

CHAPTER 18

Constructing the TIMSS 2019 Environmental Awareness Scales

Liqun Yin
Pierre Foy

Introduction

In recent years, increasing numbers of individuals and organizations around the world are raising their voices to encourage awareness and actions to protect the environment. In TIMSS 2019, there were many science items addressing a variety of environmental issues at the fourth grade and the eighth grade, ranging from local issues like water pollution to global issues like climate changes and impact. To further raise awareness of environmental issues and to understand what students around the world think about these issues, two environmental awareness achievement scales were constructed for the countries that participated in TIMSS 2019 based on the environmental science items included in the TIMSS 2019 assessments at the fourth and the eighth grade.

The environmental awareness scale includes items related to the environment from two TIMSS 2019 science content domains at each grade: Earth science and life science at fourth grade, and Earth science and biology at eighth grade. The psychometric methods implemented for scaling the environmental awareness data relied extensively on experience from scaling the TIMSS 2019 overall science scales and their content domain scales at both grades. Because constructing the environmental awareness scales is a new initiative in TIMSS 2019, the generated plausible values from a latent regression population model were examined through a series of validation analyses and quality control measures that ensure the environmental scale results are accurate, reliable, and comparable to the overall science results and across countries at each grade.

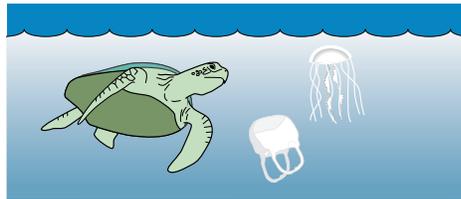
Identifying Environmental Items

TIMSS 2019 assessed a wide range of topics related to environmental issues as specified in the TIMSS science framework. The topics covered include the use and conservation of nature's resources, the interdependence among habitat members in ecosystems, the causes and consequences of pollution, the changes and impact on habitats by different climates, and various cycles in nature. For example, items ask

students to describe the effects of pollution on farm fields, evaluate resources used to produce electricity, explain benefits of planting trees, and identify evidence of climate change over time. Exhibit 18.1 shows an environmental item at the fourth grade about the effects of plastic pollution in the oceans.

Exhibit 18.1: Example Item – Effects of Plastic Pollution in the Oceans

The picture shows a turtle and jellyfish swimming in the ocean. A plastic bag is floating nearby.



Write down one reason why plastic objects in the ocean are dangerous for animals such as turtles.

The turtle could think the bag is a jellyfish and eat it. The bag could get stuck in its throat or stomach.

All TIMSS 2019 science items related to environmental issues were identified at each grade to construct an environmental awareness scale. Exhibits 18.2 and 18.3 list the items included in the environmental scales at the fourth grade and the eighth grade, respectively. There were two modes of administration in TIMSS 2019, paper-based (paperTIMSS) and computer-based (eTIMSS). Although the exhibits list the eTIMSS version of the environmental items, the paperTIMSS assessment included the same items with their specific paper-based identifiers (“SP” instead of “SE”). TIMSS 2019 included 33 environmental items worth a maximum of 33 points at the fourth grade and 41 environmental items worth up to 44 points at the eighth grade.

Exhibit 18.2: Items for the TIMSS 2019 Fourth Grade Environmental Awareness Scale

Item Block	Item ID	Max Points	Content Domain	Content Area
SE01	SE51132A	1	Life Science	Organisms, Environment, and their Interactions
SE01	SE51132B	1	Life Science	Organisms, Environment, and their Interactions
SE02	SE71077	1	Life Science	Ecosystems
SE02	SE71054	1	Life Science	Organisms, Environment, and Their Interactions
SE02	SE71920A	1	Earth Science	Earth's Physical Characteristics, Resources, and History
SE02	SE71920B	1	Earth Science	Earth's Physical Characteristics, Resources, and History
SE03	SE61023	1	Life Science	Ecosystems
SE03	SE61169	1	Earth Science	Earth's Weather and Climates
SE04	SE71223	1	Earth Science	Earth's Physical Characteristics, Resources, and History
SE05	SE51168	1	Life Science	Organisms, Environment, and their Interactions
SE05	SE51010	1	Life Science	Ecosystems
SE05	SE51035	1	Life Science	Organisms, Environment, and their Interactions
SE06	SE61016A	1	Life Science	Ecosystems
SE06	SE61016B	1	Life Science	Ecosystems
SE06	SE61011	1	Life Science	Organisms, Environment, and their Interactions
SE06	SE61115A	1	Earth Science	Earth's Weather and Climates
SE06	SE61115B	1	Earth Science	Earth's Weather and Climates
SE07	SE51194	1	Life Science	Organisms, Environment, and their Interactions
SE08	SE71065	1	Life Science	Ecosystems
SE08	SE71081	1	Life Science	Ecosystems
SE09	SE61069	1	Life Science	Ecosystems
SE09	SE61019	1	Life Science	Ecosystems
SE10	SE71069	1	Life Science	Ecosystems
SE10	SE71080	1	Life Science	Ecosystems
SE11	SE61132	1	Earth Science	Earth's Weather and Climates
SE11	SE61074	1	Life Science	Organisms, Environment, and their Interactions
SE12	SE71071	1	Life Science	Ecosystems
SE13	SE61015	1	Life Science	Ecosystems
SE13	SE61124	1	Earth Science	Earth's Physical Characteristics, Resources, and History
SE13	SE61116	1	Earth Science	Earth's Weather and Climates
SE14	SE71063	1	Life Science	Ecosystems
SE14	SE71214	1	Earth Science	Earth's Physical Characteristics, Resources, and History
SE14	SE71213	1	Earth Science	Earth's Physical Characteristics, Resources, and History

Exhibit 18.3: Items for the TIMSS 2019 Eighth Grade Environmental Awareness Scale

Item Block	Item ID	Max Points	Content Domain	Content Area
SE01	SE52021	1	Biology	Ecosystems
SE01	SE52095Z	1	Biology	Ecosystems
SE02	SE72072	1	Biology	Ecosystems
SE02	SE72902	1	Biology	Ecosystems
SE02	SE72721	1	Earth Science	Earth's Processes, Cycles, and History
SE02	SE72335	1	Earth Science	Earth's Processes, Cycles, and History
SE03	SE62116A	1	Biology	Ecosystems
SE03	SE62116B	1	Biology	Ecosystems
SE03	SE62116C	1	Biology	Ecosystems
SE03	SE62233	1	Earth Science	Earth's Structure and Physical Features
SE03	SE62171	1	Earth Science	Earth's Processes, Cycles, and History
SE04	SE72066	1	Biology	Ecosystems
SE04	SE72063	1	Biology	Ecosystems
SE04	SE72345	2	Earth Science	Earth's Resources, Their Use and Conservation
SE04	SE72349	1	Earth Science	Earth's Resources, Their Use and Conservation
SE05	SE52272	1	Biology	Ecosystems
SE05	SE52113	1	Earth Science	Earth's Processes, Cycles, and History
SE06	SE62090	1	Earth Science	Earth's Processes, Cycles, and History
SE06	SE62175	1	Earth Science	Earth's Resources, Their Use and Conservation
SE06	SE62173A	1	Earth Science	Earth's Processes, Cycles, and History
SE06	SE62173B	1	Earth Science	Earth's Processes, Cycles, and History
SE07	SE52273	2	Biology	Ecosystems
SE07	SE52099	1	Earth Science	Earth's Resources, Their Use and Conservation
SE08	SE72462	1	Biology	Ecosystems
SE08	SE72347	1	Earth Science	Earth's Resources, Their Use and Conservation
SE08	SE72351	1	Earth Science	Earth's Resources, Their Use and Conservation
SE09	SE62190	1	Earth Science	Earth's Resources, Their Use and Conservation
SE10	SE72086	1	Biology	Ecosystems
SE10	SE72720	1	Earth Science	Earth's Processes, Cycles, and History
SE11	SE62089	1	Biology	Ecosystems
SE11	SE62177	1	Earth Science	Earth's Processes, Cycles, and History
SE11	SE62211A	1	Earth Science	Earth's Processes, Cycles, and History
SE11	SE62211B	1	Earth Science	Earth's Processes, Cycles, and History
SE12	SE72460	1	Biology	Ecosystems
SE13	SE62091A	1	Biology	Ecosystems
SE13	SE62091B	1	Biology	Ecosystems
SE13	SE62180	1	Earth Science	Earth's Processes, Cycles, and History
SE13	SE62022	1	Earth Science	Earth's Structure and Physical Features
SE13	SE62243	2	Earth Science	Earth's Processes, Cycles, and History
SE14	SE72074	1	Biology	Ecosystems
SE14	SE72323	1	Earth Science	Earth's Processes, Cycles, and History

As specified in the [TIMSS 2019 assessment design](#) (Martin, Mullis, & Foy, 2017), the 14 mathematics and 14 science item blocks at each grade were assembled into 14 assessment booklets or digital “eBooklets” (also called “block combinations” in eTIMSS parlance), with each booklet having two mathematics and two science item blocks and each item block appearing in two booklets. Countries that participated in the TIMSS 2019 less difficult mathematics assessment at the fourth grade also administered booklets with two blocks of mathematics items (either less difficult or regular) and two regular blocks of science items, the same as in the regular fourth grade TIMSS 2019 assessment. Exhibits 18.4 and 18.5 present the distribution of the environmental items across the TIMSS 2019 booklets at the fourth grade and the eighth grade, respectively.

Exhibit 18.4: Distribution of Environmental Items in the TIMSS 2019 Fourth Grade Booklets

TIMSS 2019 Booklet	Number of Items	Score Points
Booklet 1	6	6
Booklet 2	6	6
Booklet 3	3	3
Booklet 4	4	4
Booklet 5	8	8
Booklet 6	6	6
Booklet 7	3	3
Booklet 8	4	4
Booklet 9	4	4
Booklet 10	4	4
Booklet 11	3	3
Booklet 12	4	4
Booklet 13	6	6
Booklet 14	5	5

Exhibit 18.5: Distribution of Environmental Items in the TIMSS 2019 Eighth Grade Booklets

TIMSS 2019 Booklet	Number of Items	Score Points
Booklet 1	6	6
Booklet 2	9	9
Booklet 3	9	10
Booklet 4	6	7
Booklet 5	6	6
Booklet 6	6	7
Booklet 7	5	6
Booklet 8	4	4
Booklet 9	3	3
Booklet 10	6	6
Booklet 11	5	5
Booklet 12	6	7
Booklet 13	7	8
Booklet 14	4	4

Constructing the Environmental Awareness Scales

In the [TIMSS 2019 Science Framework](#) (Centurino & Jones, 2017), three science content domains are specified at the fourth grade: physical science, life science, and Earth science. At the eighth grade, the science framework specifies four content domains: biology, chemistry, physics, and Earth science. The 33 fourth grade environmental items shown in Exhibit 18.2 belong either to the life science or Earth science content domains. At the eighth grade, the 41 environmental items shown in Exhibit 18.3 belong either to the biology or Earth science content domains.

