interest, 4-year colleges/universities have more general educational requirements, especially in the first year of curriculum, that may not be directly related to the interest of students. While community colleges has vocational aspects to the learning curriculum that may thus more directly reflect the value students attached to coursework, 4-year colleges and universities have more general educational requirements, especially in the first year of curriculum, that may not directly be

related to students' intrinsic and utility values. In this regard, adolescents who attend community colleges or vocational schools are likely to have higher intrinsic value than those attending 4-year colleges (see Appendix 5 in the Supplemental Materials for additional analysis for mean comparison of motivational beliefs). To investigate this possibility, we selected three groups – attending vocational school (N = 200), attending 2-year colleges (N =344) and 4-year college/university (N = 416) from the total sample at Time 4. As expected, there are significant differences in the mean of intrinsic value (F(1, 923) = 6.944, p < .001) and utility value ((F(1, 940) = 13.06, p < .001)) across three groups. Bonferroni post-hoc test showed that adolescents who studied in vocational school and community colleges have slightly higher intrinsic and utility values than those studying in 4-year college. No significant difference in intrinsic and utility values between students attending vocational school and community colleges was found. In addition, we find there were significant differences in academic self-concept across three group ((F(1, 940) = 54.07, p < .001)). In contrast, post-hoc test indicated that student attending 4-year colleges have the highest self-concept, followed by

those attending 2-year college. These findings suggest that the curriculum and instruction in vocational school, 2-year colleges and 4-year colleges have different impacts on adolescents 'motivational beliefs in coursework.

Appendix 2-F

	,										
Model		χ^2	df	CFI	TLI	RMSEA					
SEM											
Model 1	SC+IV+UV+Ach+Att	1027.802	415	.966	.959	.026					
Model 2	SC+IV+UV+Easp+Oasp	1212.002	473	.967	.961	.027					
Model 3	Model1 + Model2	1388.491	613	.967	.960	.024					
SEM with self-concept-by-value interactions											
Model4	Model3 + SCxUV	1898.760	917	.958	.951	.022					
Model5	Model3 + SCxIV	1791.174	874	.961	.953	.022					
Model6	Model3 + SCxIV + SCxUV	2536.550	1224	.958	.951	.022					

Supplemental Analyses for Interactions Effects Between Self-Concept And Value Table F1 Model fit statistics for the SEM) Models

Note. SC = self-concept; IV = intrinsic value; UV = utility value.

To probe the interaction effect between self-concept and value beliefs, a series of SEMs with latent interactions using the unconstrained approach were conducted (Marsh, Wen, & Hau, 2004). To begin with, the models with separate sets of latent product variables were evaluated: one based on product indictors for the self-concept and intrinsic value and one based on those for self-concept and utility value at T1, T2 and T4. As noted in the main text, the hypothesised models provided excellence fits to the data (i.e., Model 1-Model3, see Table F1). In Model4-6, the latent interactions were included to predict subsequent educational outcomes and motivational beliefs based on Model 3. These models also provided good fit to data.

In Model 4 where only self-concept-by-intrinsic value interactions were included, the interaction positively predicted educational achievement and aspirations across time (averaged effects; M = .091 and .060 respectively), whereas the interaction effects on educational attainment and occupational aspirations were non-significant. In Model5, self-concept-by-utility value interactions instead of self-concept-by-intrinsic value interactions were included. However, all the interaction effects on subsequent educational outcomes and motivational beliefs were non-significant. When two sets of product variables (self-concept-by-intrinsic value and self-concept-by-utility value interactions) were considered simultaneously (Model 6), all the interactions were also non-significant. It should be noted that we did not include latent interactions between self-concept and value in study 2, given that the journal editors and reviewers suggested that this issue would bring another complication to an already complex article. But the detailed discussion on these findings was provided in the general discussion and conclusion chapter.

Supplemental Materials: Study 3

External Appendix 3-A

Latent Variable	Factor loading	Item wording (Code)	Response code	Cronbach's alpha (α)	Greater lower bound (glb)	
	.719	I am just not good at Maths ^a				
	.735	I get good marks in Maths.				
Maths self-	.790	I learn Maths quickly.	1 (disagree a			
concept (MSC)	.816	I have always believed that Maths is one of my best subjects.	lot) to 4 (agree a lot)	.89	.89	
	.745	In my Maths class, I understand even the most difficult work.				
	.720	I enjoy learning Maths				
Maths	.831	I look forward to my Maths	1 (disagree a			
intrinsic	.889	I like maths	lot) to 4	.90	.91	
value (MIV)	.811	I am interested in the things I learn in Maths	(agree a lot)			
	.717	Making an effort in Maths is worth it because it will help me in the work that I want to do later on.				
Maths utility	.830	Learning Maths is worthwhile for me because it will improve my career <prospects, chances="">.</prospects,>	1 (disagree a lot) to 4	.89 .90	.90	
value (MUV)	.816	Maths is an important subject for me because I need it for what I want to study later on.	(agree a lot)			
	.767	Maths that will help me get a job.				

Table A1 A priori factor structure and reliability relating PISA2003 items used in this study

Note.^a Negatively worded items were reverse-scored.

External Appendix 3-B

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Math_Ach													
2. Read_Ach	.77***												
3. Sci_Ach	.85***	.85***	_										
4. MSC	.44***	.22***	.35***										
5. INV	.21***	.06***	.14***	.71***									
6. MUV	.19***	.09***	.16***	.4***	.59***								
7. Math cour	.41***	.29***	.35***	.40***	.33***	.30***							
8. STEM	.17***	.11**	.15***	.22***	.21***	.23***	.19***						
9. TER ¹	.58***	.55***	.56***	.32***	.20***	.17***	.39***	.57***					
10. Uni Entry	.42***	.45***	.42***	.21***	.15***	.16***	.29***	.17***	.61***				
11. Gender	06***	.18***	02**	18***	10***	11***	10***	09***	.12***	.17***			
12. SES	.37***	.38***	.39***	.14***	.06***	.08***	.15***	.07**	.36***	.32***	01		
13. Year	.28***	.19***	.18***	.02	01	08***	.21***	.02	.06***	.09***	.04***	.04***	
M	528.58	530.93	529.25	2.52	2.25	3.05	2.47	.55	0	.71	1.50	.25	10.12
SD	91.32	88.61	95.04	.68	.71	.66	.85	.50	1	.46	.50	.82	.53

Note. ¹ all the TER scores were standardised (z-scored) within each state. ASC = math academic self-concept; MIV = math intrinsic value; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; p < .05, ** p < .01, *** p < .001;

External Appendix 3-C Gender differences

C1. Measurement invariance and latent mean differences over gender

Before examining the gender differences in mean-level of latent constructs, we tested the invariance of the confirmatory factor analysis (CFA) measurement model for males and females. The CFI and the RMSEA perform well in judging the adequacy of invariance assumptions (Morin, Marsh & Nagengast, 2013). Cheung and Renswold (2002) and Chen (2007) have suggested that if the change in CFI is not more than .01 and the RMSEA increases by less than .015 for the more parsimonious model, the assumption of invariance is tenable. The unconstrained multigroup CFA model provided an adequate level of fit to the data (χ^2 (84) = 1150.331, df = 124, CFI = .978, TLI = .973, RMSEA = .040). The factor loadings and item intercepts were then subsequently constrained to be equal across gender. The changes in model fits were negligible (loading invariant CFA model: χ^2 (74) = 1215.91, df = 134, Δ CFI= -.001, Δ RMSEA = +.001, Δ TLIs = .000; intercepts invariant CFA model: χ^2 (64) = 1382.10, df = 144, Δ CFI= -.003, Δ TLI = -.001; Δ RMSEA = +.001).

Variable	Gender differences
Cohen's d value	
Reading achievement	.393***
Science achievement	031
Math achievement	104***
Math self-concept	358*** ^a
Math intrinsic value	222*** ^a
Math utility value	250*** ^a
Tertiary Entrance Rank [TER]	.291***
Math course selection	205***
Odds ratio	
University entry	1.832***
STEM	0.602**

Note. Odds ratio greater than one indicates females have higher likelihood of choosing postsecondary education than males. ** p < .01. *** p < .001; ^a Differences based on latent mean difference

C2. Moderation effect

In spite of gender differences in the mean-level of math motivational beliefs and educational outcomes, gender did not largely moderate the relations between these factors. Only three paths varied by gender. Specifically, prior achievements in math and reading are more strongly associated with math utility value for males than females. In particular, prior reading achievement negatively predicts math utility value for males, but not for females. In

Supplemental Materials: Study 3

addition, prior math achievement plays a greater role for males than females in math course selection. There are several possible explanations for this finding. First, females may perceive themselves as having lower self-concept and may attach lower intrinsic and utility values to math tasks than males do, even if they have similar math achievement (see Watt, 2010). In the present study, we found that adolescent males have higher self-concept and intrinsic and utility values than adolescent females (Cohen's ds are -.328, -.222, -.250, respectively) whereas gender difference in math achievement favouring males is small (Cohen's d -. 104). This may lead to females opting out of more math advanced courses as their math self-beliefs and value for math are lower. Second, females with comparable ability in math are more likely to outperform males in reading ability, which may offer females a broader range of school and post-school choices than males, leading to their not choosing more advanced courses in math (Ceci & Williams, 2010; Wang, Eccles, & Kenny, 2013). These gendered patterns suggest that the internal comparison process in relation to high reading competence (Cohen's d.393) would have detrimental effects on females' math self-concept and intrinsic value rather than utility value. This imbalance of motivational beliefs may play a more important role for females to select advanced math courses and STEM majors compared to math achievement. However, replication studies are warranted, given that the sizes of genderdifferentiated patterns are modest and statistically significant because of the sample size of the present study.

