Trends in student motivation profiles in TIMSS Mathematics across 20 years: Insights from cluster analysis

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Acknowledgments

- IEA Research for Education Series
- IEA Call no. IEA 07/09-2017

- Michaelides, M. P., Brown, G., & Eklöf, H., & Papanastasiou, E. C., (2019). *Profiles in TIMSS Mathematics: Exploring Student Clusters across Countries and Time.* Cham, CH: IEA & SpringerOpen.

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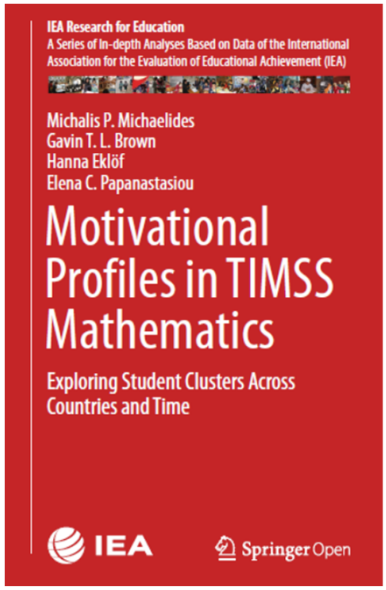

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Theoretical framework

- Various theoretical frameworks have posited the link between motivation to learn and academic success (e.g. Deci & Ryan, 1985; Wigfield & Eccles, 2000)
  - **Confidence** perceptions as indicators of self-concept are thought to relate to more engagement with purposeful behavior, academic tasks, and are more likely to lead to successful outcomes
  - Ascribing **value** to a task and its outcome is another factor linked to academic performance that includes both intrinsic characteristics like **enjoyment, interest** and importance for one's identity, as well perceptions of usefulness
  - Moreover, these affective and motivational attributes are considered as valued schooling outcomes themselves

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Meta-analytic or multiple-sample findings

- In a meta-analysis of 288 studies, Hattie (2009) reported that attitudes toward mathematics and science correlate with achievement
- This relationship has been characterized as positive and strong (Mullis, Martin, Foy, & Arora, 2012)
- But empirical evidence suggests a less pronounced network of associations.
  - For example, in multinational analyses from PISA and TIMSS, ***weak correlations*** were found between value and affect for the subject with achievement, while relationships were moderate to strong only between self-concept in the subject and achievement (Marsh et al., 2013, Lee & Stankov, 2018)

