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Appendices

Growth mindsets, workmastery, and socioeconomic status interact in predicting achievement of adolescents in Southeast Asia

Suppanut Sriutaisuk[a,b,*], Thipnapa Huansuriya[a], Allison Master[b]

[a] *Faculty of Psychology, Chulalongkorn University, Bangkok 10330, Thailand*

[b] *Department of Psychological, Health, & Learning Sciences, University of Houston, Texas 77204, United States*

Appendices

Appendix A Materials

Analysis Plan

A series of three-level multilevel models were conducted using Mplus version 8.6 through R software on a Linux cluster. We utilized three-level models because these could accommodate the nested structure of the PISA data: students (Level 1) nested within schools (Level 2) and schools nested within countries (Level 3). For each outcome (reading, math, and science achievement), we examined four three-level multilevel models: the null model, the baseline model, the two-way interaction model, and the three-way interaction model.

First, the null model estimated only the mean, within-student variance, between-school variance, and between-country variance for each outcome. Second, the baseline model examined whether student achievement in a certain domain could be predicted by growth mindset, workmastery, and socioeconomic status, controlling for gender. Third, in the two-way model, three two-way interactions between (1) growth mindsets and workmastery, (2) growth mindsets and socioeconomic status, and (3) workmastery and socioeconomic status were added to the previous model. This model addressed the first research question examining whether workmastery could moderate the predictive effect of growth mindsets on achievement. Finally, the second research question was examined by including the three-way interaction between growth mindsets, workmastery, and socioeconomic status to the previous model. Random effects of all predictors and interactions were estimated. These random effects represent whether the fixed effects of predictors and interactions differ across countries.

To probe the interaction, we computed the predicted achievement (PISA scores) at two values of growth mindsets, workmastery, and socioeconomic status. The two values were one standard deviation below and above the mean of each variable, representing *low* and *high* levels of the relevant construct. Low and high growth mindsets were defined as fixed and growth mindsets, respectively. We were especially interested in looking at the achievement benefits of growth mindsets over fixed mindsets at different levels of workmastery and socioeconomic status. The achievement benefits of growth mindsets were defined as the score-point differences in PISA scores between growth- and fixed-mindset students.

There were missing values in growth mindset (2%), workmastery (3%), and socioeconomic status (1%). We used multiple imputation to impute plausible values of these predictors, resulting in three imputed predictors. The procedure for analyzing plausible values from multiple imputation and plausible values of achievement provided by PISA is the same (OECD, 2009). First, we generated 10 imputed datasets, aligned with 10 plausible values variables for each outcome. That is, each imputed dataset contained three plausible values variables of the outcomes (reading, math, and science achievement), three imputed predictors (growth mindsets, workmastery, socioeconomic status), and other relevant variables (e.g., gender). Second, these 10 imputed datasets were analyzed one at a time, resulting in 10 sets of results for each outcome and analysis model. Lastly, each of the 10 sets of results were combined into a single set of results using Rubin's method. These steps were semi-automated in Mplus.

In addition, to ensure that we obtained unbiased population parameter estimates of 15-year-old students, the final student weights variable (W_FSTUWT) was normalized and used in all analyses.

Cross-Country Comparability

The PISA 2018 team carefully developed all measures so that they measured the same underlying constructs in different countries. For example, the procedures to assure measurement quality included (1) a review of all measures by representatives of participating countries, (2) piloting on small groups of students, (3) translatability assessment by linguistic experts, and (4) verification of all translated items by several groups of experts in each country. In addition, statistical approaches were used to evaluate each measure. The results showed that the invariance of item parameters across countries and languages could be assumed (see the *PISA 2018 Technical Report* for details).[1] However, as a single-item measure was used to assess growth mindsets, the invariance testing was not applicable for this measure.

Appendix B Results from Multilevel Models for reading achievement

Variable	Null Model		Baseline Model		Two-Way Model		Three-Way Model	
	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
				Fixed Effect				
Intercept	414.15***	23.97	398.76***	22.24	397.42***	22.82	396.84***	22.81
Gender			-19.10***	1.29	-18.94***	1.31	-18.92***	1.31
MS			14.72***	1.68	15.87***	1.60	16.25***	1.47
WM			15.47***	2.58	11.46***	2.54	12.35***	2.65
SES			12.28***	2.87	11.07**	3.92	10.40**	3.87
MS×WM					2.06***	0.47	1.57	0.82
MS×SES					1.51	1.17	1.99	1.20
WM×SES					-2.01	1.12	-0.35	0.81
MS×WM×SES							-1.06*	0.47
				Random Effect				
				School-Level				
MS			34.15**	11.48	24.16**	7.12	24.07**	7.05
WM			48.88*	19.38	12.19	10.63	15.98	10.99
SES			24.19**	9.21	22.23*	9.63	21.96*	9.67
MS×WM					11.10**	3.98	9.72*	3.87
MS×SES					0.78	1.79	0.76	1.94
WM×SES					0.01	15.01	0.09	20.68
MS×WM×SES							0.02	1.93
				Country-Level				
MS			14.11	7.84	13.21*	6.47	11.47	6.30
WM			45.36	27.95	36.56	23.45	38.09	25.36
SES			41.38*	16.43	72.16	43.32	69.34	45.48
MS×WM					0.64	0.72	2.25	1.87
MS×SES					6.58	4.33	6.88	4.58
WM×SES					6.36**	2.19	1.98	2.35
MS×WM×SES							1.10	1.03
				Variance				
Student	4806.88***	706.07	4102.23***	636.30	4088.69***	630.62	4087.84***	629.86
School	5726.77	8169.17	2146.18***	314.59	2138.44***	312.40	2134.48***	312.22
Country	5791.30	7248.58	2901.42	1863.10	3045.06	1903.54	3043.63	1916.00

Note: Pooled results across 10 imputed datasets. Estimates are unstandardized. Gender was centered (-.5 = *girls*, .5 = *boys*). *SE* = standard error; SES = socioeconomic status; MS = mindset; WM = workmastery.
* $p < .05$. ** $p < .01$. *** $p < .001$.