External Appendix 3-D

Moderated mediation

In the present study, moderation of the regression of math course selection (M) on math self-concept (X) and the regression of STEM major selection (observed binary outcome, Y) on math course selection are shown in our hypothesised model, with statistically significant estimates where intrinsic value (Z) is a moderator. According to the hypothesis of *moderated mediation* outlined by Preacher, Rucker, & Hayes (2007), the formulas below were utilised to calculate *conditional indirect effect*.

Assuming linear relationships for Y and M are

$$y_{i} = \beta_{0} + \beta_{1}m_{i} + \beta_{2}x_{i} + \beta_{3}x_{i}z_{i} + \varepsilon_{1i}$$
(1.1)

$$m_i = \gamma_0 + \gamma_1 x_i + \gamma_2 z_i + \gamma_3 x_i z_i + \varepsilon_{2i}$$
(1.2)

Where the residual ε_1 and ε_2 are assumed normally distributed with zero means. The equations were reduced by inserting (1.2) in (1.1)

$$y_{i} = \beta_{0} + \beta_{1}(\gamma_{0} + \gamma_{1}x_{i} + \gamma_{2}z_{i} + \gamma_{3}x_{i}z_{i}) + \varepsilon_{2i} + \beta_{2}x_{i} + \beta_{3}x_{i}z_{i} + \varepsilon_{1i}$$
(1.3)

$$y_i = \beta_0 + \beta_1 \gamma_0 + (\beta_2 + \beta_3 z_i) x_i + \beta_1 (\gamma_1 + \gamma_3 z_i) x_i + \beta_1 \gamma_2 z_i + \varepsilon_{2i} + \varepsilon_{1i}$$
(1.4)
It follows that the direct and indirect effects are

$$DE = (\beta_2 + \beta_3 z_i) \tag{1.5}$$

$$TIE = \beta_1(\gamma_1 + \gamma_3 z_i) \tag{1.6}$$

The effects can be calculated at different z values of interest.
External Appendix 3-E





Figure E1. Path model depicting the hypothesised relations, including latent interaction, controlling for gender, Grade and SES. For clarity, only statistically significant paths are presented in the model, and all coefficients shown are standardised. Coefficients displayed in boldface type are the probability differences calculated from probit regression.

Note. Dashed arrows represent negative association between reading achievement and motivational beliefs. ASC = math academic self-concept; MIV = math intrinsic value; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; mscXmiv = math self-concept by intrinsic value; mscXmuv = math self-concept by utility value; p < .05, ** p < .01, *** p < .001

	Math_ach	Read_ach	Sci_ach	MSC	MIV	MUV	Course	TER	STEM	Uni_Entry
Math_ach				.58***	.40***	.25***	.20***	.26***	.01	.10**
Read_ach				29***	26***	15***	.01	.11***	.00	[.04] .14***
Sci ach				.14***	.05*	.10***	.04	.10**	.05	[.05] 04
– MSC							.18***	18***	.05	.03
MIV							.07***	.08***	.09*	.06
MIW							12***	01	[.04]	10***
WIC V							.15	.01	[.06]	[.04]
mscAmv							.07.22	.08****	.02	.04
mscXmuv Course							029	.037	.012 .20***	.030
									[.08]	
TER										.48***
										[.15]
Covariates										
Gender	06***	.18***	02	09***	04**	07***	04**	.11***	10**	.17***
SES	.37***	.38***	.39***	01	.00	.01	.01	.12***	01	.16***
Vear	117***	1 🗙 🎢 🜴	1 🗙 🌴 🛣	_ ()×***	_ ()5***	_ ')***	15777	_ () / * * *	_ 01	()4*

Table E1 Standardised direct effect for the final path model with latent interaction

Year.22***.18***.18***.08***.05***..12***.15***.07***..01.04*Note. Coefficients in brackets are the probability differences calculated from probit regression. ASC = math academic self-concept; MIV = math
intrinsic value; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach =
science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university
entrance; STEM = university STEM major selection; mscXmiv = math self-concept by intrinsic value; mscXmuv = math self-concept by utility
value; * p < .05, ** p < .01, *** p < .001. Dashes indicate that it was not possible to compute coefficients.

External Appendix 3-F

The effect of Socioeconomic Status (SES)

Correlation between SES, motivational beliefs and educational outcomes

SES was moderately positively correlated with prior achievement, TER scores and university entry but its relations with motivational beliefs, math courses and STEM selection were somewhat smaller. This finding indicates students with affluent family background tend to report high math motivational beliefs and achieve high educational outcomes.

The effect of SES

With respect to SES, only the paths from SES to prior academic achievement, TER and university entry were statistically significant, indicating that students with affluent family backgrounds were more likely to have high academic performance and to enter university (Parker et al., 2012; Bowen et al., 2009; Schoon & Polek, 2011). Academic achievement fully mediated the relationship between SES and motivational beliefs. Similarly, academic achievement and motivational beliefs fully mediated the relationship between SES and math course selection. Also, prior achievement, motivational beliefs and high school outcomes mediated the predictive effects of SES on TER, STEM major selection and university entry. Based on the above findings, more attention is needed for students with disadvantaged family backgrounds, to improve their math academic achievement from early on. This might have a significant impact on students' motivational beliefs, thus promoting their enrolment in math courses and STEM degrees.

In addition, we conducted supplemental analyses to test moderation effect of SES on gender relations among achievement, motivation beliefs and educational outcomes. Specifically, we added the product term between gender and SES into the hypothesised model to predict prior achievement, educational beliefs and educational outcomes. However, we did not found statistically significant interaction effect, indicating that SES did not have moderating influences on gender relations among achievement, motivational beliefs and educational beliefs and educational outcomes (see Table F1). The rest of path coefficients in the model with gender by SES interaction were highly similar with those without this interaction (see Appendix 3-E in Supplemental Materials for more details).

Table F1 The moderation effect of SES on g	gender relations among	g achievement, m	otivation b	beliefs and	educational	outcomes

	Math_ach	Read_ach	Sci_ach	MSC	MUV	Math_Course	TER	STEM	Uni_Entry
Gender	06***	.18***	02	09***	07***	04**	.11***	11**	.18***
SES	.37***	.38***	.39***	01	.01	.01	.12***	01	.16***
GenderXSES	01	01	02	00	01	01	01	01	01

Note. ASC = math academic self-concept; MIV = math intrinsic value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; GenderXSES = Gender by SES interaction; p < .05, ** p < .01, *** p < .001





Figure G1. Path model depicting the hypothesised relations, including intrinsic value and its interaction with self-concept, controlling for gender, Grade and SES. For clarity, only statistically significant paths are presented in the model, and all coefficients shown are standardised. Coefficients displayed in boldface type are the probability differences calculated from probit regression. *Note.* Dashed arrows represent negative association between reading achievement and motivational beliefs. ASC = math academic self-concept; MIV = math intrinsic value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; mscXmiv = math self-concept by intrinsic value;* p < .05, ** p < .01, *** p < .001

	Math_ach	Read_ach	Sci_ach	MSC	MIV	Course	TER	STEM	Uni_Entry
Math_ach				.58***	.39***	.22***	.29***	.01	.12**
									[.05]
Read_ach				29***	27***	.01	.15***	.00	.14***
									[.05]
Sci_ach				.13***	.05*	.04	.08**	.05	04
						• • • • • •	10444	o -	
MSC						.20***	18***	.05	.03
NATY /						1 /***	10***	1.4*	17***
MIIV						.14***	.10***	.14* [06]	.1/***
maaVinu						07***	00***	[.00]	[.06]
IIISCAIIIV						.07	.09	.02	.04
Course								20***	
course								[08]	
TER								[]	.48***
									[.15]
Covariates									
Gender	06***	.18***	02	09***	04**	04**	.12***	11**	.17***
								[04]	[.06]
SES	.37***	.38***	.39***	01	.00	.01	.13***	01	.16***
									[.06]
Year	.22***	.18***	.18***	08***	05***	.15***	07***	01	.05*
									[.06]

Table G1 Standardised direct effect for the final path model with latent interaction

Note. Coefficients in brackets are the probability differences calculated from probit regression. ASC = math academic self-concept; MIV = math intrinsic value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; mscXmiv = math self-concept by intrinsic value; * p < .05, ** p < .01, *** p < .001. Dashes indicate that it was not possible to compute coefficients



