American Research Journal of Humanities Social Science (ARJHSS)

E-ISSN: 2378-702X
Volume-04, Issue-10, pp-44-61
www.arjhss.com

Research Paper Open Access

Identifying the Domains in Science, Reading and Mathematics in which the U.S. High School Students Perform Lower in PISA.

OnderKoklu, Susan J. Cooper, C.DawnMartelli, Megan Atha
Florida Gulf Coast University
Florida Gulf Coast University
Florida Gulf Coast University
Florida Gulf Coast University

Abstract: The present study aimed to identify mathematics, science and reading item groups and thespecification of items in which U.S. students have a significantly lower level of correct responses compared toall other participants in PISA assessment. For this purpose, 269 items were analyzed by using MultilevelMeasurement Models. Data were obtained from the results of 2015 and 2018 PISA administrations released byOECD. Of the 269 items, 115 were Science,82 were Mathematics, and 72 were Reading items. All 269 itemswere grouped according to various content and cognitive domains. Then, these item groups were analyzed byusing two-level linear measurement models via HLM-6 software with a measurement model using both first andsecond level predictors for each of the three tests separately.Results of the study clearly indicated that the U.S.students performed lower than international average on only one of the three item groups in reading and only oneof the18 item groups in science. On the other hand, the U.S. students performed significantly lower thaninternational average on five of the 12 item groups in mathematics.

Key words: Reading, Science, Mathematics, Student achievement, PISA, HLM

I. Introduction

Robust educational systems rely on accurate data to inform curricular and instructional decision-making. Thus, comparative studies have long been conducted in order to measure the quality and effectiveness of education provided to students all over the world (Kyriakides et al., 2020; Cai, et al., 2016; Vedder, 2020). Educational policymakers, educators, and curriculum designers are able to identify strengths and weaknesses of their educational systems by comparing their students` achievement levels with the students' achievement levels in other countries (Hwang, et al., 2018; Klieme, 2020; Afdal, 2019). International studies such as TIMSS and PISA provide good opportunities for educational policymakers, educational researchers and curriculum designers in order to conduct these kind of comparative research studies (Nortvedt, 2018; Cordero et al., 2018; Mullis et.al, 2009).

Achievement of the U.S. students in PISA and TIMSS has attracted the attention of researchers, educators, policymakers, and the general public in recent years in the United States (Zhang &Bray, 2020; Elliott, et al., 2019; Grabau&Ma, 2017; Han, 2017). Consequently, there is a growing body of research on factors linked to achievement. Although effects of these factors on student achievement have been hypothesized and investigated for the past two decades, few attempts have been made to systematically investigate how content and cognitive domains are related to achievement. Thus, there are limited consistent and robust findings on content and cognitive factors related to achievement.

With continuous improvement as a goal, the Organization for Economic Cooperation and Development (OECD) developed the Programme for International Student Assessment (PISA) in 2000. PISA is an international assessment administered to 15-year-old students every three years to measure reading, mathematics, and science literacy as well as cross-curricular competencies, such as collaborative and creative problem-solving (NCES, 2020).Through these foci, PISA has been designed measure how well students can apply knowledge obtained both various learning contexts to real-world tasks as they are nearing the end of formal schooling (Cogan et al., 2019; She et al., 2018).The most recent administration was conducted in 2018,and over 600,000 students participated across 79 countries (OECD, 2020).

Most PISA research focuses on domain-level differences across countries with analyses differentiating for student characteristics such as gender and socioeconomic status (Cooper &Berry, 2020; Hwang &Yeo, 2020; Thien, 2016; Teig et al., 2020). Additionally, research tends to also focus on how PISA results correlate to other standardized measures such as the National Assessment of Educational Progress (NAEP) or the Trends in InternationalMathematics and Science Study (TIMMS). While such work is important forinforming policy reform, rarely do findings from such research inform instructionaldecision-making in U.S. classrooms. If U.S. performance is to improve oninternational measures such as the PISA, a more thorough analysis of student performance at the item-level is warranted. Such research is scant.