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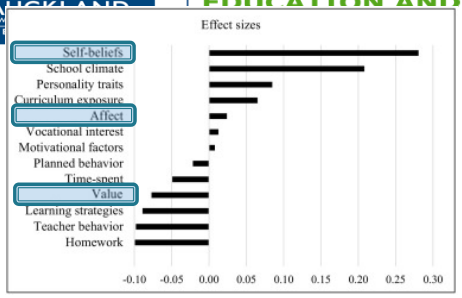
	Variable label in the TIMSS database	Variable description	Pan-cultural Level			Within-country Averages			Between-country Level		
			2011	2007	2003	2011	2007	2003	2011	2007	2003
1	BSBG05A-E	Home possessions	.462	.443	.459	.249	.275	.253	.776	.735	.774
2	BSDGEDUP	Parental education	.377	.353	.354	.313	.269	.287	.532	.582	.535
3	BSBG07	Educational aspiration	.270	.227	.299	.393	.368	.367	-.202	-.215	.073
4	BSDGSCM	Confidence with math	.253	.217	.208	.398	.397	.373	-.296	-.496	-.319
5	BSDGSBS	Feeling of school safety	.207	.177	.260	.106	.116	.113	.551	.484	.629
6	BSDGSLM	Positive affect to math	.065	.013	n/a	.258	.221	n/a	-.626	-.675	n/a
7	BSDMWKHW	Weekly time spent on math homework	.046	-.007	.013	.050	.048	.026	.008	-.152	-.082
8	BSDGSCS	Confidence with science	.039	.008	-.009	.208	.210	.190	-.621	-.688	-.631
9	BSDGSLS	Positive affect to science	-.017	-.075	n/a	.143	.087	n/a	-.765	-.696	n/a
10	BSDGSVM	Valuing math	-.038	-.025	-.085	.163	.122	.145	-.733	-.663	-.681
11	BSDGEML	Student engagement in math lessons	-.069	n/a	n/a	.145	n/a	n/a	-.785	n/a	n/a
12	BSBG12A-C	Attitude towards school	-.079	-.174	-.192	.08	.021	.033	-.712	-.721	-.736
13	BSDSWKHW	Weekly time on science homework	-.079	-.146	-.138	-.014	-.020	-.042	-.353	-.519	-.552
14	BSDGESL	Student engagement in science lessons	-.091	n/a	n/a	.104	n/a	n/a	-.842	n/a	n/a
15	BSBG11A-D	Parental involvement	-.113	n/a	n/a	-.008	n/a	n/a	-.552	n/a	n/a
16	BSDGSVS	Valuing science	-.116	-.136	-.178	.118	.095	.088	-.808	-.754	-.727
17	MATSPEC	Math specific activity	n/a	-.018	-.031	n/a	.032	.050	n/a	-.209	-.292
18	MATTRD	Traditional classroom activity in math	n/a	-.044	-.148	n/a	.098	.073	n/a	-.582	-.694
19	SCTTRD	Traditional classroom activity in science	n/a	-.06	-.226	n/a	.105	.003	n/a	-.662	-.710
20	MAHWK	Mathematics homework	n/a	-.094	n/a	n/a	-.012	n/a	n/a	-.255	n/a
21	SCEXPT	Science experiment activity	n/a	-.140	-.117	n/a	-.023	-.024	n/a	-.429	-.303
22	SCHWK	Science homework	n/a	-.145	-.187	n/a	-.037	-.007	n/a	-.417	-.509
23	BSBMEXTO	Time spent on math extra lessons	n/a	n/a	-.192	n/a	n/a	-.168	n/a	n/a	-.328
24	BSBSEXTO	Time spent on science extra lessons	n/a	n/a	-.259	n/a	n/a	-.178	n/a	n/a	-.462

Correlations between TIMSS Mathematics Achievement and Non-cognitive and SES variables



Effect sizes of TIMSS and PISA non-cognitive constructs classified into research domains.

Lee & Stankov

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Main theories considered in the theoretical framework of TIMSS

- Self-determination theory (Deci & Ryan)
- Self-concept (Marsh et al.)
- Self-efficacy (Bandura)

- Expectancy-value theory (Eccles et al.) – is not mentioned but has similarities to the operational items (Eklöf, 2007)
- Achievement goal theory (Dweck et al.) – not mentioned but past items related to performance and mastery goals

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TIMSS Confidence – Enjoyment – Value

- Three scales measured in the 8th grade assessment
- Only the first two are measured in 4th grade
- Students select the degree of agreement with each item (4-point)
- Examples from 2015

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Enjoyment: Students like learning mathematics questionnaire items

I enjoy learning mathematics

I wish I did not have to study mathematics

Mathematics is boring

I learn many interesting things in mathematics

I like mathematics

I like any schoolwork that involves numbers

I like to solve mathematics problems

I look forward to mathematics class

Mathematics is one of my favorite subjects

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Confidence: Student confidence in mathematics questionnaire items

I usually do well in mathematics

Mathematics is more difficult for me than for many of my classmates

Mathematics is not one of my strengths

I learn things quickly in mathematics

Mathematics makes me nervous

I am good at working out difficult mathematics problems

My teacher tells me I am good at mathematics

Mathematics is harder for me than any other subject

Mathematics makes me confused

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Value: Students value mathematics questionnaire items ** not administered in Gr.4 **