External Appendix 3-H Path models for the models including utility value and its interactions with self-concept



Note. Dashed arrows represent negative association between reading achievement and motivational beliefs. ASC = math academic self-concept; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; mscXmuv = math self-concept by utility value;* p < .05, ** p < .01, *** p < .001

	Math_ach	Read_ach	Sci_ach	MSC	MUV	Course	TER	STEM	Uni_Entry
Math_ach				.58***	.25***	.21***	.29***	.01	.12**
									[.05]
Read_ach				29***	15***	.01	.13***	.00	.17***
C 1				17***	10***	0.4	10**	05	[.06]
Sci_ach				.13***	.10***	.04	.10**	.05	04
MSC						22***	19***	10*	03
mbe						.22	17	[.04]	.05
MUV						.17***	.05***	.19***	.19***
								[.07]	[.07]
mscXmuv						.06***	.05***	.012	.030
G								0 0***	
Course								.20***	
TFR								[.08]	48***
TER									[15]
									[]
Covariates									
Gender	06***	.18***	02	09***	07***	04**	.11***	11**	.18***
								[04]	[.06]
SES	.37***	.38***	.39***	01	.01	.01	.12***	01	.16***
Veer	22***	10***	10***	00***	10***	1(***	07***	01	[.06]
r ear	.22***	.18***	.18***	08***	12***	.10***	0/***	01	.UO* [06]
									[.00]

Table HI Standardised	direct effect for the m	odels including intrinsic	value and its interaction	1 with self-concept
		8		1

Note. Coefficients in brackets are the probability differences calculated from probit regression. ASC = math academic self-concept; UV = math utility value; Math_Ach = math educational achievement; Read_Ach = reading educational achievement; Sci_Ach = science educational achievement; TER = Tertiary Entrance Rank; Math_Course = high school math course selection; Uni_Entry = university entrance; STEM = university STEM major selection; mscXmuv = math self-concept by utility value; * p < .05, ** p < .01, *** p < .001. Square brackets indicate probability differences calculated from probit regression. Dashes indicate that it was not possible to compute coefficients.

Supplemental Materials: Study

External Appendix A:

Science Curriculum Guidance for The Four Countries

According to Mullis, Martin, Olson, Berger, & Stance (2008),

Czech Republic

Science education begins with the local environmental studies in Grade 1-3 and continues with natural science in grade 4-5. In Grades 6-9, physics, biology (including geology), and earth science are taught separately. Chemistry is taught, beginning from Grade 7 through Grade9.

Hungary

Science education begins with the local environmental studies in Grade 1-4 and continues with natural science in grade 5-6. In Grade 7-8, science is taught as the four separate subjects (physics, biology, chemistry and earth and environment).

Slovenia

Secondary education is consisted of natural and technical topics (physics, chemistry, biology, technical science, informatics, and technology) and social science (history, economy, geography and etc). In grade 8, natural sciences are taught as separate subjects: biology, chemistry and physics. Earth science is mainly represented in physics.

Sweden

In secondary school, the natural sciences (physcis, chemistry, and biology) are taught either as an integrated, single subject or as three separate subjects. But about 80 percent of the students receive grades in separate science subjects. Earth science is taught within physics and chemistry as well as the social subject of geography.

External Appendix B

The Wording of The Items and A Prior Factor Structure of Motivational Factors in The Four OECD Countries

Table B1 A priori factor structure relating the TIMSS motivation items to latent factors

Items	Item wording	Factor loading					
		Physics	Chemistry	Earth	Biology		
				science			
Self-concept							
SCP1	I usually do well in Physics/Chemistry/Earth science/Biology	.81	.82	.81	.79		
SCP2	I learn things quickly in Physics/Chemistry/Earth science/Biology	.82	.82	.80	.79		
SCN1	Physics/Chemistry/Earth science/Biology is more difficult for me	.50	.52	.52	.54		
SCN2	Physics/Chemistry/Earth science/Biology is not one of my strengths	.60	.63	.64	.65		
Intrinsic value							
IVP1	I enjoy learning Physics/Chemistry/Earth science/Biology	.87	.88	.86	.84		
IVP2	I like Physics/Chemistry/Earth science/Biology	.66	.70	.73	.74		
IVN1	Physics/Chemistry/Earth science/Biology is boring	.88	.89	.90	.90		
Utility value							
UVP1	I think learning Physics/Chemistry/Earth science/Biology will help me in my daily life	.66	.66	.53	.57		
UVP2	I need Physics/Chemistry/Earth science/Biology to learn other school subjects	.66	.63	.59	.56		
UVP3	I need to do well in Physics/Chemistry/Earth science/Biology to get into the university						
	of my choice	.83	.83	.80	.81		
UVP4	I need to do well in Physics/Chemistry/Earth science/Biology to get the job I want	.84	.84	.81	.81		
Coursework A	spirations						
APS	I would like to do more in Physics/Chemistry/Earth science/Biology in school (single						
	item)						
Achievement		1.00	1.00	1.00	1.00		
ACH	Standardized test score represented by five plausible values (single item)	1.00	1.00	1.00	1.00		
Note. This factor	r analysis is discussed in greater detail in the presentation of results. Briefly, these results are based on Mode	el MG4 (see s	ubsequent discu	ssion of Model	MG4 in		

Table 3) and are average results over five imputed data sets. Factor loadings are unstandardized estimates in a model identified by constraining all factor variances to be 1.0. Factor loadings were constrained to be equal across the four countries. The wording of the items was rigorously parallel for the corresponding science domain-specific scales. P = physics; C = chemistry; E = earth science; B = biology; SCP = self-concept (positive); SCN = self-concept negative; IVP = intrinsic value (positive); IVN = intrinsic value (negative); UVP = utility value (positive).

	Sample Size				Reliability Estimates												
Country	Student	Class	School	%boys	PSC	CSC	ESC	BSC	PIV	CIV	EIV	BIV	PUV	CUV	EUV	BUV	Mean
Czech Republic	4842	212	147	52%	.84	.85	.83	.82	.84	.86	.86	.85	.84	.86	.86	.85	.83
Hungary	4108	246	144	50%	.83	.82	.83	.82	.84	.85	.87	.88	.84	.85	.87	.88	.83
Slovenia	4029	260	148	50%	.77	.80	.79	.80	.83	.87	.87	.87	.83	.87	.87	.87	.82
Sweden	5068	307	159	52%	.79	.79	.79	.79	.87	.88	.88	.88	.87	.88	.88	.88	.84
Total	18047	1025	598	51%	.81	.82	.81	.81	.85	.87	.87	.87	.84	.84	.80	.79	.83

Table B2 Sample size and reliabilities of the TIMSS motivation constructs based on four science domains for four OECD countries

Note. The column headed Mean is the mean of the eight reliability estimates. The wording of the items was rigorously parallel for the corresponding science domain-specific scales. Reliability estimates are Cronbach's alpha estimates. P = physics; C = chemistry; E = earth science; B = biology; SC = self-concept; IV = intrinsic value; UV = utility value

Appendix 4-C:

Unconstrained approach, standardization, and annotated mplus syntax Unconstrained Approach

In comparison to the traditional constrained approach (e.g., Jöreskog & Yang, 1996;) and the partially constrained approach (Wall & Amemiya, 2001), the unconstrained approach is relatively simple to implement in that most of the complicated constraints required in the original Kenny and Judd's approach are relaxed (Marsh et al., 2004). The unconstrained approach has shown good performance as the constrained approach when the underlying assumptions of the constrained approach are met in the simulation study, and much better performance when these assumptions are not met – which is generally the case (Marsh et al., 2004).

The SEM with two latent predictors and their interacting latent variable is typically specified as:

$$\eta = \gamma_1 \xi_1 + \gamma_2 \xi_2 + \gamma_3 \xi_1 \xi_2 + \zeta.$$
(3)

where γ_1, γ_2 and γ_3 are the partial regression coefficients of the latent predictor variables and their cross-product and ζ is the structural model residual. The latent predictors ξ_1 and ξ_2 as well as the latent outcome variable η are each inferred from at least two indicator as specified in the corresponding measurement models. ξ_1, ξ_2 and ξ_3 are allowed to be correlated with each other, but each is uncorrelated with measurement errors and the residual term ζ .

$$x_{ij} = \lambda_{xi}\xi_i + \delta_{ij}, y_k = \lambda_{yk}\eta + \varepsilon_k, \tag{4}$$

where x_{ij} is the *j* th indicator of the *i* th latent predictor variable ξ_i , λ_{xi} is the corresponding factor loading and δ_{ij} is the corresponding residual, y_k is the *k* th indicator of the latent outcome variable η , λ_{yk} is the corresponding factor loading, and ε_k is the corresponding residual.