However, one recent study examined how spatial cognition as measured by the space and shape domain related to overall performance on the mathematics portion of the test. Sorby and Panther (2020) analyzed trends among high-performing countries and other countries of interest finding that success on PISA items is significantly correlated with scores on tests of spatial cognition. The authors suggested improving spatial skills could be an overlooked strategy for improving student performance on PISA (and by extension for improving preparedness for life). More research that uses item-level analysis to inform instructional practices is needed.

Similarly, the present study aimed to identify mathematics, science and reading item groups and the specification of items in which U.S. students have a significantly lower level of correct responses compared to all other participants in PISA assessment. Considering the purpose, specific research questions are:

1. Considering content and cognitive domains, on which item groups do U.S. students perform statistically significantly lower than students from other participant countries on the reading assessment?
2. Considering content and cognitive domains, on which item groups do U.S. students perform statistically significantly lower than students from other participant countries on the science assessment?
3. Considering content and cognitive domains, on which item groups do U.S. students perform statistically significantly lower than students from other participant countries on the mathematics assessment?

II. Method

The main objective is to identify specific item groups in which statistically significant differences exist between the U.S. students' and other participants' science, mathematics and reading performances. For this purpose, 269 items, which were released by OECD, were analyzed by using Multilevel Measurement Models via HLM-6 software (Raudenbush, 2004). In the analysis of the data, the mean percent correct information for all of the items were used on a continuous scale between 0 and 100. The same scale is used for open-ended questions. Although open-ended items include partial credits, mean percent correct information represented the rates for "full credit" responses. These percent correct rates also comprised the dependent variable of two level linear hierarchical models.

2.1. Data

Program for International Student Assessment (PISA) is a measurement instrument developed and administered by The Organization for Economic Cooperation and Development (OECD). PISA has been administered worldwide since 2000 in three-year periods to measure 15-year-olds' ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges (OECD, 2019). Data from 269 items were obtained from publicly provided results of 2015 and 2018 PISA administration released by OECD. Of the 269 items, 115 were Science, 82 were Mathematics, and 72 were Reading items.

2.2. Tests' Frameworks

2.2.1. Science Assessment:

The science assessment framework for PISA-2018 is organized around three dimensions: a system dimension specifying the domains of systems or subject matter to be assessed within science, a knowledge dimension specifying the type of knowledge to be assessed and a competency dimension specifying the sets of behaviors expected of students as they engage with the science content (Table-1). Distribution of total 115 science items can be seen in table-2 below.

Table 1. PISA Science Test System, Knowledge and Competency Domains

System Domain	**Knowledge Domain**	**Competency Domain**
(1) Living Systems • Cells (e.g., structures and function, DNA, differences between plant and animal cells) • The concept of an organism (e.g., unicellular vs. multicellular) • Humans (e.g., health; nutrition; subsystems such as the digestive, the respiratory, the circulatory, the excretory and the reproductive and their relationship) • Populations (e.g., species, evolution, biodiversity, genetic variation)	**(1) Content:** The content knowledge that PISA assesses is selected from the major fields of physics, chemistry, biology, and earth and space sciences.	**(1) Explain:** Explain phenomena scientifically.
(2) Physical Systems • Structure of matter (e.g., particle model, bonds). • Properties of matter (e.g., changes of state, thermal and electrical conductivity). • Chemical changes of matter (e.g., chemical reactions, energy transfer, acids/bases). • Motion and forces (e.g., velocity, friction) and action at a distance (e.g., magnetic, gravitational and electrostatic forces). • Energy and its transformation (e.g., conservation, dissipation, chemical reactions).	**(2) Procedural:** It is this knowledge of the standard concepts and procedures essential to scientific enquiry that underpins the collection, analysis and interpretation of scientific data.	**(2) Interpret:** Interpret data and evidence scientifically.
(3) Earth and Space • Structures of the Earth (e.g., lithosphere, atmosphere, hydrosphere). • Energy in the Earth (e.g., sources, global climate). • Change in the Earth (e.g., plate tectonics, geochemical cycles, constructive and destructive forces). • Earth's history (e.g., fossils, origin and	**(3) Epistemic:** Epistemic knowledge is a knowledge of the constructs and defining features essential to the process of knowledge building in science (e.g. hypotheses, theories and observations) and their role in justifying the	**(3) Evaluate:** Evaluate and design scientific enquiry