I think learning mathematics will help me in my daily life

I need mathematics to learn other school subjects

I need to do well in mathematics to get into the <university> of my choice

I need to do well in mathematics to get the job I want

I would like a job that involves using mathematics

It is important to learn about mathematics to get ahead in the world

Learning mathematics will give me more job opportunities when I am an adult

My parents think that it is important that I do well in mathematics

It is important to do well in mathematics

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The problem

- The relationship between motivation and achievement is moderate at best
- Motivation, affective and confidence variables are moderately correlated. Are there interactions?
  - Inconsistent profiles: e.g. '*I value Math, but I do not enjoy and do not feel very competent at Math*' vs. Consistent profiles
- TIMSS background and achievement data provide a unique opportunity to employ a person-centered approach to identify and compare student motivational profiles in low-stakes context

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Purpose of the study

- To examine:
  - whether there are meaningful profiles that can be extracted with respect to motivational and affective variables from the TIMSS 2015 data across 12 jurisdictions,
  - the relationship of these profiles with achievement, and
  - their relationship to gender and a measure of home educational resources

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Sample

- Secondary data analysis
- Available data from the IEA website
- Twelve jurisdictions were examined: those participating in all rounds of TIMSS in 1995, 2007 and 2015 and both grades
- In this presentation: Results for Grade 8, 2015

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Participating jurisdictions	*TIMSS 1995*				*TIMSS 2007*		*TIMSS 2015*	
	Population 1[a] students	*Grade 4 students*	*Population 2[a] students*	*Grade 8 students*	*Grade 4 students*	*Grade 8 students*	*Grade 4 students*	*Grade 8 students*
Countries								
Australia	11,248	6065 (49.9)	12,852	7392 (51.4)	4108 (50.0)	4069 (45.3)	6057 (48.9)	10338 (50.5)
England[b]	6182	3126 (50.6)	3579	1776 (48.0)	4316 (50.0)	4025 (51.8)	4006 (50.6)	4814 (50.7)
Hong Kong	8807	4411(45.9)	6752	3339 (45.2)	3791 (48.5)	3470 (50.4)	3600 (44.9)	4155 (47.5)
Hungary	6044	3006 (49.8)	5978	2912 (51.1)	4048 (49.7)	4111 (49.9)	5036 (49.8)	4893 (50.6)
Iran	6746	3385 (48.9)	7429	3694 (44.5)	3833 (47.2)	3981 (44.9)	3823 (48.7)	6130 (48.9)
Japan	8612	4306 (50.0)	10,271	5141 (48.5)	4487 (49.3)	4312 (49.7)	4383 (50.2)	4745 (51.0)
Singapore	14169	7139 (47.4)	8285	4644 (49.7)	5041 (49.2)	4599 (48.8)	6517 (48.8)	6116 (48.7)
Slovenia	5087	2566 (50.5)	5606	2708 (51.1)	4351 (49.5)	4043 (50.0)	4445 (48.4)	4257 (48.2)
USA	11,115	7296 (51.4)	10,973	7087 (50.2)	7896 (51.0)	7377 (50.4)	10029 (50.6)	10221 (50.1)
Benchmarking participants								
Norway	4476	N/A[c]	5736	N/A[c]	4108 (49.4)	4627 (49.5)	4164 (49.4)	4795 (50.1)
Ontario	1.416	723 (45.6)	2078	1.059 (49.7)	3496 (49.3)	3448 (50.6)	4574 (48.2)	4520 (49.8)
Quebec	8.470	4488 (50.4)	8378	4245 (50.0)	3885 (51.4)	3956 (49.5)	2798 (50.0)	3950 (52.3)

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Variables used

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Construct	Measurement
1. Students Like Learning Mathematics 2. Student Confident in Mathematics 3. Student Values Mathematics	*Partial Credit IRT scaling*
Mathematics achievement	*IRT scores, five plausible values*
Sex	*Self-report*
Home educational resources	*# number of books in the home, #of home study supports (own room and internet connection), and parental educational level*