To construct the environmental awareness scales, an alternative way of specifying content domains was used for the psychometric scaling. This alternative method was modeled after the procedure for constructing the customary TIMSS science content domain subscales as described in [Chapter 12](#) (Foy, Fishbein, von Davier, & Yin, 2020). This consisted of reorganizing the life science and Earth science items at the fourth grade to construct two new scales, an environmental science scale and a “non-environmental” science scale without the environmental items, and keeping the original physical science scale intact. Similarly at the eighth grade, it consisted of reorganizing biology and Earth science items to have an environmental scale and a non-environmental scale, while keeping the original chemistry and physics scales unchanged.

At the fourth grade, three subscales were specified, an environmental scale with all environmental items, a non-environmental scale with the remainder of the Earth science and life science items, and the unchanged physical science scale. For the eighth grade, the two chemistry and physics scales were kept

the same as in the [TIMSS 2019 Science Framework](#). Two new scales, the environmental scale and the non-environmental scale, were constructed with the specified environmental items and the rest of Earth science and biology items, respectively.

It is important to note that the two “non-environmental” scales are not considered for reporting for a number of reasons, the first and foremost being that these do not cover a defined framework, or a well-defined subdomain of science. In addition, these “subdomains” were defined by being the complement or remainder of a collection of items ensures that all statistical information about the student response to the TIMSS assessment is being retained, rather than discarding items that are informative for overall achievement. Therefore, this chapter focuses on describing the creation of the environmental awareness scale, and not the other subscales.

Exhibits 18.6 and 18.7 show the numbers of items included in the alternate science content subscales at the fourth grade and eighth grade, respectively. Numbers are presented separately for eTIMSS and paperTIMSS as there were some minor differences between the two modes of administration. At the fourth grade, Earth science included one more item for eTIMSS. This item—SE71921—was included in the eTIMSS non-environmental scale. At the eighth grade, one chemistry item was present in the paperTIMSS scaling, but not in the eTIMSS scaling. On the other hand, one biology item was present in the eTIMSS scaling, but not in the paperTIMSS scaling. This biology item—SE72403—was included in the eTIMSS non-environmental scale. At both grades, the environmental scale includes the same number of items in both modes of administration.

Exhibit 18.6: Numbers of Items in the TIMSS 2019 Fourth Grade Alternate Science Subscales

Alternate Science Content Domain	eTIMSS		paperTIMSS	
	Items	Points	Items	Points
Environmental	33	33	33	33
Non-Environmental	75	79	74	78
Physical Science	61	62	61	62
Total	169	174	168	173

Exhibit 18.7: Numbers of Items in the TIMSS 2019 Eighth Grade Alternate Science Subscales

Alternate Science Content Domain	eTIMSS		paperTIMSS	
	Items	Points	Items	Points
Environmental	41	44	41	44
Non-Environmental	76	89	75	88
Chemistry	42	46	43	47
Physics	52	54	52	54
Total	211	233	211	233

Scaling the Environmental Awareness Data

The TIMSS scaling process consists of four major tasks: calibrating the achievement items (estimating model parameters for each item) including model fit assessment, creating principal components from the student and home questionnaire data for use in conditioning, generating plausible values (proficiency estimates) for mathematics and science, and placing these plausible values on the metrics used to report trend results from previous assessments. Each of the four steps includes extensive quality control measures and revisions of analytic steps that ensure the analysis produces meaningful results. The data product of these scaling procedures is plausible values representing achievement on the overall mathematics and science scales jointly at each grade. In addition, the same set of item parameters and conditioning variables for producing the overall scales also are used to generate plausible values for the content and cognitive domains of mathematics and science. Therefore, the same scale transformation parameters are applied for the overall scales and the subscales for each subject and grade.

Item Calibration

As described in [Chapter 12](#) (Foy et al., 2020), the item parameters estimated from the TIMSS 2019 calibrations were used not only to estimate student overall mathematics proficiency and overall science proficiency for all countries, but also to estimate student proficiency for the mathematics and science content and cognitive domain subscales. Because the environmental scale is a science subscale, the same approach was followed in the process of scaling the alternate science content domains. The corresponding science item parameters of paperTIMSS and eTIMSS data were used to estimate student proficiency for the environmental subscales at both grades.

Conditioning Variables

In order to generate plausible values representing the TIMSS achievement distribution, conditioning was used to estimate a latent regression item response model that incorporates the available student and parent context variables, as well as students' mathematics and science item responses. Similar to the scaling procedures used for the customary TIMSS subdomain scales, the same sets of conditioning variables and principal components as those in scaling TIMSS 2019 overall mathematics and science for each country were included for the latent regression (conditioning) model to generate plausible values for the alternate science content domains with the environmental scale included. Details on the conditioning variables and models used for proficiency estimation for each country can be found in [Chapter 12](#) (Foy et al., 2020).

Generating Plausible Values

As described in [Chapter 11](#) (von Davier, 2020), TIMSS uses a population model to estimate distributions of proficiencies based on the likelihood function of an IRT model and a latent regression of the proficiency on contextual data. This approach can be viewed as an imputation model for the unobserved proficiency distribution that aims to obtain unbiased group-level proficiency distributions. In TIMSS 2019, five plausible values (PVs) were drawn to represent the proficiency variable. The same procedures were applied for producing the environmental scales.

Educational Testing Service's DGROUPE program (Rogers et al., 2006) was used to estimate the latent regression model and to generate plausible values. A useful feature of DGROUPE is its ability to estimate multi-dimensional latent regression models using the responses to all items across the proficiency scales and the correlations among the scales to improve the reliability of each individual scale. In TIMSS 2019, the multi-dimensional latent regression models for subdomains included the subdomains in each subject along with the other overall subject domain at each grade. For example, to generate the plausible values for the science content subscales, the overall mathematics scale was included in the multidimensional population model.

The ability to estimate multi-dimensional population models was also used to generate plausible values for the alternate science content domains with the environmental scale included. Even though the plausible values generated for the environmental scale are of primary interest under this scaling effort, including the other subscales in the latent regression model is crucial. There are two main purposes for this: to improve the reliability of environmental scale and to use the re-estimated fourth grade physical science scale and eighth grade chemistry and physics scales as a quality control measure.

At the fourth grade, the population modeling conducted for the alternate science content domains used a four-dimensional model which included the environmental scale, non-environmental scale, physical science scale, and overall mathematics scale. At the eighth grade, the alternate science content domain modeling required a five-dimensional model consisting of: the environmental scale, non-environmental scale, chemistry scale, physics scale, and overall mathematics scale.

Scale Transformation

The plausible values that were drawn using the model parameters of each population model were not immediately ready for tabulation. The numerical scale of these plausible values was set by means of the IRT calibration, rather than aligned with the TIMSS trend reporting metric established during the analysis of the initial TIMSS 1995 assessment that has a defined midpoint and standard deviation. In TIMSS 2019, transformation constants were determined to put the 2019 data on this reporting metric. The same constants calculated for TIMSS 2019 science reported in [Chapter 12](#) (Foy et al., 2020) were used not only for transforming the overall science PVs but also for transforming the science content and cognitive domain PVs to the reporting metric. Because the same sets of item parameters as those in TIMSS 2019 overall science were used to generate the plausible values for alternate science content domains, the same transformation constants for science were also applied for transforming the environmental scale PVs on the reporting metric. The transformation was applied to the data for all paperTIMSS, eTIMSS, and less difficult countries.

Quality Assurance and Validation

The quality assurance procedures included two main aspects: 1) checking the re-estimated fourth grade physical science and eighth grade chemistry and physics country average achievement scores from the multi-dimensional scaling model for producing the environmental scales against the original published values, and 2) examining whether there is a dependency of the distribution of the generated plausible values on the number of items in each assessment booklet.

Checking Re-estimated Science Content Domain Subscales

As described in the previous section, while generating the plausible values of the environmental scale, the multi-dimensional population models also included overall mathematics and the other associated science subscales. At the fourth grade, it also included the non-environmental and physical science subscales. At the eighth grade, there were three other subscales in the model, the non-environmental scale, physics scale, and chemistry scale.

At the fourth grade, the re-estimated physical science country average scale scores were compared to the published TIMSS 2019 physical science scores. Similarly, the re-estimated chemistry and physics country average scale scores under the environmental population model were compared to the published TIMSS 2019 physics and chemistry scores at the eighth grade. The two population models produced highly consistent results for the unchanged science subscales for all countries at both grades. The results of these comparisons are presented in Appendix 18A and Appendix 18B for the fourth grade and eighth grade, respectively. All differences between the published and re-estimated achievement scores are small and have small standard errors. These small standard errors are indicative of the high correlations between the two sets of scores.

Validating the Environmental Scale Scores

Constructing the environmental awareness scale was a new initiative for TIMSS 2019, as issues about the environment are not explicitly accounted for in the [TIMSS 2019 Science Framework](#) (Centurino & Jones, 2017). Consequently, the environmental items were not considered in the specifications for building the science item blocks and so there are potential imbalances in their distribution across the assessment booklets. Although Exhibits 18.4 and 18.5 show that at least some environmental items were present in all booklets, there was some variation in the numbers per booklet. For example, Booklets 3, 7, and 11 have the least number of environmental items at the fourth grade, and Booklet 9 has the least number of items at the eighth grade. To check if the environmental scales were affected by the unbalanced item distributions across booklets, a series of validation steps was conducted. The examinations mainly focused on investigating the relationship between the environmental scale plausible values and the number of environmental items at the booklet level.

First, box plots were produced for each plausible value by assessment booklet. Exhibits 18.8 and 18.9 show the box plots of these distributions of the first plausible value across all counties at the fourth grade and eighth grade, respectively.