Product-indicator approaches such as the unconstrained approach identify the latent cross-product $\xi_1 \xi_2$ by products of indicators of the latent predictor variables, according to the following measurement model

$$x_{1i}x_{2l} = \lambda_{1i2l}\xi_1\xi_2 + \delta_{1i2l}, \tag{3}$$

where x_{1i} is the *i* th indictor of ξ_i and x_{2l} is the *l* th indicator of ξ_2 , λ_{1i2l} is the corresponding factor loading on the latent product variable and δ_{1i2l} is the corresponding residual. The critical problem with the indicator approach is how to form the product indicator.

Supplemental Materials: Study 4

All indicators of the latent variables are centred before the product indicators are compute (Marsh et al., 2004). According to the guiding principles proposed in Marsh et al. (2004), (a) all the multiple indicators of both latent predictors are needed to use, and (b) the same indicator should not be re-used the same indicator in forming the indicators for the latent product variable (also see Marsh, Hau, Wen, Nagengast, & Morin, 2013). Hence, each indicator in ξ_1 and ξ_2 should be used only once in the formation of the product indicators. In this study, product indicators are formed based on the reliabilities of the indicators of ξ_1 and ξ_2 (i.e., the best item in ξ_1 with the best item in ξ_2 , for detailed discussion about construction of product indicators see Marsh et al., 2004; Marsh, Hau et al., 2013).

Standardization

First, all individual indicators (rating item, test scores and coursework aspirations) were standardised in relation to the total sample mean and standard deviation, as recommended by Marsh and his colleagues (Marsh et al., 2004). Second, for total group analysis, product indicators for the latent interactions were formed using the match-pair strategy according to Marsh, Hau et al. (2013)'s guiding principles (also see Marsh et al., 2004 for more discuss about the product predictors selection procedure). For the multi-group analysis, the standardised indicators were centred (but not re-standardised the product term) within country-specific mean before forming the product indictors for the latent interaction variable (Nagengast et al., 2011). In order to obtain appropriate standardised results (Wen, Marsh, & Hau, 2010), for total group analysis all latent factors (including the latent product variables) were then standardise in relation to the total sample. For multi-group analyses, the critical assumption of test whether the pattern of results generalises across groups is invariance of factor structure. To provide parameter estimates standardised to a common metric over the multiple groups, factor loadings and factor variances are needed to be invariant across the four countries. More specifically, we conducted a preliminary CFA model in which factor loadings and factor variances were constrained to be invariant over the multiple groups, and the metric was identified by fixing the factor variances of constructs to be 1.0 across the four groups, instead of fixing the first factor loading to 1.0. In subsequent SEMs these standardised factor loadings were used to define the latent factors, fixing the first factor loading for each factor to the value obtained in the CFA, in which the factor variances were fixed to be 1.0. In this way, all parameter estimates were estimated in relation to a standardised metric that was common across the four countries, providing appropriate standardised results (see Marsh et al., 2015; Wen et al., 2010 for more details; also see below for the Mplus syntax). As showed in the main text, we also conducted a series of invariance tests with respect to factor covariances and path coefficient for multi-group measurement and

Supplemental Materials: Study 4

structural models As the assumption of invariance was tenable, all results reported in this study were based on multi-group SEM with factor loading, path coefficients and factor variances and covariance invariances.

Appendix 4-D:

Weight and goodness of fit

Weighting

Consistent with its two-stage stratified sampling design, TIMSS provides the HOUWGT weighting variable that has six components, one each for school, class and student level, and one each for adjustment factors associated with non-participation at these three levels (See Marsh, Abduljabbar et al., 2013 for additional detail on the development of this weighting variable). HOUWGT is based on the actual number of students in each participating countries that is appropriate for correct computation of standard errors and tests of statistical significance. Thus, the HOUWGT weighting variable was taken into account in the data analysis.

Goodness of Fit

A number of traditional indices that are relatively independent of sample size were utilised to assess model fit (Hu & Bentler, 1999): the comparative fit index (CFI), the rootmean-square error of approximation (RMSEA) and the Tucker-Lewis Index (TLI). To explore how well the hypothesised relations generalise across the four OECD countries, we conducted multiple-group analyses (Bollen, 1989) and tested a series of increasingly stringent invariance constraints on the parameters of measurement and structural parts of the model, in which little or no change in goodness of fit supported invariance of the factor structure and parameter estimates (Millsap, 2011; see Appendix D in the supplemental materials for more details). We note that to compare differences in patterns of relations among multiple groups, it is only necessary to have factor loadings invariant for latent variable models (Millsap, 2011; Nagengast et al., 2011). Nevertheless, to facilitate interpretation of the parameter estimates in relation to a common metric over the multiple groups, we also tested invariance models of factor variances/covariances and path coefficients over the four countries (see Appendix C in the supplemental materials for the standardization procedure).

Values greater than .95 and .90 for CFI and TLI typically indicate excellent and acceptable levels of fit to the data. RMSEA values of less than .06 and .08 are considered to reflect good and acceptable levels of fit to the data. To explore how well the hypothesised relations generalise across the four OECD countries, we conducted multiple-group analyses (Bollen, 1989) and tested a series of increasingly stringent invariance constraints on the parameters of measurement and structural parts of the model, in which little or no change in goodness of fit supported invariance of the factor structure (Marsh, Hau et al., 2013). Chen (2007) have suggested that if the decrease in CFI is not more than .01 and the RMSEA

Supplemental Materials: Study 4

increases by less than .015 for the more parsimonious model, then invariance assumptions are tenable. To facilitate interpretation of parameter estimates in relation to a common metric over the multiple groups, factor variances and covariances are also constrained to be invariant over the four countries in this study (see Appendix E in the supplemental materials for the standardization procedure). Other more stringent tests would have been necessary in order to support the test of latent mean differences over time or models based on the use of manifest, rather than latent, scale scores, which is not the case in the present study.

Appendix 4-E:

Preliminary analyses tests

Table E1 Model fit statistics for the CFA and SEM Models used in the present study

Model	Description	γ^2	df	CEI	TLI	PMSE	Model Description
Widder	Description	λ	ц	CIT	1 L/1	A	Woder Description
Total groun	n (TG) analysis						
CFA							
TG1	SC + IV + UV	10757	722	.963	.952	.028	Motivational constructs in the four science domains
TG2	SC + IV + UV + SCxIV + SCxUV	16766	2090	.953	.942	.020	TG2 + two latent product variables
TG3	SC + IV + UV + SCxIV + SCxUV + ACH + ASP	19406	2506	.957	.946	.019	TG4 + ASP and ACH
Second-ord	ler CFA model						
TG4	SO(SC + IV + UV)	40918	773	.852	.820	.054	High-order CFA model
Multi-grou	p (MG) analysis						
CFA							
MG1	SC + IV + UV + ACH + ASP, CUs, Configural	18038	3912	.964	.951	.028	Correlated Uniqueness + No invariance
MG2	SC + IV + UV + ACH + ASP, CUs , $IN = FL$	19416	4008	.961	.948	.029	MG1 + factor loading invariance
MG3	SC + IV + UV + ACH + ASP, CUs , $IN = FL$, FV	20138	4068	,959	.947	.030	MG2 + factor variance invariance
MG4	SC + IV + UV + ACH + ASP, CUs , $IN = FL$, FV , CV	23961	4638	.951	.944	.030	MG3 + factor covariance invariance
Additional	tests of measurement invariance						
MGE5	SC + IV + UV + ACH + ASP, CUs , $IN = FL$, INT	19427	4104	.961	.950	.029	MG2 + intercepts invariance
MGE6	SC + IV + UV + ACH + ASP, CUs, IN = FL, INT, Unq	24271	4236	.949	.936	.032	MGE5 +uniquenesses invariance
MGE7	SC + IV + UV + ACH + ASP, CUs , $IN = FL$, INT , FMn	19264	4164	.962	.951	.028	MGE5 + latent mean invariance
MGE8	SC + IV + UV + ACH + ASP, CUs, IN = FL, INT, Unq, FMn	24075	4296	.950	.938	.032	MGE7 + uniquenesses invariance
MGE9	SC + IV + UV + ACH + ASP, CUs, IN = FL, INT, Unq, FV, CV, FMn	28925	4926	.033	.939	.934	MGE8 + factor variance and covariance invariance
SEM							
MG5	SC + IV + UV + ACH + ASP, CUs , $IN = FL$, PC	21088	4344	.958	.948	.029	MG2 + path coefficients invariance
MG6	SC + IV + UV + ACH + ASP, CUs , $IN = FL$, FV , CV , PC	23961	4638	.951	.944	.030	MG4 + path coefficients invariance
MG7a	SC + IV + UV + ACH + ASP, CUs, IN = FL, FV, CV, PC; Free = SCxIV	29880	6934	.945	.936	.027	MG6 + freely estimated factor loading, factor variances and covariance and path coefficients relating to SCxIV
MG7b	SC + IV + UV + SCxIV + ACH + ASP, CUs, IN = FL, FV, CV, PC	31512	7228	.942	.936	.027	factor loading, factor variances and covariance and path coefficients invariance for all latent variable
MG8a	SC + IV + UV + ACH + ASP, CUs, IN = FL, FV, CV, PC; Free = SCxUV	25644	7740	.955	.947	.023	MG6 + freely estimated factor loading, factor variances and covariance and path coefficients relating to SCXUV
MG8b	SC + IV + UV + SCxUV + ACH + ASP, CUs, IN = FL, FV, CV, PC	28647	8184	.948	.942	.024	factor loading, factor variances and covariance and path coefficients invariance for all latent variable

Note. CFA = confirmatory factor analysis; SEM = Structural equation modelling; PC = path coefficients; SC = self-concept; IV= intrinsic value; UV = utility value; ASP = coursework aspirations; SCxIV = the product term of self-concept by intrinsic value interaction; SCxUV = the product term of self-concept by utility value interaction; IN = invariant; CUs = correlated uniquenesses; UCUs = uncorrelated uniquenesses; FL = factor loading; FV = factor variances; CV = factor covariances; INT= item intercepts; Unq = item uniquenesses; FMn = factor latent mean.