Table 2. Distribution of science items used in PISA-2018 by subdomains.

Systems	Knowledge	Competency	Number of Items		
Living Systems	Content	Explain	18	18	47
		Interpret			
		Evaluate			
	Procedural	Explain	3	22	
		Interpret	12		
		Evaluate	7		
	Epistemic	Explain		7	
		Interpret	2		
		Evaluate	5		
Physical Systems	Content	Explain	14	17	38
		Interpret	3		
		Evaluate			
	Procedural	Explain	1	14	
		Interpret	4		
		Evaluate	9		
	Epistemic	Explain		7	

		Interpret			
		Evaluate	7		
Earth and Space Systems	Content	Explain	12	14	30
		Interpret	2		
		Evaluate			
	Procedural	Explain		11	
		Interpret	11		
		Evaluate			
	Epistemic	Explain	1	5	
		Interpret	2		
		Evaluate	2		

2.2.2. Mathematics Assessment:

The mathematics assessment framework for PISA-2018 is organized around two dimensions: a content dimension specifying the domains or subject matter to be assessed within mathematics and a process dimension specifying the domains or thinking processes to be assessed (Table-3). The cognitive process domains describe the sets of behaviors expected of students as they engage with the mathematics content. Distribution of total 82 math items can be seen in table-4 below.

Table 3.PISA Mathematics Test Content, and Cognitive Process Domains

Content Domain	Process Domain
(1) Space and Shape	(1) Employ: Employing Mathematical Concepts, Facts and Procedures.
(2) Quantity	(2) Interpret: Interpreting, Applying and Evaluating Mathematical Outcomes.
(3) Change and Relationships	(3) Formulate: Formulating Situations Mathematically
(4) Uncertainty and Data	

Table 4. Distribution of mathematics items used in PISA-2018 by subdomains.

	Space and Shape	Quantity	Change and Relationships	Uncertainty and Data	TOTAL
Employ	8	12	10	5	35
Interpret	1	6	5	11	23
Formulate	10	3	7	4	24
TOTAL	19	21	22	20	82

2.2.3. Reading Assessment:

The reading assessment framework for PISA-2018 is organized around two dimensions: a subordinate category dimension specifying the essential cognitive components of reading to be assessed, a cognitive process dimension specifying the sets of behaviors expected of students as they engage with reading (Table-5). Distribution of total 72reading items can be seen in table-6 below. Since the data could not be obtained for each of the cognitive process seen in table-5 below, number of test items were only categorized by subordinate categories.

Table 5. PISA Reading Test Dimensions

Subordinate Category	Cognitive Processes
(1) Locating Information On a daily basis, readers most often use texts for purposes that require the location of specific information, with little or no consideration for the rest of the text. Locating information is an obligatory component of reading when using complex digital information such as search engines and websites	• Accessing and retrieving information within a text. • Searching for and selecting relevant text.
(2) Understanding A large number of reading activities involve the parsing and integration of extended passages of text in order to form an understanding of the meaning conveyed in the passage.	• Representing literal meaning. • Integrating and generating inferences.
(3) Evaluating and Reflecting Reasoning beyond the literal or inferred meaning of the text. Reflecting on the content and form of the text and critically assessing the quality and validity of the information therein.	• Assessing quality and credibility. • Reflecting on content and form. • Detecting and handling conflict.