Exhibit 18.8: TIMSS 2019 Fourth Grade Environmental Scale Box Plots of 1st Plausible Values

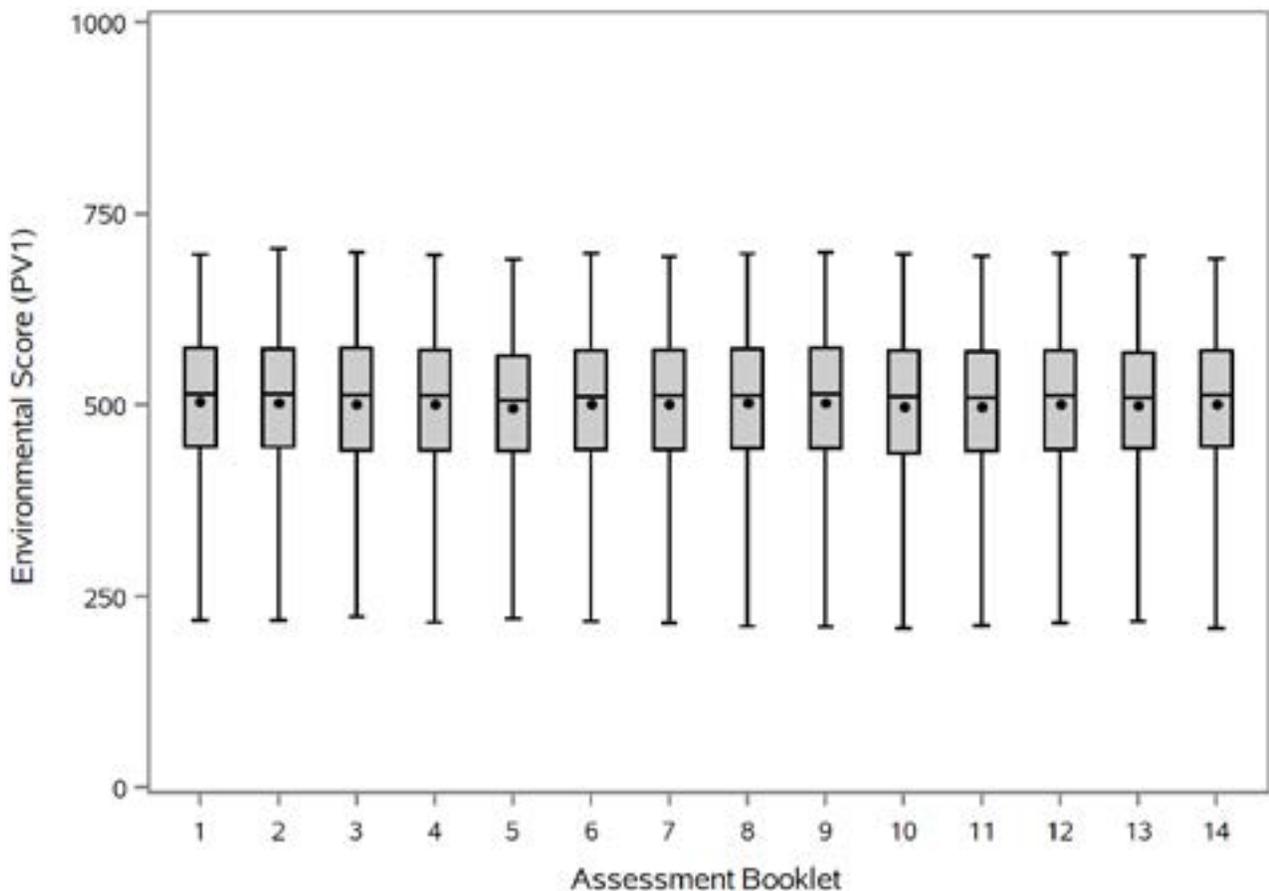
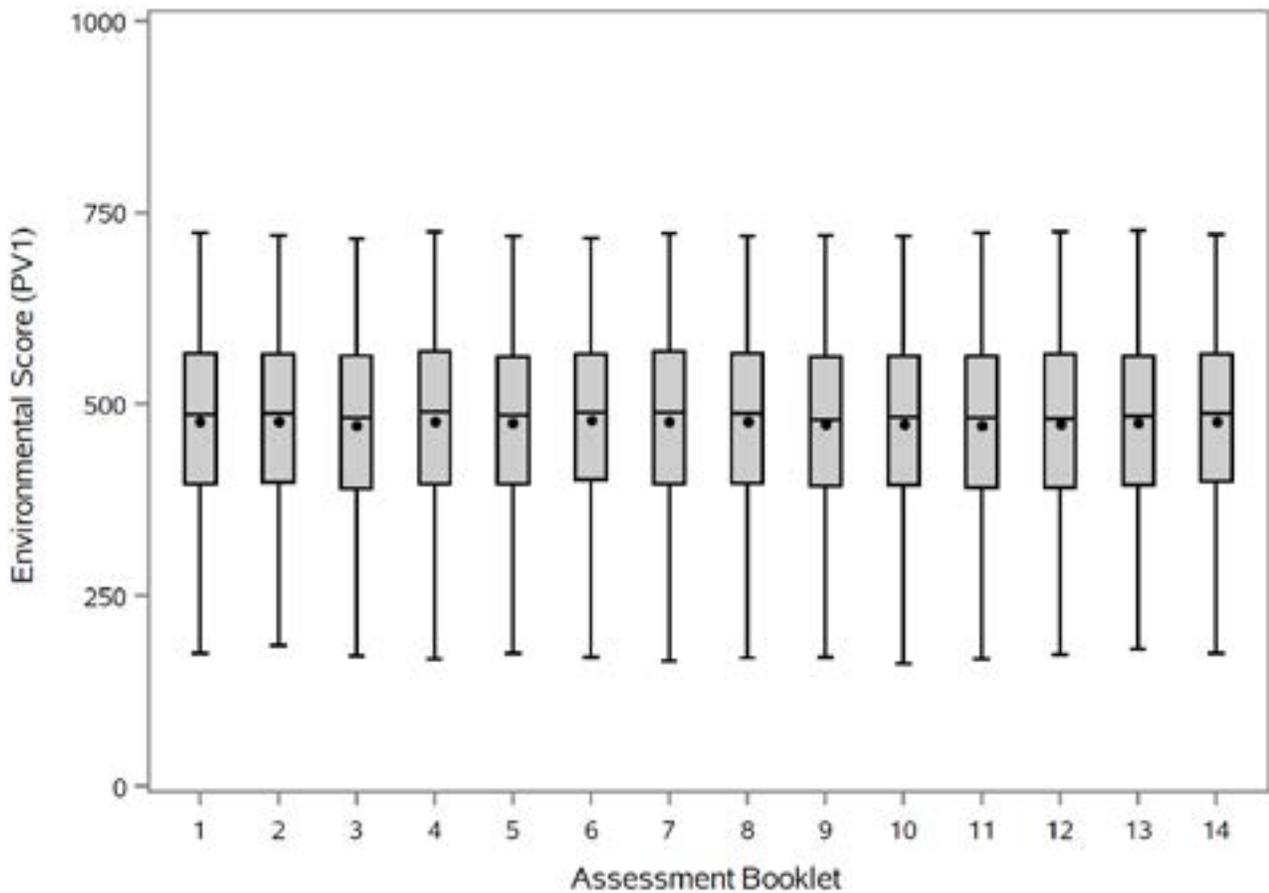


Exhibit 18.9: TIMSS 2019 Eighth Grade Environmental Scale Box Plots of 1st Plausible Values



As can be seen in these box plots, the distributions of plausible values for each booklet are nearly identical in their inter-quartile ranges (the boxes), their medians (the horizontal line within the boxes), and their means (the circle within the boxes). Only the 1st and 99th percentiles (the whiskers below and above the boxes) show minor variations. The box plots for all five plausible values show identical patterns. They are presented in Appendix 18C and Appendix 18D for the fourth grade and eighth grade, respectively.

The posterior distributions of student ability across the TIMSS 2019 countries in the environmental domains from which the five plausible values were drawn also were examined for each booklet. To examine the posterior distributions, box plots of the standard deviations of the posterior distributions were produced for the 14 assessment booklets at each grade.

Exhibits 18.10 and 18.11 show the box plots of the posterior standard deviations at the fourth grade and eighth grade, respectively. The posterior standard deviations were transformed to the TIMSS reporting metrics to make them more relevant and comparable to the achievement scale scores described

in this chapter. All box plots from Exhibits 18.8 to 18.11 illustrate the consistent and precise estimation of student achievement across all 14 achievement booklets at both grades.

Exhibit 18.10: TIMSS 2019 Fourth Grade Environmental Scale Box Plots of Posterior Standard Deviations