Factor structure: preliminary CFA

In the preliminary analyses, we evaluated a series of CFAs of the factor structures underlying the multiple domains of self-concept, intrinsic value and utility value, and their relations to parallel measures of achievement and coursework aspirations. We began with an evaluation of the results based on the total group. A critical feature of the TIMSS data is that each motivation construct was measured by a mixture of positively and negatively worded items, with parallel wording across the four science domains. This requires the inclusion of a priori correlated uniquenesses, relating responses to negatively worded items and parallel worded items, to obtain unbiased parameter estimates (see Marsh, Abduljabbar et al., 2013, 2015). Following previous TIMSS research (Marsh, Abduljabbar et al., 2013), these a priori correlated uniquenesses were included in all CFA and SEM models. The goodness of fit for the CFA models with proper methodological control for item wordings was good (e.g., CFI &TLI > .942; see models TG1–TG3 in Table E1).

We also tested a second-order CFA model where global science self-concept, intrinsic value and utility value were formed by the four corresponding first-order constructs from each science domain. However, the second-order CFA model was highly unsatisfactory in terms of model fits (e.g., CFI & TLI < .852; Model TG6 in Table E1), thus providing support for the domain specificity and discriminant validity of these factors. This result indicates that it is important to distinguish the patterns of theoretical predictions in relation to each of the four science domains.

Tests of invariance of factorial structure over countries

A key interest of the present study is to evaluate the degree to which the results generalise across the four OECD countries included in our sample. We began with an evaluation of invariance of the factor structure over multiple groups (four OECD countries) based on CFAs. The fit indices for the baseline model with no invariance constraints were very good (e.g., CFI = .964, Model MG1 in Table E1). There was a negligible decrease in fit (Δ CFI = .003, Δ TLI = .003) for Model MG2, in which the factor loadings were constrained to be equal across groups, suggesting that the invariance of factor loadings was supported by the data. Similarly, adding equality constraints on the factor variances (MG3) and covariances (MG4) resulted in a satisfactory level of fit to the data, and only a negligible change in fit (Δ CFI = .008, Δ TLI = .003). These results support the generalizability of the factor structure of the five constructs across the four countries (also see supplement analyses for a more complete evaluation of invariance).

Domain specificity of Motivation Responses, Achievement, and Aspirations

We examined relations among the five constructs to evaluate the expected domain specificity of the motivation responses. Latent correlations among the 20 constructs (4 domains x 5 constructs) based on Model MG4 with invariant factor loadings, variances, and covariances for motivational beliefs, achievement, and aspirations over the four OECD countries, are presented in Table E2(below). The latent correlations among the four self-concept factors (r = .28 to .42) and among the four intrinsic value factors (r = .23 to .40) in different science domains were modest. These correlations were smaller than those among utility value factors (r = .46 to .65). Of particular relevance, correlations among the four achievement scores (r = .77 to .81). In summary, there was good support for the high domain specificity of self-concept and intrinsic value, but the support for utility value was much weaker. Our findings also provided good support for the domain specificity of achievement scores

.09 .19 .11 .57

20.BAPS

selence u																				
	Scie	ence se	lf-con	cept	Scie	nce in	trinsic	value	Scie	ence ut	ility va	alue	Scie	nce ad	chieve	ment	Scie	ence a	spirat	ions
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Science sel	lf-conc	ept																		
1.PSC	—	-																		
2.CSC	.42	—																		
3.ESC	.34	.28	_																	
4.BSC	.31	.41	.35	—																
Science int	rinsic	value																		
5.PIV	.79	.27	.20	.18	—															
6.CIV	.27	.79	.15	.30	.38	-														
7.EIV	.20	.14	.77	.19	.28	.23	_													
8.BIV	.13	.25	.15	.74	.25	.40	.28	_												
Science uti	lity va	lue																		
9.PUV	.41	.23	.14	.14	.50	.28	.19	.18	_											
10.CUV	.19	.40	.11	.22	.25	.49	.16	.29	.65	-										
11.EUV	.13	.14	.34	.13	.18	.19	.45	.19	.50	.53	-									
12.BUV	.13	.21	.11	.39	.18	.30	.19	.51	.46	.63	.56	_								
Science acl	hieven	nent																		
13.PACH	.32	.25	.21	.20	.16	.12	.07	.02	.09	01	05	02	_							
14.CACH	.31	.25	.21	.26	.16	.13	.07	.08	.09	.02	02	.03	.77	-						
15.ECAH	.29	.23	.24	.25	.13	.09	.09	.06	.07	02	03	02	.77	.78	-					
16.BACH	.28	.25	.23	.30	.12	.12	.08	.11	.04	01	05	.00	.80	.80	.81	_				
Science co	ursewo	ork asp	oiratio	ns																
17.PAPS	.57	.20	.12	.11	.75	.30	.21	.18	.44	.25	.18	.18	.08	.05	.04	.03	_			
18.CAPS	.21	.62	.09	.22	.30	.78	.16	.31	.26	.44	.19	.27	.07	.05	.04	.06	.38	—		
19.EAPS	.14	.09	.60	.13	.21	.16	.76	.19	.18	.15	.40	.17	.03	.02	.06	.04	.26	.21	_	

.20

.18 .31

.75

Table E2 Latent correlations among self-concept, intrinsic value, utility value, achievement scores and coursework aspirations based on four science domains

Note. P = physics; C = chemistry; E = earth science; B = biology; SC = self-concept; IV= intrinsic value; UV = utility value; Standardised errors for all correlation coefficients are approximately .01. All correlations greater than .023 or less than -.023 are statistically significant (p < .05); shaded correlations are convergent validity coefficients involving two constructs in matching domains.

.45

.01 .03 .04

.06

.22 .35 .25 -

.17 .27 .19

Supplement analyses for invariance tests of item uniquenesses and intercepts and factor means

As noted in the main text, our findings provided strong support the generalizability of the factor structure of the five constructs (self-concept, intrinsic value, utility value, academic achievement, and coursework aspirations) across the four OECD countries. We also conducted supplement analyses to provide a more complete evaluation of measurement structure.

In Model MGE5, we tested strong measurement invariance in which item intercepts, as well as factor loadings, were constrained to be invariant across countries. Strong measurement invariance is an important precondition for the comparability of factor means (and, in fact, also of manifest mean comparisons) across countries. The changes in model fit between the weak invariance model (MG2) and strong invariance model (MGE5) were negligible (equivalent CFIs and RMSEAs and only slight decreases in TLIs). Thus, this finding provided strong support for strong measurement invariance for the five constructs.

Subsequently, we tested strict measurement invariance (Model MGE6), which required that item uniquenesses, item intercepts, and factor loadings were all invariant over the countries. The fit of Model MGE6 was reasonable (CFI = .949, TLI = .936; RMSEA = .029), but compared to the strong invariance model (MGE5), the decrease in fit indices (Δ CFI = .012, Δ TLI = .014, Δ RMSEA = .003) was substantially greater than the recommended cut-off values typically used to argue for the less parsimonious model. The lack of support for uniqueness invariance suggests that comparisons of manifest means of the constructs across countries is apparently inappropriate.

In Model MGE7, we tested latent mean invariance by imposing constraints on latent mean based on Model MG5. The change in model fit is marginal (Δ CFI = .001, Δ TLI = .001, Δ RMSEA = .003; also see MGE6 versus MGE8), indicating that there is no difference at the mean level of the five constructs across the four OECD countries.

An evaluation of invariance of path coefficients in multiple-group SEMs

We began with an evaluation of the SEM models without latent product variables (Models MG5- MG6). In comparison to the model with only factor loadings invariant (MG2), there was a very small decrement in fits (Δ CFI = .001, equivalent TLI& RMSEA) for Model MG5 in which factor loading and path coefficients were constrained to be the same. Model MG6 with the invariance of factor loadings, path coefficients, and factor variances and covariances (equivalent to the CFA measure model [Model MG4] with factor loading and factor variances and covariances invariances in terms of goodness of fit) provided a somewhat poorer fit to the data than Model MG5, but the difference in fit is tenable (Δ CFI = .007, Δ TLI = .004, Δ RMSEA = .001). When latent product variables were included, we also found good support for the invariance of factor loadings, path coefficients, and factor variances and covariances (Models MG6 – MG8b).