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Cluster Analysis

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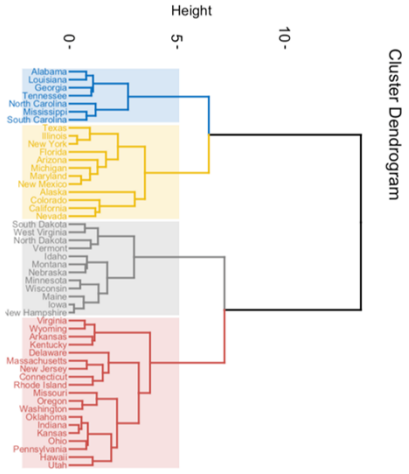
- Exploratory:
  - correct solution not known; 3 major techniques
- hierarchical cluster analysis
  - **agglomerative** procedure that begins with each observation as a separate group, and gradually combines observations or groups based on similarity (**Euclidean** distance), until one large cluster is formed.
  - recommended when input variables are **continuous** and the sample of observations is small.
  - A **dendrogram** is produced and examined to ascertain the number of clusters to retain and their meaning.



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Cluster Analysis

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- K-means clustering:
  - used with **continuous** variables and **large** datasets.
  - Number of clusters defined in advanced.
  - Multiple solutions inspected and compared.
- two-step cluster analysis:
  - handles **continuous and categorical** variables in **very large** datasets
  - runs pre-clustering first and then runs hierarchical methods.
  - **Distances: Log-likelihood.** The likelihood measure places a probability distribution on the variables. Continuous variables are assumed to be normally distributed, while categorical variables are assumed to be multinomial. All variables are assumed to be independent.
  - more clusters were examined for grade eight because one additional input variable ("Value for mathematics") was available

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How many clusters?

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- different numbers of clusters may be extracted and interpreted
- preliminary step extracted few clusters (e.g., two or three).
  - clusters were consistent and not very informative with respect to the input variables.
    - i.e., cluster 1 = all high scores on all input variables,
    - cluster 2 = students with moderate scores,
    - cluster 3 = students with rather low motivation scores.
  - This approach did not permit the identification of possible inconsistent profiles across the motivational constructs, which was an important aim of our study.

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How many clusters?

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- So tested 3-6 clusters in each jurisdiction
  - evaluation of competing cluster solutions was not automatically determined.
  - Criteria:
    - statistical measure, the silhouette measure of cohesion and separation (at least "fair"; Kaufman and Rousseeuw 1990), and
    - the relative size of the smallest cluster (>7% of the sample).
    - Possibility of mixed clusters
    - Interpretability of the derived clusters.
  - The final number of clusters for each country sample, in each cycle of TIMSS (2015, 2007, and 1995), and at each grade (four and eight) was decided based on the assessment of two independent researchers.
  - When agreement could not be reached, a decision was adjudicated in the presence of a third researcher.

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SPSS syntax

```
TWOSTEP CLUSTER
/CONTINUOUS VARIABLES=Motivation1 Motivation2 Motivation3
/DISTANCE LIKELIHOOD
/NUMCLUSTERS FIXED=X /* Specify number of clusters.
/HANDLENOISE 0
/MEMALLOCATE 64
/CRITERIA INITHRESHOLD(0) MXBRANCH(8) MXLEVEL(3)
/VIEWMODELDISPLAY=YESEVALUATIONFIELDS=PV1 PV2 PV3 PV4 PV5
ITSEX <other demographics>
/PRINT IC COUNT SUMMARY
/SAVE VARIABLE=Cluster_noX. /* Save cluster membership variable.
```

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Cluster characteristics

- Pairwise mean comparisons were carried out to compare clusters on mean achievement and on home educational resources
  - weighted statistics and corrected standard errors (IEA's IDB Analyzer)
  - alpha level of .001
  - Chi-square test for independence for sex * cluster membership