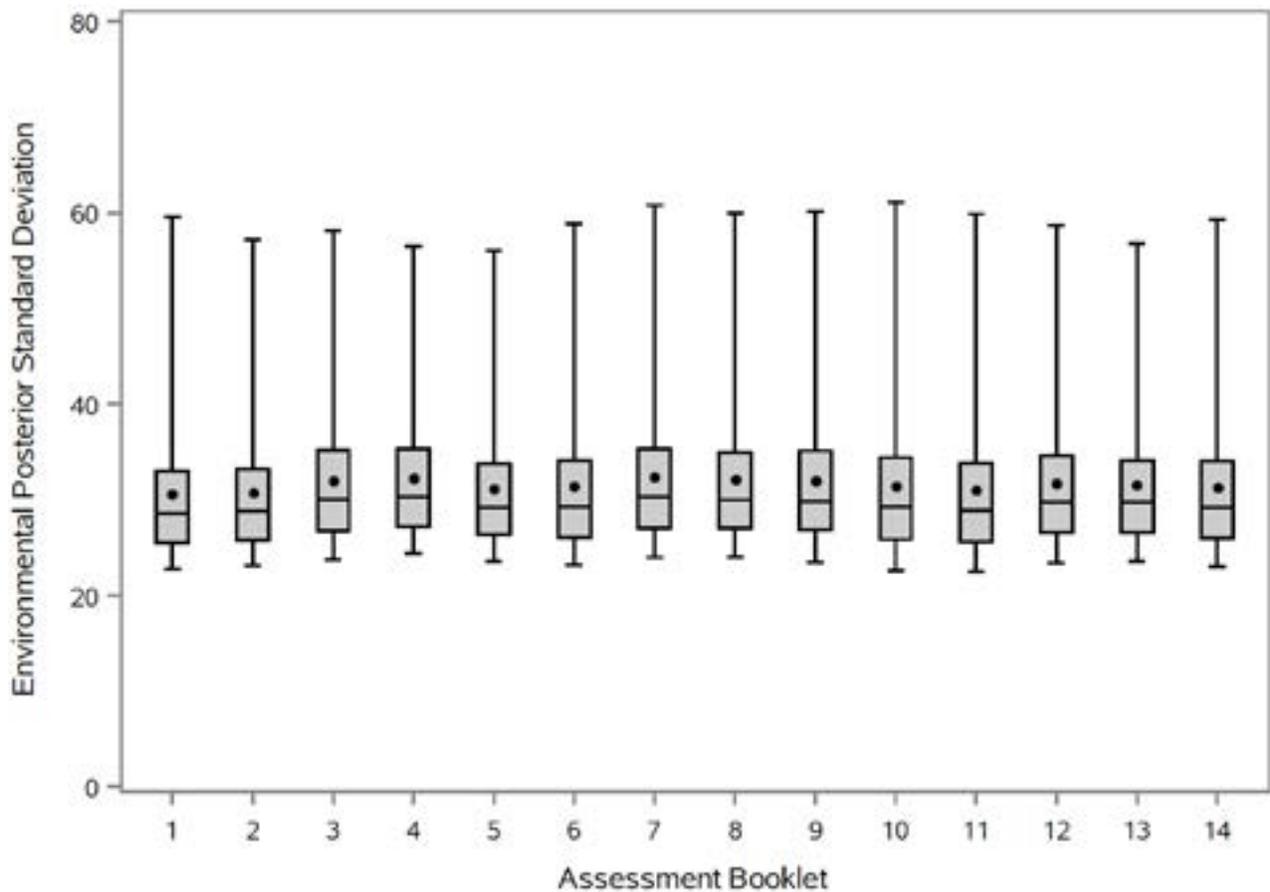
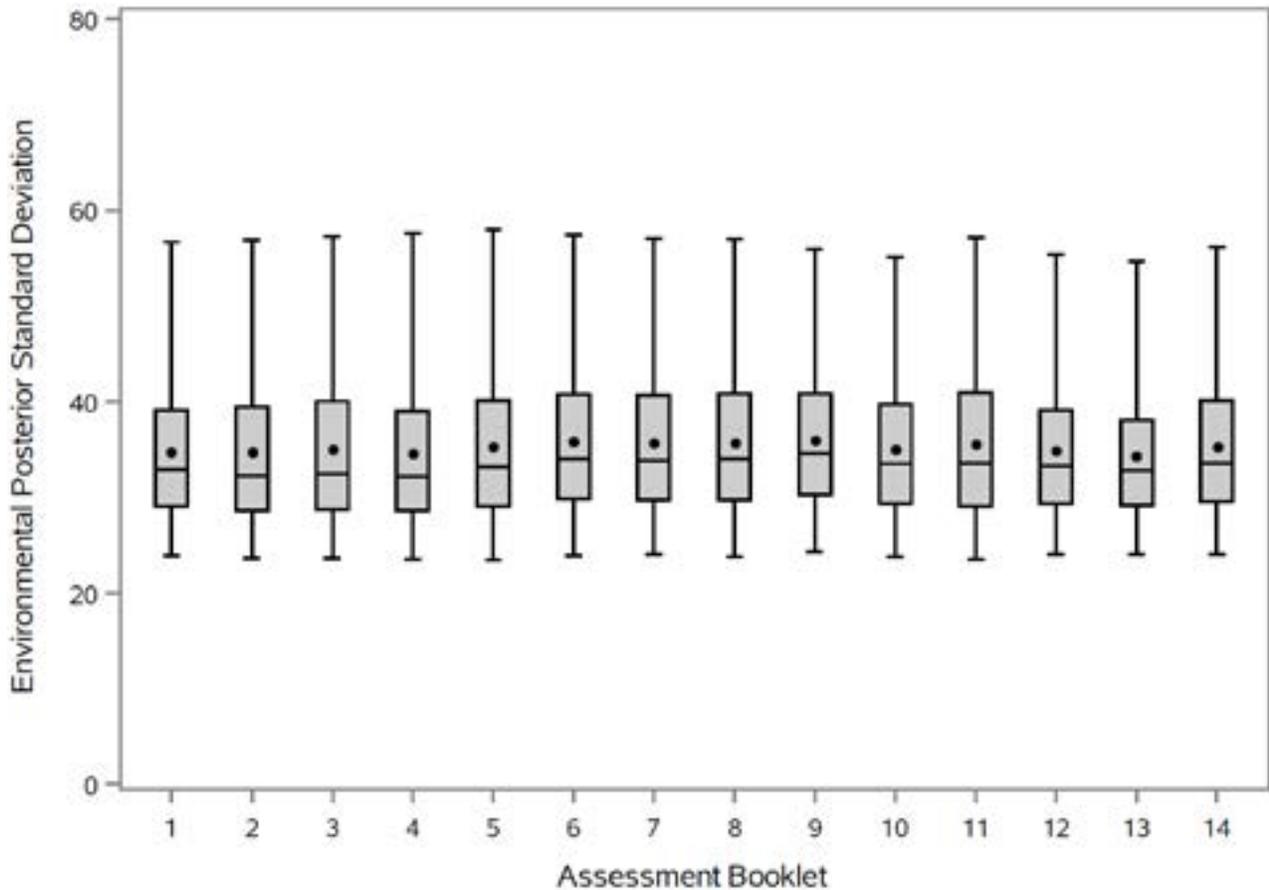


Exhibit 18.11: TIMSS 2019 Eighth Grade Environmental Scale Box Plots of Posterior Standard Deviations



All of these examinations demonstrate a robust estimation of the environmental scales at both grades. Although there are variations in terms of the number of environmental items and associated score points across the assessment booklets, the estimation of achievement is consistent across all assessment booklets at each grade. In other words, the numbers of environmental items in each booklet are adequate to produce accurate and reliable achievement results from the latent regression population model for the environmental scales at both grades.

Conclusion

Estimating an environmental awareness scale is a new initiative in TIMSS 2019. The psychometric methods implemented and described in this document relied extensively on experience from scaling the TIMSS 2019 overall science scales and their content domain scales at both grades.

Because constructing an environmental awareness scale was not specified explicitly in the TIMSS 2019 Science Framework, estimating environmental scales required careful consideration. The apparent imbalance in environmental items across the assessment booklets was one of those concerns. A series of validation analyses found that the generated plausible values from a latent regression population model had no observable relationship with the number of environmental items in the assessment booklets. The environmental scale results are accurate, reliable, and comparable to the overall science results and across countries.

References

- Centurino, V. A. S., & Jones, L. (2017). TIMSS 2019 Science Framework. In I. V. S. Mullis & M. O. Martin (Eds.), *TIMSS 2019 Assessment Frameworks* (pp. 27–55). Retrieved from Boston College, TIMSS & PIRLS International Study Center website: <https://timssandpirls.bc.edu/timss2019/frameworks/>
- Foy, P., Fishbein, B., von Davier, M., & Yin, L. (2020). Implementing the TIMSS 2019 scaling methodology. In M. O. Martin, M. von Davier, & I. V. S. Mullis (Eds.), *Methods and Procedures: TIMSS 2019 Technical Report* (pp. 12.1–12.146). Retrieved from Boston College, TIMSS & PIRLS International Study Center website: <https://timssandpirls.bc.edu/timss2019/methods/chapter-12.html>
- Martin, M. O., Mullis, I. V. S., & Foy, P. (2017). TIMSS 2019 assessment design. In I. V. S. Mullis & M. O. Martin (Eds.), *TIMSS 2019 Assessment Frameworks* (pp. 79–91). Retrieved from Boston College, TIMSS & PIRLS International Study Center website: <http://timssandpirls.bc.edu/timss2019/frameworks/>
- Rogers, A., Tang, C., Lin, M. J., & Kandathil, M. (2006). DGROUPE [Computer software]. Princeton, NJ: Educational Testing Service.
- von Davier, M. (2020). TIMSS 2019 scaling methodology: Item Response Theory, population models, and linking across modes. In M. O. Martin, M. von Davier, & I. V. S. Mullis (Eds.), *Methods and Procedures: TIMSS 2019 Technical Report* (pp. 11.1–11.25). Retrieved from Boston College, TIMSS & PIRLS International Study Center website: <https://timssandpirls.bc.edu/timss2019/methods/chapter-11.html>

Appendix 18A: TIMSS 2019 Re-Estimated Fourth Grade Physical Science Content Domain

Country	Physical Science		
	Published Score	Re-Estimated Score	Difference
Albania	493 (4.1)	493 (4.1)	0.1 (0.18)
Armenia	454 (3.4)	454 (3.4)	-0.2 (0.29)
Australia	526 (2.7)	526 (2.7)	-0.1 (0.15)
Austria	519 (2.6)	519 (2.6)	-0.1 (0.06)
Azerbaijan	427 (3.3)	427 (3.3)	0.0 (0.10)
Bahrain	496 (3.8)	496 (3.8)	0.0 (0.12)
Belgium (Flemish)	502 (2.3)	502 (2.3)	0.0 (0.05)
Bosnia and Herzegovina	450 (3.3)	450 (3.4)	-0.1 (0.13)
Bulgaria	518 (6.4)	518 (6.4)	0.0 (0.11)
Canada	513 (1.8)	513 (1.8)	-0.1 (0.10)
Chile	458 (3.8)	458 (3.8)	0.0 (0.10)
Chinese Taipei	573 (1.9)	573 (1.9)	0.0 (0.09)
Croatia	528 (2.4)	528 (2.3)	-0.1 (0.10)
Cyprus	511 (3.2)	511 (3.2)	-0.1 (0.10)
Czech Republic	528 (2.5)	528 (2.5)	-0.1 (0.07)
Denmark	507 (2.3)	507 (2.3)	-0.1 (0.07)
England	537 (3.2)	537 (3.2)	0.0 (0.13)
Finland	544 (3.2)	544 (3.2)	-0.1 (0.08)
France	477 (3.1)	477 (3.1)	0.0 (0.21)
Georgia	452 (4.6)	453 (4.6)	0.0 (0.17)
Germany	518 (3.0)	518 (3.0)	-0.1 (0.10)
Hong Kong SAR	529 (3.5)	529 (3.5)	0.0 (0.12)
Hungary	524 (2.8)	524 (2.8)	0.0 (0.07)
Iran, Islamic Rep. of	453 (4.7)	453 (4.7)	0.0 (0.18)
Ireland	523 (3.2)	523 (3.2)	0.0 (0.06)
Italy	502 (3.4)	502 (3.4)	0.0 (0.11)
Japan	579 (1.9)	579 (1.9)	0.0 (0.09)
Kazakhstan	506 (3.3)	506 (3.3)	0.0 (0.12)
Korea, Rep. of	607 (2.7)	607 (2.8)	0.0 (0.14)
Kosovo	415 (4.2)	415 (4.2)	0.3 (0.19)
Kuwait	--	--	--
Latvia	553 (3.6)	553 (3.6)	0.0 (0.06)
Lithuania	547 (3.0)	547 (3.1)	-0.1 (0.08)
Malta	492 (2.9)	492 (2.8)	-0.1 (0.11)
Montenegro	446 (2.8)	446 (2.8)	-0.1 (0.08)
Morocco	379 (6.2)	378 (6.3)	0.3 (0.11)
Netherlands	516 (2.8)	516 (2.8)	0.0 (0.10)
New Zealand	492 (2.1)	492 (2.1)	-0.1 (0.06)
North Macedonia	432 (7.2)	432 (7.2)	-0.1 (0.11)

A dash (–) indicates comparable data not available because average achievement could not be accurately estimated.