Table 6. Distribution of reading items used in PISA-2018 by categories.

Subordinate Category	Number of Items
Locating Information	14
Understanding	41
Evaluating and Reflecting	17

2.3. Establishing item groups and coding

In the Science test, considering the “System”domain (3 groups), “Knowledge”domain (3 groups), and “Competency” domain (3 groups), a total of 27 (3x3x3) item groups can be made up for expressing all futures of each individual items. However, nine of those item groups have no items (i.e., questions) (see Table-2). Therefore, only 18 of these item groups can be found explaining the 115science items. In order to represent these groups in a systematic and more understandable way, an index made up by using letter and number codes. For example, the item group “Living Systems-Procedural-Evaluate” is indicated as (S_S1_K2_C3) meaning “Science, System-1, Knowledge-2, Competency-3” by using codes shown in Table 1.

Similarly, in the Mathematics test, item groups were established considering the “Content” domain (4 groups) and “Process” domain (3 groups) (see Table-3). A total of 12 (4x3) item groups were made up for expressing all futures of 82 items used in mathematics test. In order to represent these groups in a systematic and more understandable way, an index made up by using letter and number codes. For example, the item group “Quantity-Formulate” is indicated as (M_C2_P3) meaning “Math, Content-2, Process-3” by using codes shown in Table 3.

Finally, in the Reading test, item groups were established considering the “Subordinate Category” domain (3 groups) as seen in table-5. Although, there is another dimension called “Cognitive process” in specifications of reading items seen in Table-5, data could not be obtained for each of these categories. Therefore, number of test items were only categorized by subordinate categories. A total of three item groups were made up for expressing all futures of 72 items used in the reading test. In order to represent these groups in a systematic and more understandable way, an index made up by using letter codes. For example, the item group “Locate” is indicated as (R_L) meaning “Reading, Locate”.

These item groups were used as indicator variablesin the first level of two-level linear hierarchical measurement model. If an item belongs to a group represented by indicator variable it was coded as “1” otherwise it was coded as “0”. In the second step of two-level linear hierarchical measurement model,another indicator variable was made up to be able to identify “U.S.” among other participant countries. This indicator variable was coded as “1” for “U.S.” and “0” for the remaining participants.

2.4. Data Analysis

Data used in this study were filtered and reorganized as result of series of phases. All 269items (115 science, 82 math and 72 reading) were grouped according to various domains. Then, these item groups were analyzed by using Multilevel Measurement Models for science, math, and reading separately. First, the mean correct responses of obtained items for each participant country were obtained from OECD’s database. Then, items in three tests (science, math and reading) were grouped and coded as explained in previous section. In the third stage, data obtained from first and second stages were combined via SAS program and data files needed for the next phase were made up. Finally, data were analyzed by using two-level linear measurement models via HLM-6 software (Raudenbush, 2004) for each of the three tests separately.

Average rate of correct response variable is continuous dependent variable in this model. This variable is expressed as a percentage within the scale between 0 and 100.According to multilevel linear measurement model defined by Kamata, Bauer and Miyazaki (2008), the average correct responses for item groups are nested in individual participants. In this study, the same methodology was followed but average correct responses for item groups were nested in groups of individuals. First level of the two-level measurement model is shown in Equation 1 in which "*i*" indicates item (*i* = 1, 2,..., İ), "*j*" indicates group of individuals (*j* = 1, 2,..., J) and k indicates predictor (*k* = 1, 2,..., K).

$$Y_{ij} = \pi_{0j} + \pi_{1j}D_{1ij} + \pi_{2j}D_{2ij} + ... + \pi_{(k-1)j}D_{(k-1)ij} + \pi_{Kj}D_{Kij} + \varepsilon_{ij} \qquad \text{Eq. 1}$$

In this equation, Y_{ij} represents predicted outcome indicating average correct response of individuals in group "*j*" for item "*i*" in the test. Similarly, D_{kij} represents value of item "*i*" for predictor variable "k". In other words, it is an indicator variable that represents the item group where item "*i*" is.Parameter π_{kj} represents the effect of the predictor variable *"k"*. Basically, it indicates the average rate of correct response of individual in group "*j*" for item "*i*". Similarly, ε_{ij} represents the error for achievement levels of individuals in group "*j*" for item group "*i*".