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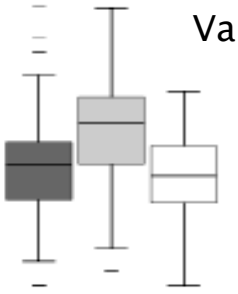
Results

- Self-confidence (light)
- Enjoyment (dark) Value (white)



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Australia

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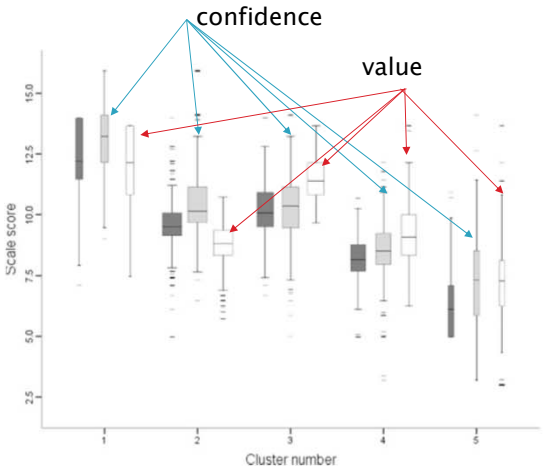

Table 4.13 Descriptive statistics by cluster for Australia, TIMSS 2015 grade 8

Cluster characteristics	Cluster				
	1	2	3	4	5
Size (% of total number of students)	11.5	30.5	26.0	23.3	8.7
Mean plausible value	570.5^{a}	517.5^{b}	519.8^{b}	471.7^{c}	446.0^{d}
Female students in cluster (%)*	37.8	49.5	44.9	60.6	66.2
Students spending >45 min per week on homework (%)	45.9	39.0	48.6	37.1	28.0
Mean home educational resources scale score	11.6^{a}	11.1^{c}	11.3^{b}	11.0^{c}	10.7^{d}

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$

*Chi-square test of independence of gender × cluster was significant ($\chi^2(4) = 286.415$, $p < 0.001$)

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Quebec

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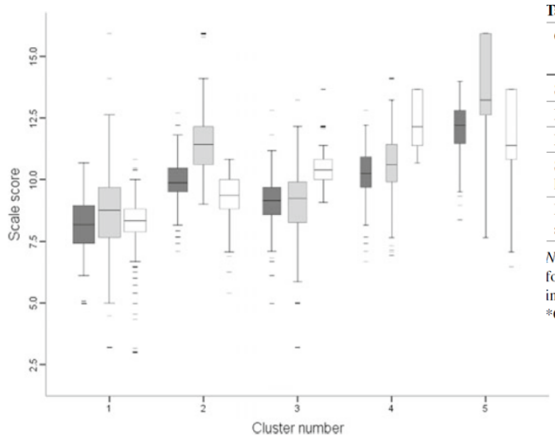

Table 4.15 Descriptive statistics by cluster for Quebec, TIMSS 2015 grade 8

Cluster characteristics	Cluster				
	1	2	3	4	5
Size (% of total number of students)	26.8	24.0	22.3	13.3	13.6
Mean plausible value	510.7^{a}	$573.4^{b,c}$	531.4^{d}	559.6^{b}	588.5^{c}
Female students in cluster (%)*	56.9	48.5	58.6	44.4	48.6
Students spending >45 min per week on homework (%)	75.4	68.1	81.1	76.3	60.0
Mean home educational resources scale score	10.6^{c}	11.0^{b}	$10.9^{b,c}$	$11.1^{a,b,c}$	11.3^{a}

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$

*Chi-square test of independence of gender × cluster was significant ($\chi^2(4) = 42.725$, $p < 0.001$)