1 https://www.oecd.org/pisa/data/pisa2018technicalreport/

Appendix C Results from Multilevel Models for math achievement

Variable	Null Model		Baseline Model		Two-Way Model		Three-Way Model	
	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
				Fixed Effect				
Intercept	433.04***	24.72	421.33***	24.03	421.15***	24.81	420.79***	24.78
Gender			-0.37	2.25	-0.24	2.24	-0.23	2.24
MS			12.59***	1.32	13.50***	1.22	13.74***	1.21
WM			12.98***	2.58	9.09***	2.26	9.68***	2.15
SES			11.40***	2.87	10.52*	4.16	10.04*	4.09
MS×WM					2.02**	0.64	1.70*	0.80
MS×SES					1.09	1.06	1.43	1.10
WM×SES					-1.86*	0.90	-0.65	0.67
MS×WM×SES							-0.77†	0.39
				Random Effect				
				School-Level				
MS			28.57**	10.76	18.39*	7.18	18.16*	7.09
WM			45.97***	13.07	21.65*	9.37	22.21*	9.46
SES			28.15**	8.28	20.25*	9.31	20.34*	9.36
MS×WM					8.53	4.63	8.11	4.50
MS×SES					3.82*	1.93	3.74	1.98
WM×SES					0.05	5.29	0.28	6.69
MS×WM×SES							0.04	1.00
				Country-Level				
MS			7.63	6.26	5.96	4.79	6.02	4.67
WM			44.86	25.90	29.33	17.84	28.34	18.03
SES			40.33*	16.99	79.47	50.09	76.48	51.66
MS×WM					1.92	1.24	2.30	1.93
MS×SES					4.57	3.97	4.94	4.17
WM×SES					3.51*	1.69	0.89	1.50
MS×WM×SES							0.80	0.70
				Variance				
Student	4676.88***	417.88	4208.12***	367.89	4191.17***	365.91	4190.78***	365.91
School	5785.69	6687.37	2466.25***	496.38	2464.63***	496.27	2463.04***	495.40
Country	5895.29	5995.40	3404.01	1976.61	3600.96	2102.67	3598.67	2109.29

Note: Pooled results across 10 imputed datasets. Estimates are unstandardized. Gender was centered (-.5 = *girls*, .5 = *boys*). *SE* = standard error; SES = socioeconomic status; MS = mindset; WM = workmastery.

† $p = .051$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix D Results from Multilevel Models for science achievement

Variable	Null Model		Baseline Model		Two-Way Model		Three-Way Model	
	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
				Fixed Effect				
Intercept	436.28***	22.34	419.41***	19.93	418.38***	20.66	417.82***	20.62
Gender			0.63	2.07	0.75	2.07	0.76	2.07
MS			14.86***	1.73	16.02***	1.61	16.39***	1.50
WM			13.17***	2.08	9.43***	2.02	10.35***	2.18
SES			11.83***	2.78	10.92**	4.13	10.27*	4.05
MS×WM					1.92**	0.60	1.40	0.84
MS×SES					1.22	1.20	1.68	1.21
WM×SES					-1.89	1.00	-0.26	0.84
MS×WM×SES							-1.06*	0.43
				Random Effect				
				School-Level				
MS			32.16**	11.09	21.48**	6.30	21.44**	6.35
WM			30.08**	10.44	1.83	7.80	1.69	8.97
SES			21.55*	9.23	11.23	7.90	11.67	8.00
MS×WM					8.04*	3.14	7.55*	3.15
MS×SES					3.85**	1.22	3.70**	1.25
WM×SES					0.02	9.20	0.10	11.11
MS×WM×SES							0.02	1.21
				Country-Level				
MS			14.63	9.46	13.72	7.76	12.37	7.62
WM			25.69	14.05	20.97	14.81	23.70	16.34
SES			41.44*	19.10	85.04	56.57	82.08	57.82
MS×WM					1.24	0.84	2.32	1.49
MS×SES					7.09	5.19	7.18	5.29
WM×SES					4.39*	1.91	1.62	1.78
MS×WM×SES							0.72	0.58
				Variance				
Student	4314.82***	564.08	3808.33***	480.58	3798.46***	476.41	3798.35***	476.17
School	3069.50***	502.44	1884.51***	320.68	1856.62***	315.56	1853.35***	314.43
Country	4994.98	7309.48	2276.37	1285.39	2503.46	1438.91	2500.57	1444.93

Note: Pooled results across 10 imputed datasets. Estimates are unstandardized. Gender was centered (-.5 = *girls*, .5 = *boys*). *SE* = standard error; SES = socioeconomic status; MS = mindset; WM = workmastery.

* $p < .05$. ** $p < .01$. *** $p < .001$.