Parameters such as π_{0j} and π_{kj} presented in the first level of the model are defined as dependent variables in the second level of the model. In this case the second level of the model was formulized as follows.

$$\begin{aligned}
\pi_{0j} &= \beta_{01}(grup)_j + r_{0j} \\
\pi_{1j} &= \beta_{10} + \beta_{11}(grup)_j \\
\pi_{2j} &= \beta_{20} + \beta_{21}(grup)_j \\
&\vdots \\
\pi_{(k-1)j} &= \beta_{(k-1)0} + \beta_{(k-1)1}(grup)_j \\
\pi_{Kj} &= \beta_{K0}
\end{aligned} \qquad \text{Eq. 2}$$

In the equation, parameters β_{10}, β_{20}, $\beta_{(k-1)0}$ and β_{K0} present the rate of correctresponses for each item group and they don't change by groups. The term r_{0j} indicates achievement levels of groups. As aimed in this study, the purpose is to compare average correct response rates of item groups in level two. Therefore, an indicator variable was added to the model as shown in Equation 2 in level two. Here, $(grup)_j$ is an indicator variable with two categories. While the focal group takes the value 1, reference group takes value 0. Coefficients β_{10}, β_{20}, $\beta_{(k-1)0}$ and β_{K0} represent mean correct response of item groups for reference category. Coefficient β_{01} represents the difference between mean correct responses for focal and reference groups for selected reference item group (last item group above). Coefficients β_{11}, β_{21} and $\beta_{(k-1)1}$ represent the difference between mean correct responses for focal and reference groups for remaining item groups and is computed as deviation from coefficient β_{01} .Coefficient β_{01} is called the main effect since it shows the achievement level differencesbetween groups in terms of reference item while coefficients β_{11}, β_{21} and $\beta_{(k-1)1}$ are called interaction effects since they represent the deviation of achievement differences between groups from main effect. Therefore,the sum of the main effect and interaction effects give the total effect. Interaction effects mentioned here are called "cross-level interaction effect" in statistical literature and mentioned as fundamental advantage of hierarchical modeling over traditional modeling (Raudenbush&Bryk; 2002).

III. Results

2.5. Two Level Measurement Model with Level-One Predictors Only

Analysis of data using this model reveals both average correct response for each item group and achievement levels of all PISA participant countries. The predicted average rate of correct responses and standard errors are shown in Table7, Table8, and Table9 below for science, math and reading respectively.

Table 7. Item Groups Descriptive for Science

Item Groups	Number of Items	Predicted Average Percent	Standard Error
S_S1_K1_C1	18	45.45	1.78
S_S1_K2_C1	3	33.36	1.45
S_S1_K2_C2	12	51.59	1.77
S_S1_K2_C3	7	52.82	1.94
S_S1_K3_C2	2	56.71	1.95
S_S1_K3_C3	5	31.66	1.88
S_S2_K1_C1	14	47.3	1.79
S_S2_K1_C2	3	44.97	2.13
S_S2_K2_C1	1	22.81	1.35
S_S2_K2_C2	4	65.92	1.82
S_S2_K2_C3	9	50.25	2.01
S_S2_K3_C3	7	33.73	1.56
S_S3_K1_C1	12	42.61	1.91
S_S3_K1_C2	2	46.25	1.92
S_S3_K2_C2	11	53.27	1.86
S_S3_K3_C1	1	18.8	1.41
S_S3_K3_C2	2	33.77	1.67
S_S3_K3_C3	2	65.89	1.77