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Hong Kong

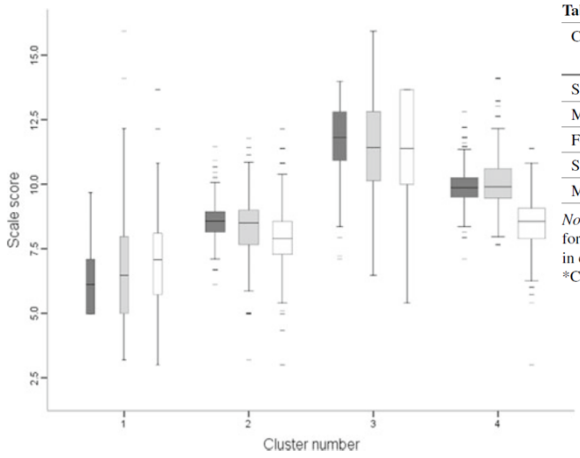

Table 4.17 Descriptive statistics by cluster for Hong Kong, TIMSS 2015 grade 8

Cluster characteristics	Cluster			
	1	2	3	4
Size (% of total number of students)	12.4	28.6	19.8	39.3
Mean plausible value	546.6^{d}	572.3^{c}	631.9^{a}	606.7^{b}
Female students in cluster (%)*	56.8	57.8	32.4	45.2
Students spending >45 min per week on homework (%)	63.0	68.2	60.5	65.6
Mean home educational resources scale score	10.0^{b}	10.0^{b}	10.6^{a}	10.2^{b}

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$
*Chi-square test of independence of gender × cluster was significant ($\chi^2(3) = 144.759$, $p < 0.001$)

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Iran

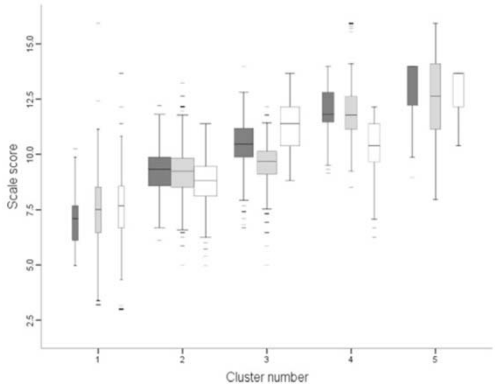

Table 4.19 Descriptive statistics by cluster for Iran, TIMSS 2015 grade 8

Cluster characteristics	Cluster				
	1	2	3	4	5
Size (% of total number of students)	8.6	32.4	27.5	16.6	14.9
Mean plausible value	396.6^{d}	416.9^{c}	418.1^{c}	493.6^{b}	473.2^{a}
Female students in cluster (%)*	54.6	52.4	47.6	50.4	40.1
Students spending >45 min per week on homework (%)	49.7	55.5	59.3	65.4	67.3
Mean home educational resources scale score	$9.2^{b,c}$	9.1^{b}	9.1^{b}	9.9^{a}	$9.7^{a,c}$

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$
*Chi-square test of independence of gender × cluster was significant ($\chi^2(4) = 46.370$, $p < 0.001$)