Appendix 4-F

Full results for the models

Table F1 The predictive effects of achievement on self-concept, intrinsic value and utility value based on four science domains

	Motivation outcome variables								
		Model MG6							
Predictors	Self-concept	Intrinsic value	Utility value						
		Physics							
Physics Ach	.16 (.02)*	.13 (.02)*	.09 (.02)*						
Chemistry Ach	.17 (.02)*	.11 (.02)*	.11 (.02)*						
Earth science Ach	.06 (.02)*	00 (.02)	.01 (.02)						
Biology Ach	02 (.02)	08 (.02)*	13 (.02)*						
		Chemistry							
Physics Ach	.09 (.02)*	.03 (.02)	.00 (.02)						
Chemistry Ach	.12 (.02)*	.11 (.02)*	.09 (.02)*						
Earth science Ach	.01 (.02)	.06 (.02)*	08 (.02)*						
Biology Ach	.07 (.02)*	.04 (.02)*	01 (.02)						
		Earth science							
Physics Ach	.00 (.02)	03 (.02)	07 (.02)*						
Chemistry Ach	.00 (.02)	03 (.02)	.08 (.02)*						
Earth science Ach	.15 (.02)*	.10 (.02)*	.02 (.02)						
Biology Ach	.11 (.02)*	.04 (.02)*	07 (.02)*						
		Biology							
Physics Ach	14 (.02)*	18 (.02)*	08 (.02)*						
Chemistry Ach	.08 (.02)*	.05 (.02)*	.13 (.02)*						
Earth science Ach	.04 (.02)*	.03 (.02)	07 (.02)*						
Biology Ach	.32 (.02)*	.23 (.02)*	.02 (.02)						
Summary (Means acros	ss different sets of	f path coefficients ba	ased on 4 domains						
Mn Total	.07 (.00)*	.03 (.00)*	.00 (.00)						
Mn Match	.19 (.01)*	.14 (.02)*	.05 (.01)*						
Mn NoMatch	.04 (.01)*	02 (.00)*	02 (.00)*						
Difference	.15 (.01)*	.16 (.01)*	.07 (.01)*						

Note. SC = self-concept; IV= intrinsic value; UV = utility value; Ach = Achievement; shaded estimates are path coefficients from achievement to motivational constructs in the matching domain; * p < .05

Table F2 The predictive effects of self-concept, intrinsic value, utility value and their interactions on coursework aspiration based on four science domains

	Motivation predictors									
				Model	MG6					
		SC	IV	UV	SC	IV	UV			
Physics	Physics	.07 (.03)*	.68 (.03)*	.06 (.01)*	.05 (.03)*	.72 (.03)*	.06 (.01)*			
Coursework	Chemistry	02 (.03)	.04 (.03)	.02 (.01)	02 (.02)	.03 (.02)	.02 (.01)			
Aspirations	Earth science	.05 (.02)*	.06 (.02)*	.01 (.01)	.05 (.02)*	.04 (.02)	.01 (.01)			
	Biology	05 (.02)*	08 (.02)*	.03 (.01)*	05 (.02)*	06 (.02)*	.02 (.01)			
Chemistry	Physics	01 (.03)	.02 (.03)	.02 (.01)	.01 (.02)	01 (.02)	.02 (.01)			
Coursework	Chemistry	.08 (.03)*	.69 (.03)*	.06 (.01)*	.08 (.03)*	.73 (.03)*	.06 (.01)*			
Aspirations	Earth science	.06 (.02)*	.02 (.02)	.01 (.01)	.05 (.02)*	.01 (.02)	.02 (.01)			
	Biology	.02 (.02)	02 (.02)	.01 (.01)	.02 (.02)	02 (.02)	01 (.01)			
Earth	Physics	05 (.03)	.06 (.03)	.01 (.01)	03 (.02)	.02 (.02)	.02 (.01)			
science	Chemistry	.03 (.02)	04 (.02)	.01 (.01)	.02 (.02)	04 (.02)	01 (.01)			
Coursework	Earth science	.10 (.03)*	.66 (.02)*	.06 (.01)*	.07 (.02)*	.71 (.02)*	.05 (.01)*			
Aspirations	Biology	03 (.02)	.01(.02)	.01 (.01)	02 (.02)	00 (.02)	.01 (.01)			
Biology	Physics	05 (.02)*	.01 (.03)	.02 (.01)	05 (.02)*	02 (.02)	.02 (.01)			
Coursework	Chemistry	02 (.03)	.05 (.02)*	01 (.01)	01 (.02)	.05 (.02)*	01 (.01)			
Aspirations	Earth science	04 (.02)	.02 (.02)	.01 (.01)	04 (.02)	.01 (.02)	.01 (.01)			
	Biology	.13 (.02)*	.63 (.02)*	.07 (.01)*	.08 (.02)*	.66 (.02)*	.07 (.01)*			
Mn Total		.03 (.01)*	.17(.00)*	.03 (.00)*	.01 (.01)	.18 (.00)*	.02 (.00)*			
Mn Match		.10(.01)*	.67 (.01)*	.06 (.01)*	.07 (.01)*	.70 (.01)*	.06 (.01)*			
Mn NoMate	h	.01 (.01)	.01 (.01)	.02 (.00)*	01 (.01)	.00 (.00)	.01 (.00)*			
Difference		.09 (.02)*	.66 (.01)*	.05 (.01)*	.08 (.02)*	.70 (.02)*	.06 (.01)*			

Note. SC = self-concept; IV= intrinsic value; UV = utility value; SCxIV = self-concept by intrinsic value interaction; SCxUV = self-concept by utility value interaction; shaded estimates are path coefficients from motivational constructs to coursework aspirations in the matching domain; * p < .05.

Table F3 The predictive effects of self-concept, intrinsic value, utility value and their interactions on coursework aspiration based on four science domains

		Motivation predictors												
			Model	MG7b			Model	MG8b						
Outcomes		SC	IV	UV	SCxIV	SC	IV	UV	SCxUV					
Physics	Physics	.08 (.03)*	.67 (.03)*	.07 (.01)*	.09 (.01)*	.05 (.03)*	.72 (.03)*	.06 (.01)*	.07 (.01)*					
Coursework	Chemistry	02 (.03)	.05 (.03)	.02 (.01)	02 (.01)	02 (.02)	.03 (.02)	.02 (.01)	01 (.01)					
Aspirations	Earth science	.05 (.02)*	.06 (.02)*	.01 (.01)	02 (.01)*	.05 (.02)*	.04 (.02)	.01 (.01)	00 (.01)					
_	Biology	05 (.02)*	07 (.02)*	.03 (.01)*	01 (.01)	05 (.02)*	06 (.02)*	.02 (.01)	00 (.01)					
Chemistry	Physics	01 (.03)	.03 (.03)	.02 (.01)	04 (.01)*	.01 (.02)	01 (.02)	.02 (.01)	.01 (.010)					
Coursework	Chemistry	.07 (.03)*	.68 (.03)*	.05 (.01)*	.12 (.01)*	.07 (.03)*	.73 (.03)*	.06 (.01)*	.06 (.01)*					
Aspirations	Earth science	.06 (.02)*	.03 (.02)	.01 (.01)	03 (.01)*	.06 (.02)*	.01 (.02)	.02 (.01)	02 (.009)					
	Biology	.02 (.02)	03 (.02)	.01 (.01)	.01 (.01)	.01 (.02)	02 (.02)	01 (.01)	.05 (.010)					
Earth science	Physics	05 (.03)	.05 (.03)	.01 (.01)	02 (.01)*	03 (.02)	.02 (.02)	.02 (.01)	.01 (.01)					
Coursework	Chemistry	.03 (.02)	04 (.02)	.01 (.01)	.01 (.01)	.02 (.02)	04 (.02)	01 (.01)	.02 (.01)					
Aspirations	Earth science	.11 (.03)*	.65 (.02)*	.05 (.01)*	.13 (.01)*	.08 (.02)*	.71 (.02)*	.05 (.01)*	.07 (.01)*					
	Biology	03 (.02)	.01(.02)	.01 (.01)	02 (.01)*	02 (.02)	00 (.02)	.01 (.01)	02 (.01)*					
Biology	Physics	05 (.02)*	.01 (.03)	.02 (.01)	03 (.01)*	05 (.02)*	02 (.02)	.02 (.01)	.00 (.01)					
Coursework	Chemistry	02 (.03)	.05 (.02)*	01 (.01)	01 (.01)	01 (.02)	.05 (.02)*	01 (.01)	02 (.01)					
Aspirations	Earth science	04 (.02)	.02 (.02)	.01 (.01)	03 (.01)*	04 (.02)	.01 (.02)	.01 (.01)	01 (.01)					
	Biology	.12 (.02)*	.62 (.02)*	.08 (.01)*	.15 (.01)*	.08 (.02)*	.66 (.02)*	.07 (.01)*	.08 (.01)*					
Summary (Me	ans across different	sets of path coe	fficients based	on 4 domains										
Mn Total		.03 (.01)*	.17(.00)*	.03 (.00)*	.02 (.00)*	.01 (.01)	.18 (.00)*	.02 (.00)*	.02 (.00)*					
Mn Match		.10(.01)*	.66 (.01)*	.06 (.01)*	.12 (.01)*	.07 (.01)*	.70 (.01)*	.06 (.01)*	.07 (.01)*					
Mn NoMatch		.01 (.01)	.01 (.01)	.02 (.00)*	02 (.00)*	01 (.01)	.00 (.00)	.01 (.00)*	00 (.00)					
Difference		.09 (.02)*	.66 (.01)*	.05 (.01)*	.14 (.01)*	.08 (.02)*	.70 (.02)*	.06 (.01)*	.08 (.01)*					

Note. SC = self-concept; IV= intrinsic value; UV = utility value; SCxIV = self-concept by intrinsic value interaction; SCxUV = self-concept by utility value interaction; shaded estimates are path coefficients from motivational constructs to coursework aspirations in the matching domain; * p < .05.