Country	Physical Science		
	Published Score	Re-Estimated Score	Difference
Northern Ireland	511 (2.2)	511 (2.2)	0.0 (0.05)
Norway (5)	525 (3.0)	525 (3.1)	-0.1 (0.19)
Oman	437 (4.7)	437 (4.6)	-0.1 (0.08)
Pakistan	--	--	--
Philippines	--	--	--
Poland	526 (2.9)	526 (2.9)	-0.1 (0.11)
Portugal	496 (2.4)	497 (2.4)	-0.1 (0.29)
Qatar	451 (4.0)	451 (4.0)	0.0 (0.14)
Russian Federation	572 (2.9)	572 (2.9)	-0.1 (0.13)
Saudi Arabia	--	--	--
Serbia	524 (4.2)	524 (4.3)	-0.1 (0.21)
Singapore	613 (3.7)	613 (3.7)	0.0 (0.06)
Slovak Republic	525 (3.9)	525 (3.9)	-0.1 (0.08)
South Africa (5)	--	--	--
Spain	503 (2.3)	503 (2.3)	0.0 (0.08)
Sweden	525 (3.3)	525 (3.3)	-0.1 (0.08)
Turkey (5)	538 (4.6)	538 (4.6)	0.0 (0.16)
United Arab Emirates	477 (2.2)	477 (2.2)	-0.1 (0.17)
United States	527 (2.8)	527 (2.8)	-0.1 (0.06)
Benchmarking Participants			
Ontario, Canada	512 (2.9)	512 (2.9)	-0.1 (0.14)
Quebec, Canada	514 (2.8)	514 (2.7)	-0.1 (0.21)
Moscow City, Russian Fed.	598 (2.7)	599 (2.7)	-0.1 (0.17)
Madrid, Spain	514 (2.5)	514 (2.6)	-0.1 (0.10)
Abu Dhabi, UAE	418 (2.6)	418 (2.6)	0.0 (0.34)
Dubai, UAE	556 (2.1)	556 (2.1)	-0.1 (0.27)

A dash (–) indicates comparable data not available because average achievement could not be accurately estimated.

Appendix 18B: TIMSS 2019 Re-estimated Eighth Grade Chemistry and Physics Content Domains

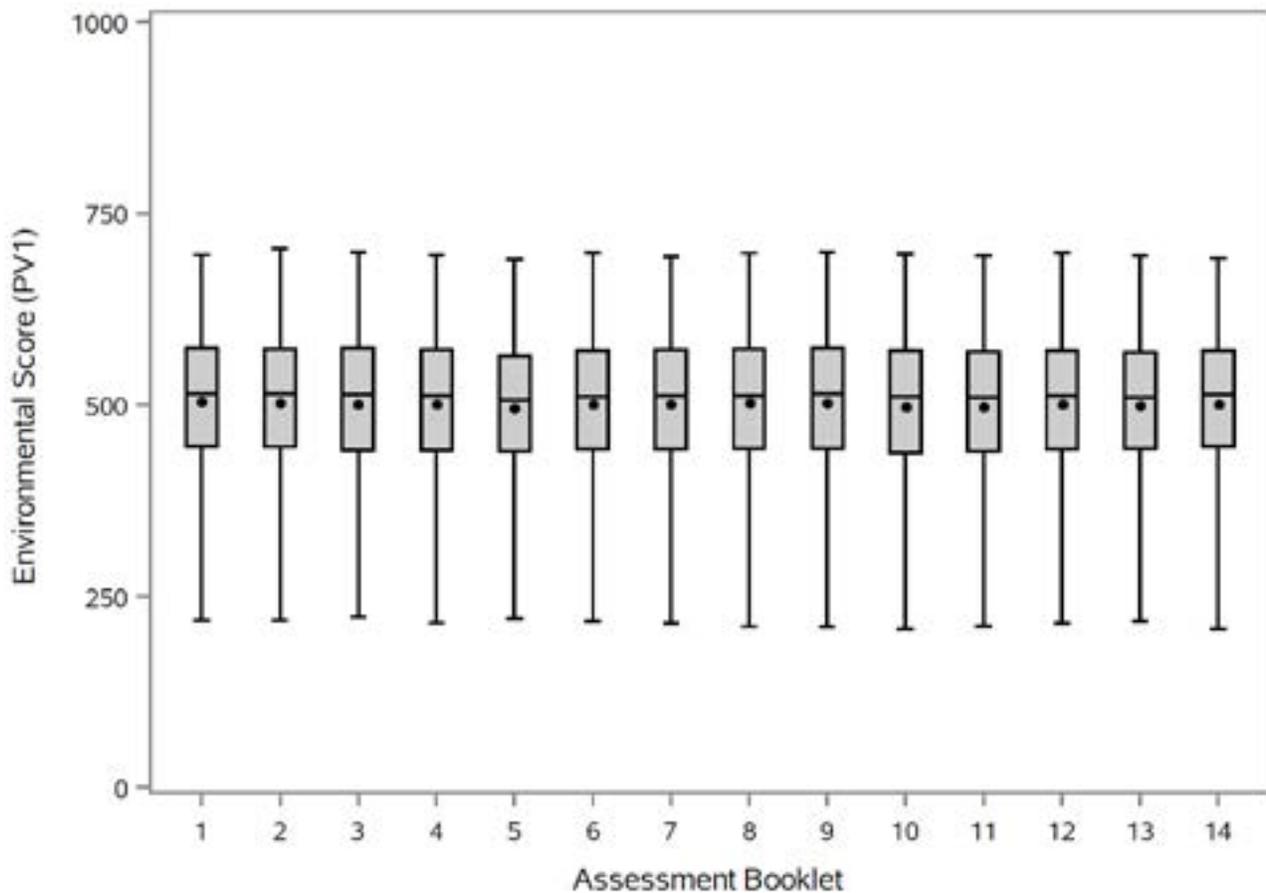
Country	Chemistry			Physics		
	Published Score	Re-Estimated Score	Difference	Published Score	Re-Estimated Score	Difference
Australia	515 (3.8)	515 (3.8)	0.0 (0.04)	529 (3.6)	529 (3.6)	-0.1 (0.07)
Bahrain	480 (2.4)	480 (2.4)	0.0 (0.08)	480 (2.6)	480 (2.6)	0.0 (0.07)
Chile	442 (2.9)	442 (2.9)	-0.1 (0.04)	450 (3.7)	450 (3.7)	-0.1 (0.06)
Chinese Taipei	594 (2.4)	594 (2.4)	0.0 (0.03)	555 (2.7)	555 (2.7)	0.0 (0.03)
Cyprus	478 (2.1)	478 (2.1)	0.1 (0.08)	480 (3.6)	480 (3.7)	-0.1 (0.08)
Egypt	397 (5.9)	397 (5.9)	0.1 (0.06)	394 (5.0)	394 (5.0)	0.0 (0.07)
England	512 (6.0)	512 (6.0)	0.0 (0.06)	516 (5.1)	516 (5.1)	0.0 (0.05)
Finland	545 (3.8)	545 (3.8)	0.0 (0.06)	539 (3.9)	539 (3.9)	0.0 (0.17)
France	465 (3.2)	465 (3.2)	0.1 (0.13)	491 (3.6)	491 (3.5)	-0.1 (0.20)
Georgia	456 (4.3)	456 (4.3)	0.1 (0.14)	436 (5.0)	436 (4.9)	0.0 (0.20)
Hong Kong SAR	485 (5.5)	485 (5.5)	0.0 (0.12)	510 (5.6)	510 (5.6)	-0.1 (0.10)
Hungary	527 (3.5)	527 (3.5)	0.1 (0.07)	528 (2.9)	528 (2.9)	0.0 (0.07)
Iran, Islamic Rep. of	450 (4.5)	450 (4.5)	-0.1 (0.04)	453 (4.2)	454 (4.1)	-0.1 (0.06)
Ireland	512 (3.9)	512 (3.9)	-0.1 (0.08)	519 (3.8)	519 (3.8)	0.0 (0.06)
Israel	518 (4.6)	519 (4.6)	-0.1 (0.08)	520 (4.9)	520 (4.9)	0.0 (0.07)
Italy	484 (3.0)	484 (3.0)	0.0 (0.06)	487 (4.5)	486 (4.5)	0.2 (0.06)
Japan	560 (2.7)	560 (2.7)	0.0 (0.06)	570 (2.5)	570 (2.5)	0.0 (0.11)
Jordan	454 (5.3)	454 (5.3)	-0.1 (0.05)	449 (4.6)	449 (4.6)	-0.1 (0.04)
Kazakhstan	494 (3.6)	494 (3.6)	-0.1 (0.15)	476 (3.9)	475 (3.8)	0.1 (0.29)
Korea, Rep. of	551 (2.5)	551 (2.5)	0.1 (0.07)	569 (2.7)	569 (2.8)	-0.1 (0.14)
Kuwait	--	--	--	--	--	--
Lebanon	412 (4.6)	412 (4.6)	0.2 (0.06)	378 (4.9)	378 (4.9)	0.2 (0.06)
Lithuania	530 (3.2)	530 (3.2)	0.0 (0.05)	529 (3.5)	529 (3.4)	0.0 (0.10)
Malaysia	434 (4.2)	434 (4.2)	-0.1 (0.04)	475 (3.4)	475 (3.4)	-0.1 (0.04)
Morocco	402 (3.0)	402 (3.0)	-0.1 (0.06)	402 (2.9)	402 (2.9)	0.0 (0.07)
New Zealand	482 (3.8)	482 (3.8)	0.0 (0.04)	502 (3.8)	502 (3.8)	-0.1 (0.04)
Norway (9)	492 (3.7)	492 (3.7)	-0.1 (0.15)	493 (3.6)	493 (3.6)	0.0 (0.19)
Oman	443 (3.1)	443 (3.2)	0.0 (0.07)	449 (3.1)	449 (3.1)	0.1 (0.05)
Portugal	512 (3.5)	512 (3.5)	0.1 (0.06)	497 (3.5)	497 (3.5)	0.0 (0.08)
Qatar	474 (4.4)	474 (4.4)	0.0 (0.10)	469 (4.4)	470 (4.4)	-0.1 (0.08)
Romania	466 (5.0)	467 (5.0)	-0.1 (0.28)	458 (4.3)	458 (4.3)	-0.1 (0.21)
Russian Federation	551 (4.2)	551 (4.2)	0.1 (0.15)	540 (4.7)	540 (4.7)	0.0 (0.15)
Saudi Arabia	--	--	--	--	--	--
Singapore	616 (5.0)	615 (5.0)	0.1 (0.14)	619 (4.1)	619 (4.1)	0.0 (0.12)
South Africa (9)	372 (4.2)	371 (4.2)	0.1 (0.06)	381 (3.0)	381 (3.1)	0.0 (0.06)
Sweden	509 (3.7)	509 (3.7)	-0.2 (0.24)	520 (3.8)	520 (3.8)	0.0 (0.09)
Turkey	516 (4.8)	516 (4.8)	-0.1 (0.06)	518 (4.0)	518 (4.0)	-0.2 (0.10)
United Arab Emirates	475 (2.4)	475 (2.4)	0.2 (0.04)	469 (2.3)	469 (2.3)	0.1 (0.03)
United States	509 (5.2)	509 (5.2)	0.0 (0.04)	515 (5.0)	515 (5.0)	0.0 (0.05)

A dash (-) indicates comparable data not available because average achievement could not be accurately estimated.