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Norway

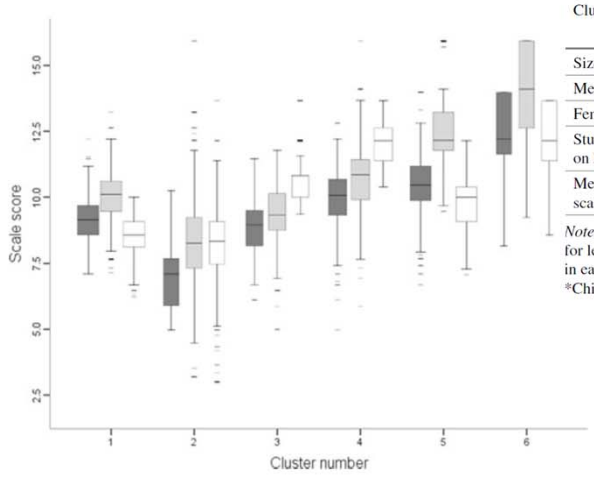

Table 4.21 Descriptive statistics by cluster for Norway, TIMSS 2015 grade 8

Cluster characteristics	Cluster					
	1	2	3	4	5	6
Size (% of total number of students)	19.9	14.3	15.6	16.9	19.2	14.0
Mean plausible value	478.9^{b}	443.8^{d}	462.3^{c}	481.3^{b}	523.7^{a}	535.1^{a}
Female students in cluster (%)*	47.5	57.6	59.4	47.3	48.0	42.9
Students spending >45 min per week on homework (%)	56.5	63.0	62.1	61.1	51.8	50.7
Mean home educational resources scale score	$11.3^{a,b}$	11.0^{a}	$11.1^{a,b}$	11.4^{b}	11.6^{c}	11.8^{c}

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$

*Chi-square test of independence of gender × cluster was significant ($\chi^2(5) = 61.050$, $p < 0.001$)

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Singapore

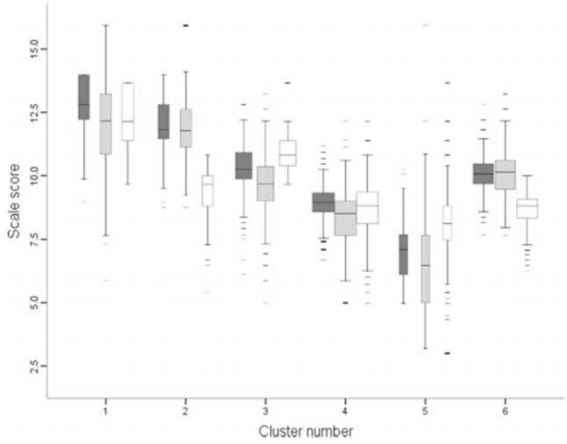

Table 4.22 Descriptive statistics by cluster for Singapore, TIMSS 2015 grade 8

Cluster characteristics	Cluster					
	1	2	3	4	5	6
Size (% of total number of students)	12.6	12.3	18.4	24.6	9.5	22.7
Mean plausible value	652.3^{a}	666.6^{b}	616.8^{c}	597.0^{d}	559.0^{e}	632.6^{f}
Female students in cluster (%)*	38.8	48.6	49.1	52.6	52.0	48.5
Students spending >45 min per week on homework (%)	77.5	75.3	79.2	76.9	69.3	75.5
Mean home educational resources scale score	10.6^{a}	$10.6^{a,b}$	$10.4^{a,b}$	10.2^{c}	10.0^{c}	10.4^{b}

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$

*Chi-square test of independence of gender × cluster was significant ($\chi^2(5) = 41.695$, $p < 0.001$)

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USA

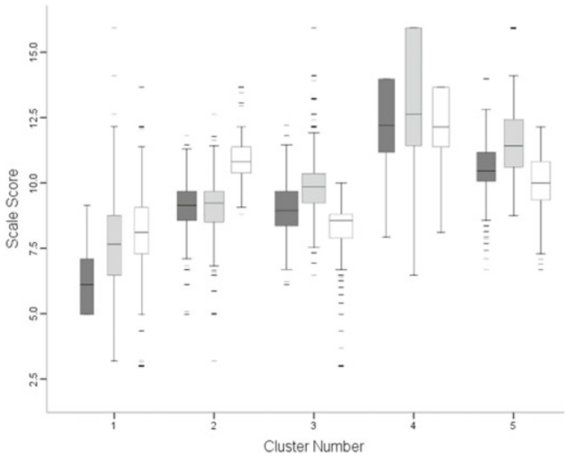

Table 4.24 Descriptive statistics by cluster for USA, TIMSS 2015 grade 8

Cluster characteristics	Cluster				
	1	2	3	4	5
Size (% of total number of students)	14.9	21.3	25.3	17.8	20.7
Mean plausible value	479.5[a]	494.1[b]	509.7[c]	558.9[d]	553.1[d]
Female students in cluster (%)*	57.9	54.0	47.6	44.0	51.1
Students spending >45 min per week on homework (%)	56.8	57.9	52.7	50.9	52.0
Mean home educational resources scale score	10.7[a]	10.8[a]	10.7[a]	11.2[b]	11.1[b]