Table 8. Item Groups Descriptive for Mathematics

Item Groups	Number of Items	Predicted Average Percent	Standard Error
M_C1_P1	8	35.68	1.66
M_C1_P2	1	78.82	1.34
M_C1_P3	10	22.02	1.32
M_C2_P1	12	49.97	1.87
M_C2_P2	6	55.05	1.53
M_C2_P3	3	43.96	1.96
M_C3_P1	10	40.83	1.39
M_C3_P2	5	49.98	1.81
M_C3_P3	7	31.06	1.41
M_C4_P1	5	46.02	1.47
M_C4_P2	11	50.62	1.86
M_C4_P3	4	32.48	1.9

Table 9. Item Groups Descriptive for Reading

Item Groups	Number of Items	Predicted Average Percent	Standard Error
R_L	14	55.62	1.67
R_U	41	54.50	1.71
R_E	17	53.37	1.54

Predicted within-participants variance, $\hat{\sigma}^2$, and predicted between-participants variance, $\hat{\tau}_{00}$, were computed for each of the three tests in order to calculate reliability coefficient for predictions. The following tables (Table 10, Table 11, and Table 12) shows those variances for each of the 3 tests.

Table 10. Science: Two Level Measurement Model with Level-One Predictors Only

Random Effect	Parameter	Variance	Degrees of Freedom (df)	Chi-Square value	p- value
Level-2 Error Term	$\hat{\tau}_{00}$	95.24	35	4382.17	<0.001
Level-1 Error Term	$\hat{\sigma}^2$	149.53			

Table 11. Math: Two Level Measurement Model with Level-One Predictors Only

Random Effect	Parameter	Variance	Degrees of Freedom (df)	Chi-Square value	p- value
Level-2 Error Term	$\hat{\tau}_{00}$	102.31	35	4511.24	<0.001

Level-1 Error Term	$\hat{\sigma}^2$	156.82

Table 12. Reading: Two Level Measurement Model with Level-One Predictors Only

Random Effect	Parameter	Variance	Degrees of Freedom (df)	Chi-Square value	p- value
Level-2 Error Term	$\hat{\tau}_{00}$	77.24	34	3974.62	<0.001
Level-1 Error Term	$\hat{\sigma}^2$	80.59			

As indicated in the above tables, obtained variances are statistically significant (p-value <0.001) in 0.05 alpha level. The reliability coefficient, $\hat{r}$, of predicted achievement levels of all PISA participants were calculated for each of the three tests by using the formula shown below. Reliability coefficients were found as 0.92, 0.88, 0.75 for science, math and reading respectively.

$$\hat{r} = \frac{\hat{\tau}_{00}}{\hat{\tau}_{00} + \hat{\sigma}^2 / n}$$

2.6. Two Level Measurement Model with Level-One and Level-Two Predictors

Both the average rate of correct responses and the standard errors for each item group for all PISA participants (36, including the U.S.) were predicted by previous model. Achievement level differences between the U.S. and all other participants for each item group were predicted and tested statistically by this model. Predicted differences in average rate of correct responses, standard errors, and p-values were given in Table13. In the table, while p-values in blue colored cells show statistically significant differences, orange colored rows indicate item groups on which U.S. students significantly lower than international average.

Table 13. Predicted Differences in Average Rate of Correct Responses Between the United States and Other PISA Participants and Standard Errors.