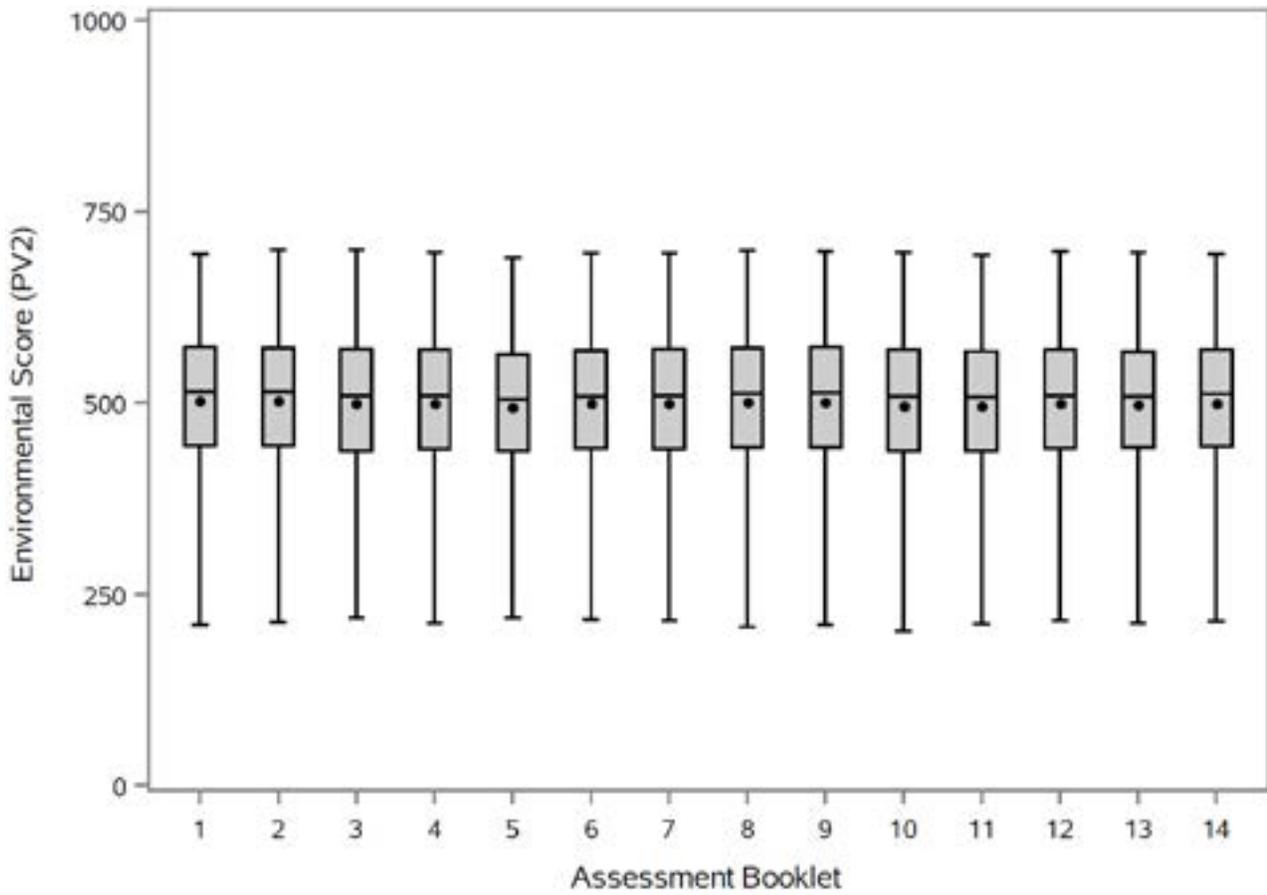
Country	Chemistry			Physics		
	Published Score	Re-Estimated Score	Difference	Published Score	Re-Estimated Score	Difference
Benchmarking Participants						
Ontario, Canada	492 (3.9)	492 (4.0)	-0.1 (0.07)	520 (3.5)	520 (3.5)	-0.1 (0.07)
Quebec, Canada	548 (4.1)	548 (4.1)	0.0 (0.11)	521 (4.2)	521 (4.3)	-0.1 (0.17)
Moscow City, Russian Fed.	561 (2.9)	561 (2.9)	0.0 (0.05)	576 (3.6)	576 (3.6)	0.0 (0.13)
Gauteng, RSA (9)	423 (4.2)	422 (4.2)	0.1 (0.08)	428 (4.5)	428 (4.5)	0.0 (0.07)
Western Cape, RSA (9)	442 (7.2)	442 (7.3)	0.1 (0.10)	442 (6.2)	442 (6.2)	0.1 (0.07)
Abu Dhabi, UAE	421 (4.1)	421 (4.1)	0.2 (0.05)	420 (3.8)	420 (3.8)	0.2 (0.04)
Dubai, UAE	554 (2.2)	554 (2.2)	0.1 (0.09)	539 (2.6)	539 (2.6)	0.0 (0.05)

Appendix 18C: TIMSS 2019 Fourth Grade Environmental Scale Box Plots of Plausible Values

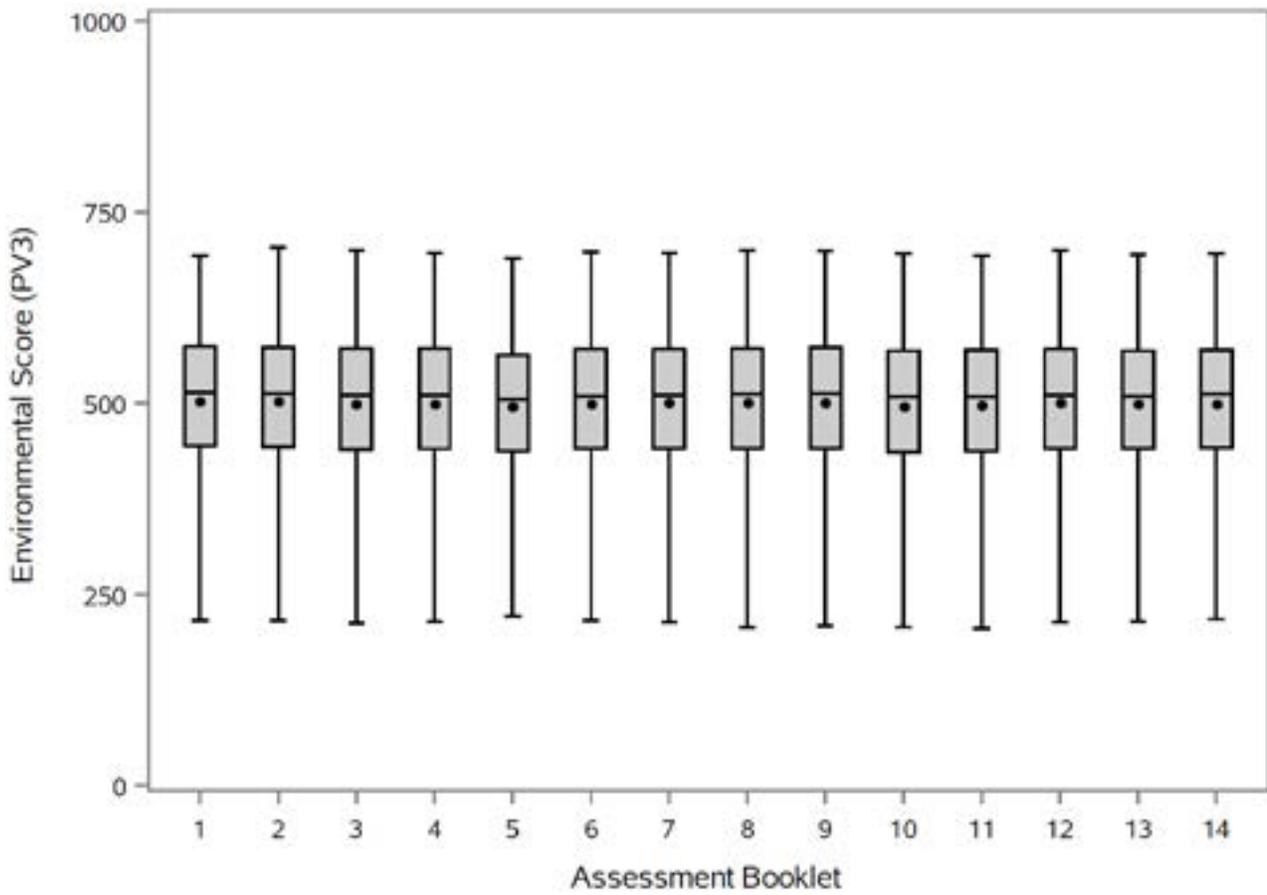
TIMSS 2019 Environmental Scale Box Plot of 1st Plausible Value – Fourth Grade