Notes Different superscripts (a, b, c, etc.) indicate significantly different mean PV or home resources for learning based on t-statistics in pairwise comparisons. Due to multiple comparisons conducted in each sample, a difference was considered significant if $|t| > 3.29$

*Chi-square test of independence of gender × cluster was significant ($\chi^2(4) = 81.820$, $p < 0.001$)

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Consistent profiles

- Students reporting similar level of agreement on all three contextual measures:
  - self-confidence, enjoyment, value for mathematics
- Higher motivation distributions <=> higher mean achievement

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Inconsistent profiles

- Found in all twelve samples, except Hong Kong
- The usual mixture was students endorsing higher value for mathematics with lower agreement with self-confidence and enjoyment items
  - Less often, there were clusters where the distributions of self-confidence and enjoyment did not overlap
- In the inconsistent cases, it was self-confidence that seem to be positively associated with mean achievement

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Inconsistent profiles

- More males were found in clusters with high motivation (or at least high self-confidence) score distributions. Iran was an exception
- Clusters with higher motivation score distributions (and higher mathematics achievement) had significantly higher scores on the home educational resources variable.

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Implications

- Value, as an external type of motivation. When aligned with self-confidence and enjoyment, then relates to achievement (as hypothesized)
  - But there are clusters of students who report high value for mathematics, and lower self-confidence and enjoyment. This is not adaptive for achievement
- Less often, when self-confidence and enjoyment did not overlap, self-confidence was more closely aligned with mean achievement
- Positive affect, enjoyment and value are adaptive if accompanied by **VERIDICAL** high self-confidence
  - Verifiable, justified

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Final points

- **Justified confidence**: students with stronger endorsement of confidence rightly believed they could do the mathematics in the TIMSS tests
  - They achieved higher scores than their peers who prioritized value or enjoyment, but lacked strong beliefs in their capabilities
- Implications for teaching:
  - a sense of confidence, independent of real capability, is unlikely to be effective (Pajares, 2008).
  - How to move classroom practice of teachers from making students interested in mathematics or knowing its value, to one in which teachers focus on helping students become competent;
  - lead students to intrinsic interest as a consequence of greater competence, expertise, and knowledge (Murphy & Alexander, 2002).
- Replication of similar trends across twelve diverse and large countries or jurisdictions lends credibility to the generalizability of the findings

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Better methods?

- Latent profile/class analysis
  - Model based using Gaussian finite mixture with different covariance structures and different numbers of mixture components
  - Tests for selecting number of clusters
- We don't know if this approach generates different results with the same data
  - Yifei Wu is doing a test with TIMSS Science using 'mclust' R library
  - Watch this space

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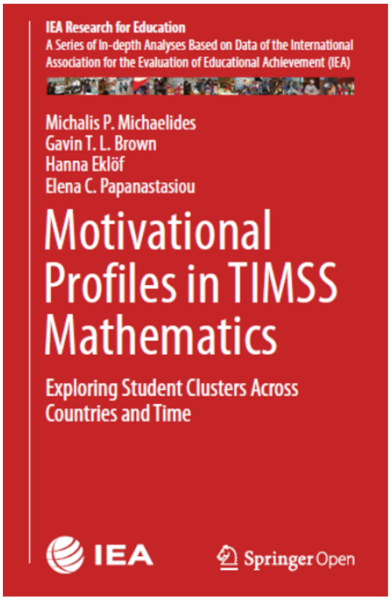
- Michaelides, M. P., Brown, G., & Eklöf, H., & Papanastasiou, E. C., (2019). *Profiles in TIMSS Mathematics: Exploring Student Clusters across Countries and Time.* Cham, Switzerland: SpringerOpen.



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