External Appendix G:

Supplemental analyses for interaction effect between self-concept and value

In the main text, latent interactions between self-concept and intrinsic value as well as between self-concept and utility value, when these two multiplicative terms (self-concept x intrinsic value and self-concept x utility value) are considered separately. Subsequently, we included the two sets of latent interactions into the same model (i.e. Model MG9a – MG9c in Table G1). All first-order effects and interaction effects between selfconcept and intrinsic value were significantly positive and similar in size with the pattern of results from Model MG7a-MG7b (See Table 2 in the main text) where only self-concept and intrinsic value interactions were included (see Table G2). However, the interactions between self-concept and utility value lost their predictive power on coursework aspirations. Given that correlations between matching domains of latent product variables were substantial (r = .58 to .69, Table G3), we argue that the parameters involving interaction effects in this model should be interpreted with caution. In Model MG10c, we constrained the paths leading from self-concept by intrinsic value interactions to aspirations and those from self-concept by utility value interactions to be equal. The model fits the data as well, and there was a very small decrement in CFI (Δ .001) and RMSEA (Δ .001) but no difference in TLI in comparison to Model MG9c. We also found a notable reduction in the size of the standard errors (from [.011 to .016] to [.004 to .006]) associated with the paths from all domainspecific interactions to aspirations. The results for this model show that all domain-specific interactions positively predicted matching measures of aspirations (M = .06, SE = .003). Thus, the results suggest that both types of domain-specific latent interaction (self-concept-byintrinsic value, and self-concept-by- utility value) may make similar contributions to the prediction of coursework aspirations (Marsh, Dowson, Pietsch & Walker, 2004).

Model	Description	χ^2	df	CFI	TLI	RMSEA
SEM						
MG9a	SC + IV + UV + ACH + ASP, CUs, INV = FL, FV, PC; Free = PT(scXiv, scXuv)	33843	10516	.946	.936	.022
MG9b	SC + IV + UV + PT(scXiv,scXuv) + ACH + ASP, CUs, INV = FL, FV, PC	34934	10792	.945	.935	.022
MG9c	SC + IV + UV + PT(scXiv,scXuv) + ACH + ASP, CUs, INV = FL, FV, CV, PC	38453	11398	.939	.931	.023
MG10a	SC + IV + UV + ACH + ASP, CUs, INV = FL, FV, PC; Free = PT(scXiv, scXuv), PC (scXiv = scXuv)	34039	10580	.946	.936	.022
MG10b	SC + IV + UV + PT(scXiv,scXuv) + ACH + ASP, CUs, INV = FL, FV, PC (scXiv = scXuv)	35081	10808	.944	.935	.022
MG10c	SC + IV + UV + PT(scXiv,scXuv) + ACH + ASP, CUs, INV = FL, FV, CV, PC (scXiv = scXuv)	38629	11414	.938	.931	.023

Table G1 Model fit statistics for cfa and sem models used in the present study

Note. SC = self-concept; IV= intrinsic value; UV = utility value; PT = product term; ASP = coursework aspirations; scXiv = the product term of self-concept by intrinsic value interaction; scXuv = the product term of self-concept and utility value interaction; INV = invariant; CUs = correlated uniquenesses; UCUs = uncorrelated uniquenesses; FL = factor loading; FV = factor variances; CV = factor covariances; Free = PT (scXiv): freely estimate factor loading, factor variances and covariance and path coefficients with respect to scXiv; Free = PT (scXuv): freely estimate factor loading, factor variance and path coefficients with respect to scXiv; Free = PT (scXiv): freely estimate factor variance and path coefficients with respect to scXiv; PC (scXiv = scXuv): constrain the path coefficients from scXiv to ASP and from scXuv to ASP to be equal

Table G2 the predictive effects of self-concept, intrinsic value, utility value and their interactions on coursework aspiration based on four science domains (standardised path coefficients as a ratio of standard errors)

Outcome♥					Motivation	Predictors				
			Ν	Iodel MG9c				Mod	el MG10c	
		SC	IV	UV	SCxIV	SCxUV	SC	IV	UV	scXiv = scXuv
Physics	Physics	.064/.028	.686/.030	.083/.016	.063/.015	.045/.013	.060/.027	.696/.029	.078/.016	.053/.005
Coursework	Chemistry	026/.025	.040/.026	.016/.013	021/.013	.004/.013	019/.025	.032/.025	.018/.013	008/.005
Aspirations	Earth science	071/.024	.054/.023	.004/.011	025/.012	.008/.013	062/.023	.044/.022	.007/.011	009/.005
	Biology	047/.023	065/.022	.022/.012	.002/.013	008/.015	047/.023	061/.022	.022/.012	002/.005
Chemistry	Physics	011/.027	.024/.027	.023/.015	048/.014	.024/.013	.017/.028	012/.027	.030/.015	008/.006
Coursework	Chemistry	.074/.027	.689/.027	.057/.013	.113/.013	.005/.014	.061/.028	.718/.028	.053/.013	.059/.006
Aspirations	Earth science	061/.023	.019/.022	.017/.011	031/.013	.001/.013	061/.024	.019/.022	.017/.011	015/.005
	Biology	.018/.022	016/.021	002/.013	010/.013	.018/.014	.015/.022	013/.021	004/.013	.003/.005
Earth science	Physics	067/.027	.024/.028	.019/.014	051/.013	.029/.013	035/.027	.024/.027	.027/.015	009/.006
Coursework	Chemistry	.028/.024	043/.024	.006/.014	011/.012	.020/.013	.029/.025	045/.025	.007/.014	.006/.005
Aspirations	Earth science	.101/.025	.662/.024	.060/.011	.130/.014	001/.013	.067/.025	.703/.024	.048/.011	.063/.005
	Biology	033/.022	.005/.021	.011/.013	021/.014	005/.014	024/.022	001/.021	.012/.013	015/.004
Biology	Physics	023/.027	.004/.028	.021/.016	036/.013	.017/.011	006/.026	019/.026	.020/.015	006/.005
Coursework	Chemistry	048/.024	.046/.024	001/.014	017/.012	.006/.012	054/.024	.052/.025	001/.014	010/.005
Aspirations	Earth science	042/.023	.018/.022	.007/.012	030/.013	.007/.013	041/.023	.017/.021	.016/.012	014/.005
	Biology	.123/.023	.635/.022	.077/.012	.159/.015	019/.016	.110/.023	.644/.022	.063/.013	.073/.004
Summary (Me	ans across differe	ent sets of path	coefficients ba	used on 4 dom	nains)					
Mn Total		.003/.003	.174/.003	.027/.002	.010/.003	.010/.003	.003/.003	.175/.003	.027/.002	.010/.001
Mn Match		.090/.012	.668/.013	.069/.006	.116/.007	.008/.007	.075/.013	.690/.013	.061/.006	.062/.003
Mn NoMacth		032/.005	.011/.005	.013/.003	025/.003	.010/.003	024/.005	.003/.005	.015/.003	007/.001
Difference		.122/.016	.657/.017	.056/.007	.141/.008	002/.008	.099/.017	.687/.017	.046/.007	.069/.004

Note. SC = self-concept; IV = intrinsic value; UV = utility value; scXiv = self-concept by intrinsic value interaction; scXuv = self-concept by utility value interaction. Shaded estimates are path coefficients from motivational constructs to coursework aspirations in the matching domain

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an		U.			, correlation	among	produce	variables	Dascu	UII	IUUI	science	uomanns

	Self-co	oncept by	v intrinsi	c value	Self-co	Self-concept by utility value						
	1	2	3	4	5	6	7	8				
Science self-concept by intrinsic value												
1.PSCxIV	_											
2.CSCxIV	.379	_										
3.ESCxIV	.251	.214	_									
4.BSCxIV	.220	.334	.279	_								
Science self-	-concept	by utilit	y value									
5.PSCxUV	.577	.196	.152	.135	_							
6.CSCxUV	.235	.586	.131	.201	.345	_						
7.ESCxUV	.136	.101	.574	.139	.226	.213	_					
8.BSCxUV	.130	.149	.144	.637	.192	.255	.214	_				

Note. P = physics; C = chemistry; E = earth science; B = biology; SC = self-concept; IV = intrinsic value; UV = utility value; scXiv = self-concept by intrinsic value interaction; scXuv = self-concept by utility value interaction.