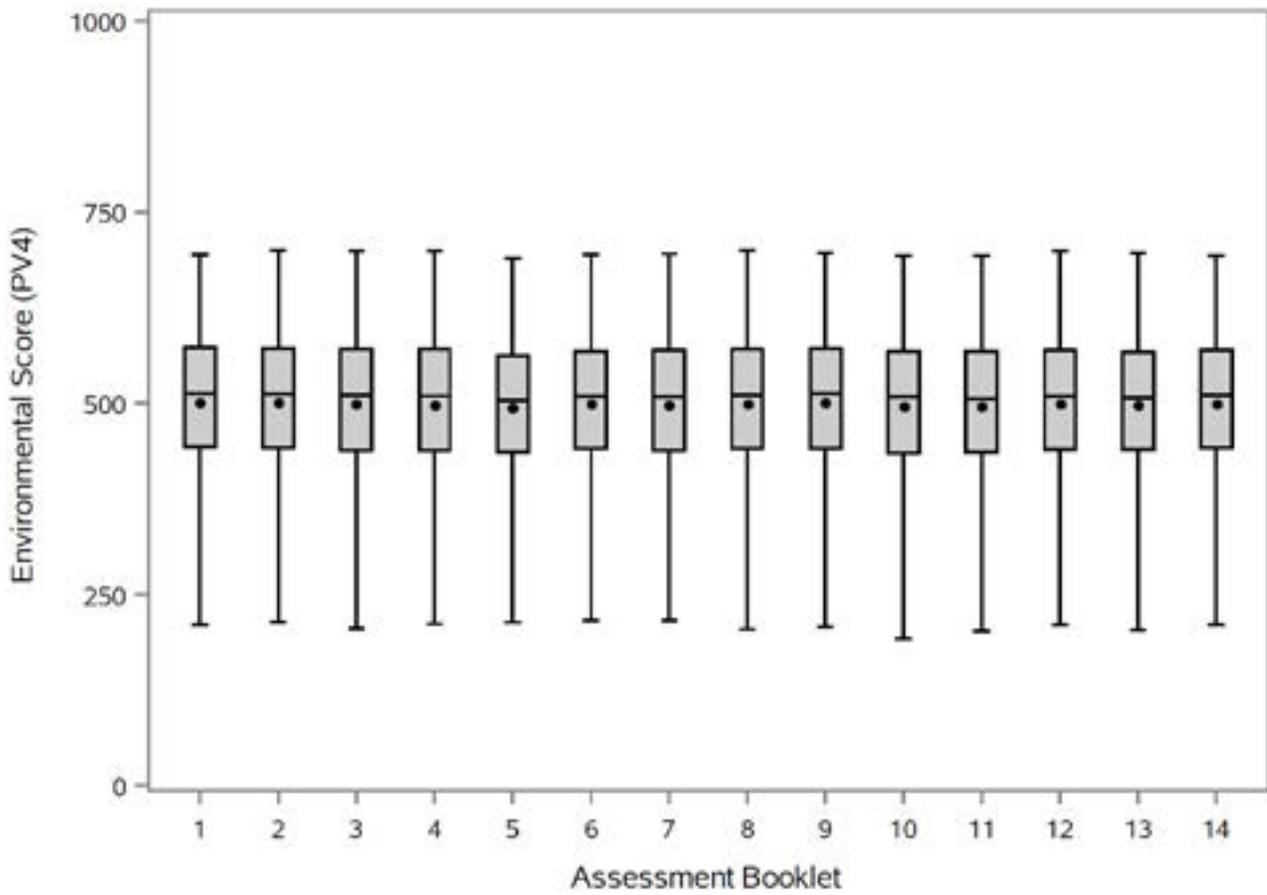
TIMSS 2019 Environmental Scale Box Plot of 2nd Plausible Value – Fourth Grade



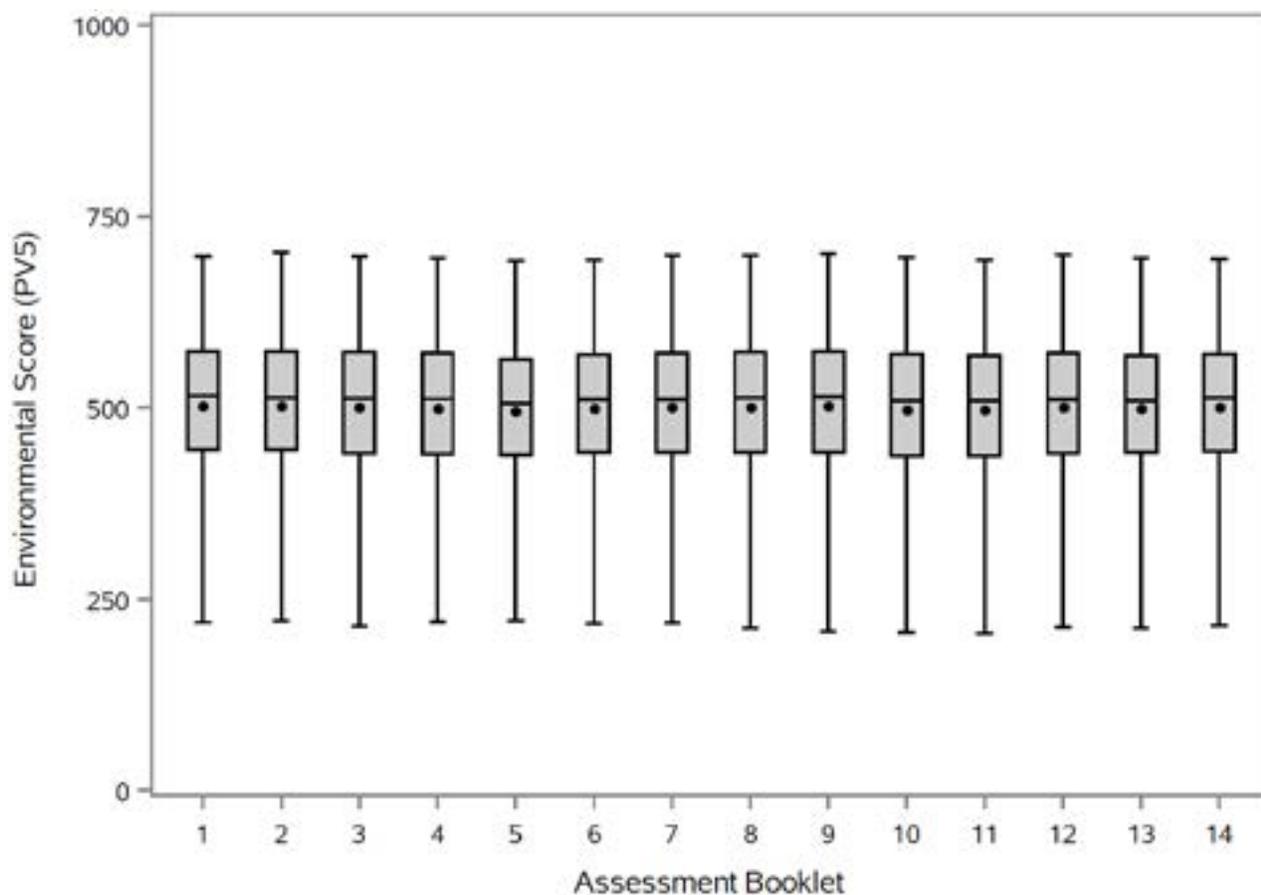
TIMSS 2019 Environmental Scale Box Plot of 3rd Plausible Value – Fourth Grade



TIMSS 2019 Environmental Scale Box Plot of 4th Plausible Value – Fourth Grade

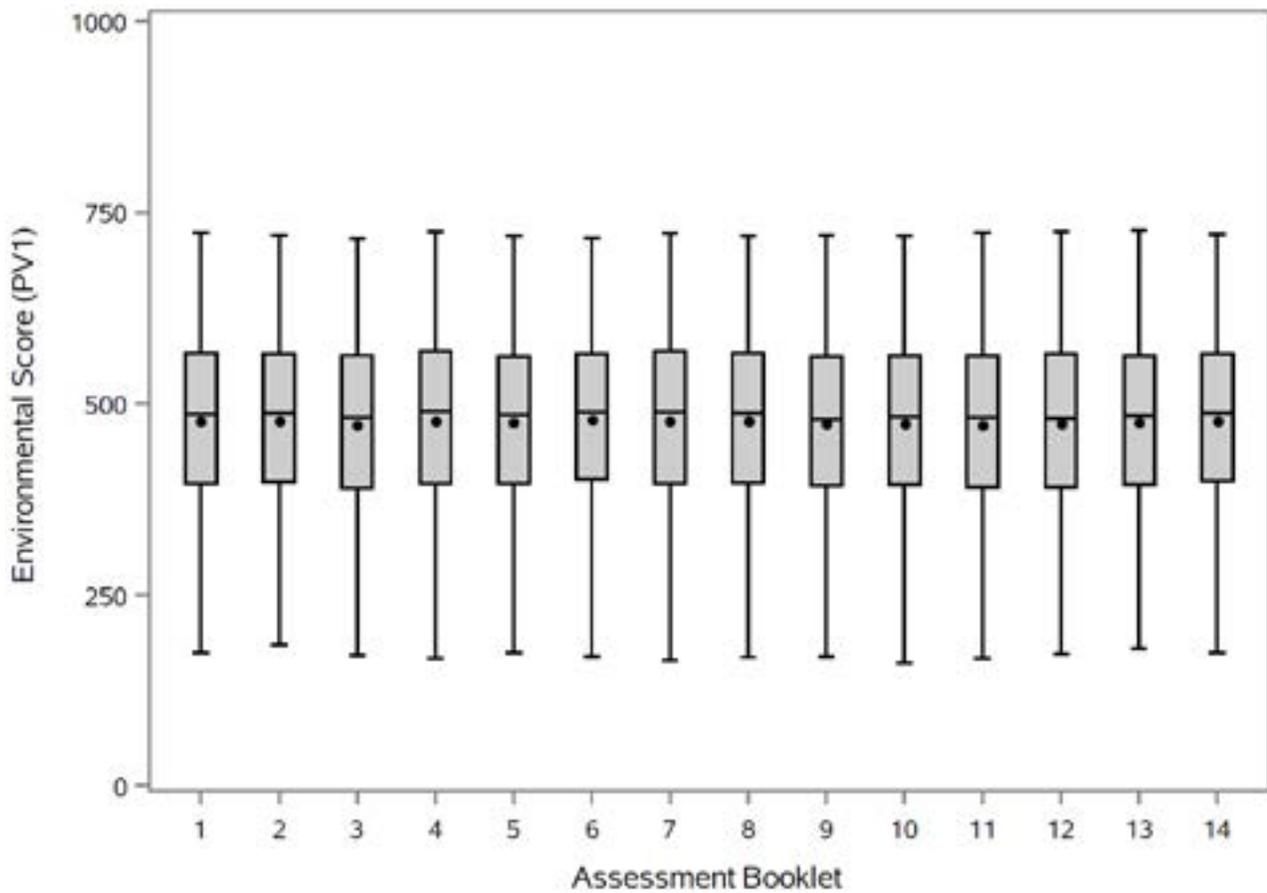


TIMSS 2019 Environmental Scale Box Plot of 5th Plausible Value – Fourth Grade

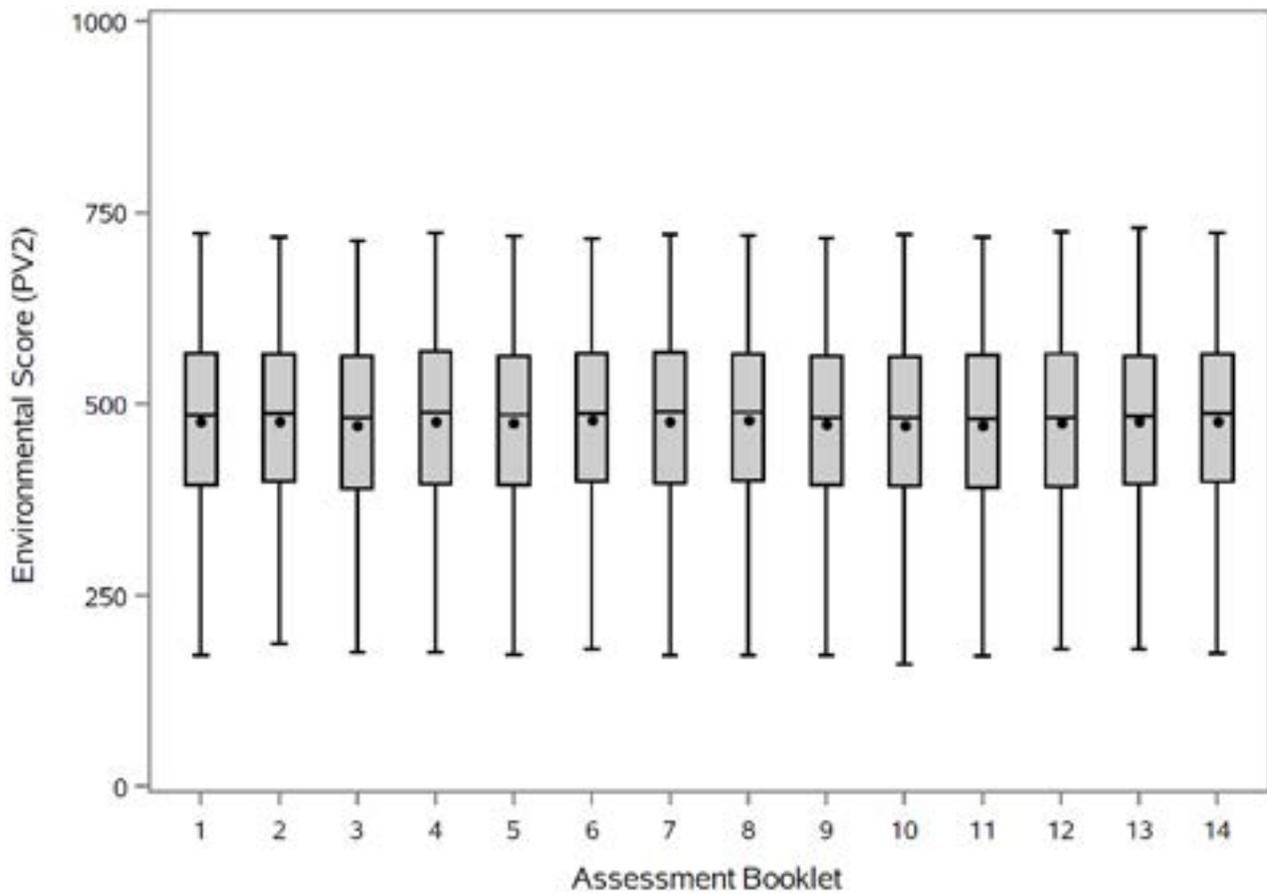


Appendix 18D: TIMSS 2019 Eighth Grade Environmental Scale Box Plots of Plausible Values

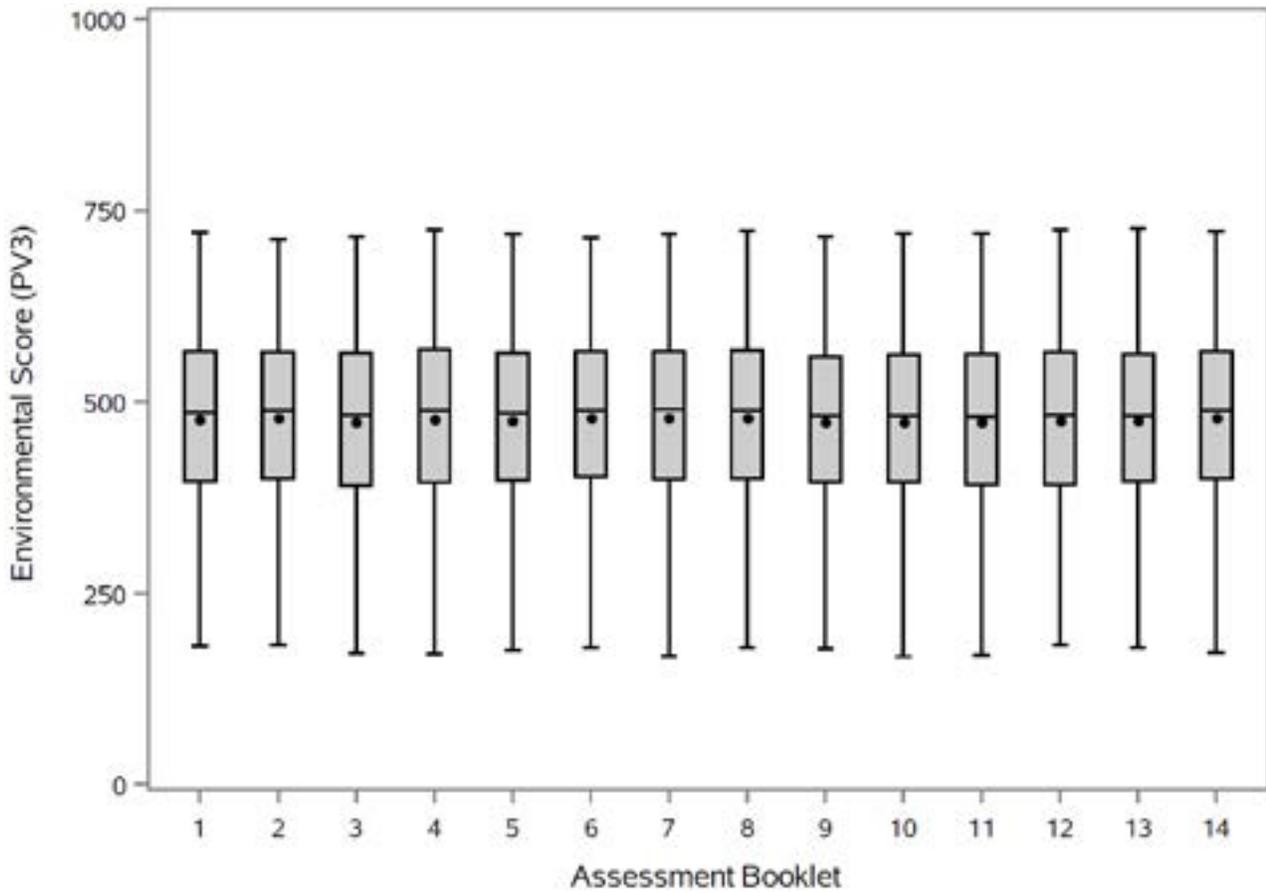
TIMSS 2019 Environmental Scale Box Plot of 1st Plausible Value – Eighth Grade



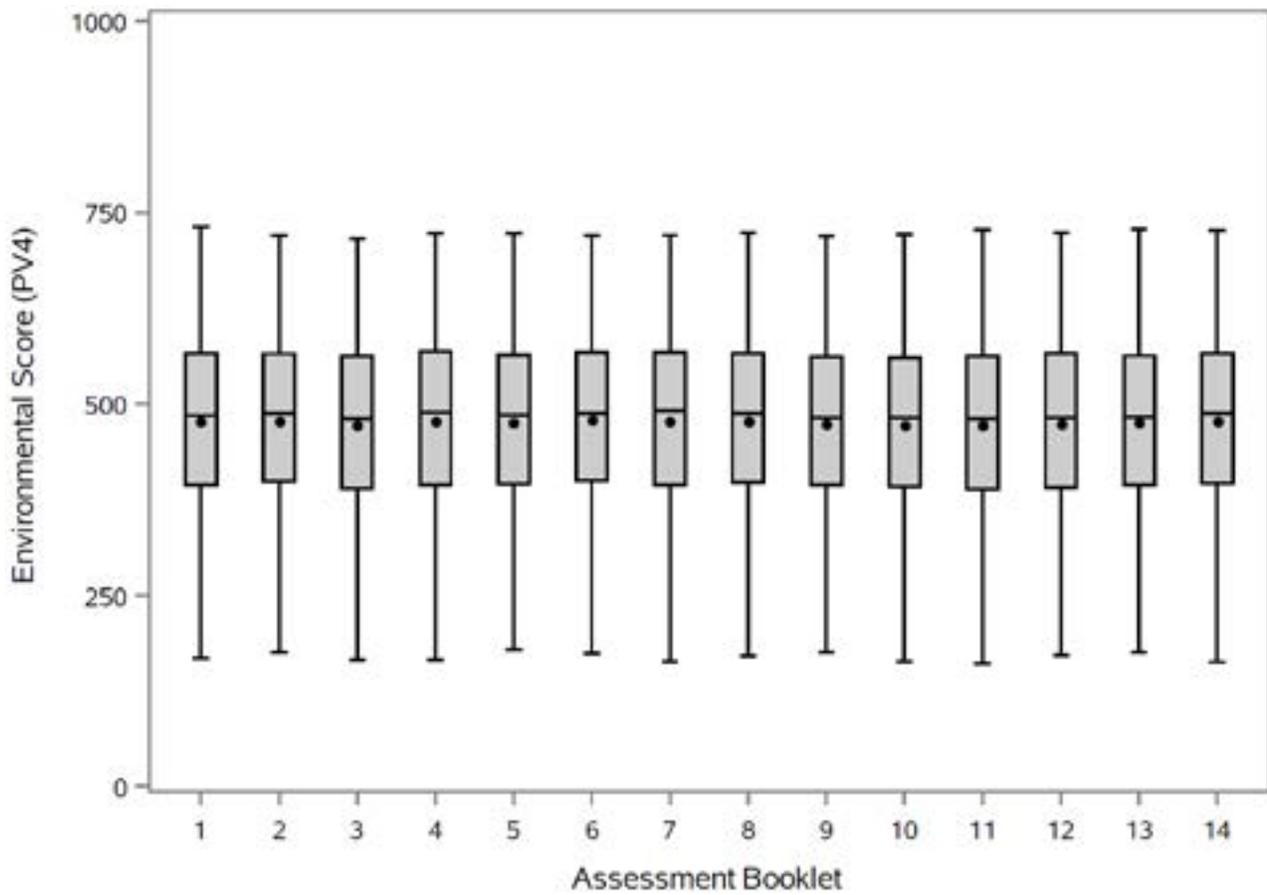
TIMSS 2019 Environmental Scale Box Plot of 2nd Plausible Value – Eighth Grade



TIMSS 2019 Environmental Scale Box Plot of 3rd Plausible Value – Eighth Grade



TIMSS 2019 Environmental Scale Box Plot of 4th Plausible Value – Eighth Grade



TIMSS 2019 Environmental Scale Box Plot of 5th Plausible Value – Eighth Grade