Supplemental Materials: Study 5

External Appendix 5-A

Factor structure, mean, standard deviation, distribution for the scales of self-concept and self-reported effort Table A1 Factor structure, mean, standard deviation, and distribution for the scales of self-concept and self-reported effort

Variables	Items	Factor	М	SD	Skewness	Kurtosis
		loading				
Self-concept	I'm not talented in math.	.83	2.17	.96	.42	79
	Doing math does not come naturally to me.	.88	2.34	.98	.18	99
	I'm good at math.	.88	2.67	.89	13	74
	Doing math is easy for me.	.88	2.49	.93	.00	86
	I always have a hard time with math tasks.	.71	2.07	.82	.40	40
Self-reported effort	I work hard in math.	.68	2.45	.72	.06	27
	I give my best in math.	.78	3.02	.78	43	31
	I really put an effort into math.	.81	2.89	.77	28	35
	I work very thoroughly on all of my math tasks and homework assignments	.60	2.73	.78	14	42
	I don't give up even when math tasks are difficult.	.43	2.66	.82	01	61
	I participate in math classes as well as I can.	.58	3.14	.74	51	19

External Appendix 5-B

Supplemental materials for descriptive statistics and intercorrelations

Table B1 Mean, standard deviation, distribution and intercorrelations among motivational beliefs and outcome variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Self-concept																		
First-order value components																		
2. Importance of achievement	.41																	
3. Personal importance	.58	.87																
4. Utility of school	.20	.68	.69															
5. Utility for diary life	.35	.43	.61	.47														
6. Social utility	.28	.39	.46	.30	.36	—												
7. Utility for job	.35	.55	.63	.66	.51	.27												
8. General utility for future life	.45	.48	.69	.52	.86	.32	.76											
9. Low effort required	.76	.25	.45	.12	.25	.20	.21	.33										
10. Low emotional cost	.79	.34	.56	.31	.33	.19	.31	.44	.90									
11. Low opportunity cost	.58	.17	.27	.10	.16	(.04)	.14	.23	.65	.67								
12. Intrinsic value	.80	.50	.76	.38	.49	.40	.39	.53	.70	.76	.47							
Second-order value components																		
13. Attainment value	.55					—						.72						
14. Utility value	.45					—						.57	.75					
15. Low cost	.82					—						.76	.50	.41				
Outcomes																		
16. Achievement	.53	.22	.27	.16	.20	.10	.18	.23	.42	.45	.32	.42	.27	.24	.46			
17. Self-reported effort	.30	.52	.60	.24	.30	.15	.28	.35	.23	.24	.17	.40	.60	.36	.25	.18		
18. Teacher-rated engagement	.36	.23	.28	.12	.15	.07	.14	.17	.29	.30	.22	.31	.28	.18	.31	.47	.38	
M	2.72	2.95	2.67	3.12	2.40	1.74	3.08	2.70	1.63	1.98	2.28	2.25	2.95	2.61	1.93	48.25	2.82	2.90
SD	.81	.65	.62	.59	.73	.63	.70	.74	.83	.78	.73	.85	.65	.48	.68	17.31	.55	.81
Skewness	26	32	14	42	.06	.68	53	16	07	62	95	.27	32	05	39	.25	22	26
Kurtosis	85	14	36	.22	55	.06	18	48	.88	.27	31	82	14	24	.60	34	.09	68

External Appendix 5-C

Supplemental materials for factor structure based on second-factor models Table C1 Standardised factor loadings for second-order cfa of value beliefs (SO-4V)

Items							Fa	ctor					
	IV	ACH	PER	SCH	DAI	SOC	JOB	FUT	EFF	EMO OPP	AV	UV	СО
Y1	.91												
Y2	.92												
Y3	.90												
Y4	.81												
Y5		.78											
Y6		.82											
Y7		.84											
Y8		.78											
Y9			.70										
Y10			.70										
Y11			.68										
Y12			.79										
Y13			.59										
Y14			.77										
Y15				.53									
Y16				.66									
Y17					.79								
Y18					.80								
Y19					.79	6.0							
Y20						.69							
Y21						.63							
Y22						.83	-1						
Y23							.71						
Y24							.72	0.0					
Y25								.80					
Y26								.81	77				
Y2/									.//				
Y 28									.81				
Y 29									.86				
Y 30									.90	76			
1 3 I V22										./0			
1 32 V22										./ð 07			
1 3 3 V 2 4										.0/ 75			
1 54 V25										./3			
155 V26										.00			
1 30 V27										.02 92			
										.03	83		
PER											1 00		
SCH											1.00	65	
SCII												.05	

Supplemental Materials – Study 5	300
DAI	.83
SOC	.41
JOB	.76
FUT	.95
EFF	.91
EMO	.99
OPP	.68
X = I = I = I = I = I = I = I = I = I =	-1

Note. IV = Intrinsic value; AV = Attainment value; ACH= Importance of achievement; PER = Personal importance; UV = Utility value; SCH = Utility for school; DAI = Utility for daily life; SOC = Social utility; JOB = Utility for job; FUT = General utility for future life; CO = Cost; EFF = Effort required; EMO = Emotional cost; OPP = Opportunity cost.

Table C2 Standardised factor loadings for second-order bi-factor cfa model (SO-B-4V)

Items									Factors	3				
	IV A	АСН	PER	SCH	DAI	SOC	JOB	FU	JT EFI	F EMO	OPP AV	UV	CO	Global
Y1	.36													.84
Y2	.35													.85
Y3	.30													.84
Y4	.22													.78
Y5		.63												.46
Y6		.65												.49
Y7		.68												.47
Y8		.72												.37
Y9			.53											.48
Y10			.24	Ļ										.67
Y11			.52	2										.47
Y12			.33											.72
Y13			.23											.55
Y14			.53											.58
Y15				.47	7									.22
Y16				.60)									.31
Y17					.62	2								.47
Y18					.65	5								.45
Y19					.73	3								.38
Y20						.64	4							.23
Y21						.48	8							.44
Y22						.8	1							.30
Y23							.6	1						.34
Y24							.64	4						.36
Y25									.62					.51
Y26									.67					.49
Y27									.4	7				63 ^a
Y28									.5	8				56 ^a
Y29									.6	8				55 ^a
Y30									.6	5				62 ^a

Y31	.44	62 ^a
Y32	.43	64 ^a
Y33	.58	66 ^a
Y34	.57	51 ^a
Y35	.71	19 ^a
Y36	.78	32 ^a
Y37	.67	46 ^a
ACH	.94	
PER	.90	
SCH	.41	
DAI	.75	
SOC	.11	
JOB	.62	
FUT	1.00	
EFF		.85
EMO		.91
OPP		.63

Note. ^a items were used to measure perceived cost. All factor loadings were statistically significant at the .001 level of confidence. All value facets are labelled by acronym (see Table C1).

External Appendix 5-D

Plot comparisons between uncentred (raw scores) and centred regression equations according to Aiken & West (1991)

Capital letters were assigned to a raw score and lowercase letters were assigned to its deviation from the mean. Two regression models describe the same regression surface:

$$Y = \beta_{10} + \beta_{11}X + \beta_{12}Z + \beta_{13}XZ + \varepsilon_1$$
(1)

$$Y = \beta_{20} + \beta_{21}x + \beta_{22}z + \beta_{22}xz + \varepsilon_2$$

$$\tag{2}$$

$$x = X - \mu , y = Y - \mu$$
(3)

And

After substituting (1) into (2) and regrouping terms,

$$Y = (\beta_{20} - \beta_{21}\mu_x - \beta_{22}\mu_y + \beta_{23}\mu_x\mu_y) + (\beta_{21} - \beta_{23}\mu_y)X + (\beta_{22} - \beta_{23}\mu_x)Z + \beta_{23}XZ$$
(4)

Supposed that the lowercase letter *x*,*z* presented centred predictors with 1 SD. The capital letter *X*,*Z* presented the raw categorical predictors ranging from 1 to 5 with mean = 3 and 1 SD. The outcome Y was also mean centred with 1SD. We supposed the pure synergistic interaction ($\beta_{20} = 0, \beta_{21} = 0, \beta_{22} = 0, \beta_{23} = .30$). Based on (1.4), these regression coefficients were converted to

$$(\beta_{10} = 2.7, \beta_{21} = -0.9, \beta_{22} = -0.9, \beta_{23} = .30).$$


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Research Portfolio Appendix

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