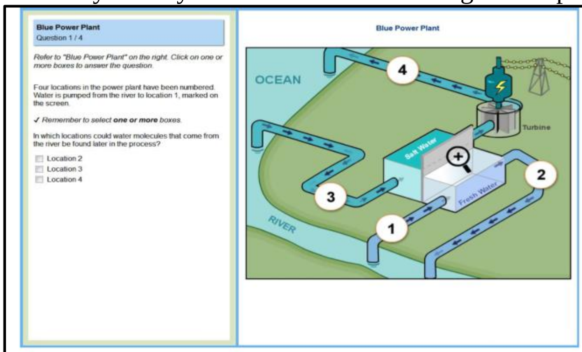
Item Groups	Number of Items	Predicted Average Percent Correct	Predicted Difference in Percent Correct	Standard Error	P-Value	Number of countries higher than U.S.	Number of countries lower than U.S.
S_S1_K1_C	18	45.45	+2.86	1.78	0.0030	10	26
S_S1_K2_C	3	33.36	+3.27	1.45	0.0000	11	25
S_S1_K2_C	12	51.59	+1.52	1.77	0.1320	15	21
S_S1_K2_C	7	52.82	+1.80	1.94	0.0481	11	25
S_S1_K3_C	2	56.71	+1.82	1.95	0.1888	15	21
S_S1_K3_C	5	31.66	+2.25	1.88	0.0540	16	20
S_S2_K1_C	14	47.3	+3.11	1.79	0.0046	12	24
S_S2_K1_C	3	44.97	-3.19	2.13	0.0342	24	12
S_S2_K2_C	1	22.81	+1.15	1.35	0.3680	17	19
S_S2_K2_C	4	65.92	+4.21	1.82	0.0007	11	25
S_S2_K2_C	9	50.25	+3.13	2.01	0.0018	11	25
S_S2_K3_C	7	33.73	+3.30	1.56	0.0000	11	25
S_S3_K1_C	12	42.61	+2.68	1.91	0.0161	12	24
S_S3_K1_C	2	46.25	+3.76	1.92	0.0059	14	22
S_S3_K2_C	11	53.27	+4.90	1.86	0.0000	8	28
S_S3_K3_C	1	18.8	+2.32	1.41	0.0002	7	29
S_S3_K3_C	2	33.77	+1.75	1.67	0.0795	13	23
S_S3_K3_C	2	65.89	+3.57	1.77	0.0001	9	27
M_C1_P1	8	35.68	-3.08	1.66	0.0066	29	7
M_C1_P2	1	78.82	-1.44	1.34	0.1658	28	8
M_C1_P3	10	22.02	-3.25	1.32	0.0002	28	8
M_C2_P1	12	49.97	-2.84	1.87	0.0114	30	6
M_C2_P2	6	55.05	-2.08	1.53	0.0396	27	9
M_C2_P3	3	43.96	-1.77	1.96	0.0597	28	8
M_C3_P1	10	40.83	-1.22	1.39	0.0801	24	12
M_C3_P2	5	49.98	+1.13	1.81	0.4239	22	14
M_C3_P3	7	31.06	-1.74	1.41	0.0743	27	9
M_C4_P1	5	46.02	+1.31	1.47	0.9303	20	16
M_C4_P2	11	50.62	-1.97	1.86	0.0840	27	9
M_C4_P3	4	32.48	-3.42	1.9	0.0397	29	7
R_L	14	55.62	-1.6	1.67	0.1092	18	17
R_U	41	54.5	+2.03	1.71	0.0315	12	23
R_E	17	53.37	+4.71	1.54	0.0000	3	32

2.7. Results for Science

Overall, the results from the current study revealed that the U.S. students have performed well in science assessment compared to other participants. Specifically, the U.S. students have performed significantly higher than international average on 11 of the 18 item groups in science. Similarly, they performed higher than international average on six item groups although the differences were not significant. Data analysis also revealed that while students from12 countries have performed better than U.S. students on these 17 item groups, students from 23 countries have performed lower than the U.S. students.

On the other hand, U.S. students have performed significantly lower than international average on only one of the 18 item groups in science. As seen in table-13, average percent correct responses of U.S. students on the item group S_S2_K1_C2 (Physical Systems / Content Knowledge / Interpret) was 3.19 percent lower than the international average. Sample items in this group can be seen in the following figures (figures-1-4). Data analysis also revealed that while students from 26 countries have performed better than U.S. students on this item group, U.S. students have performed better than only 11 of 35 countries.

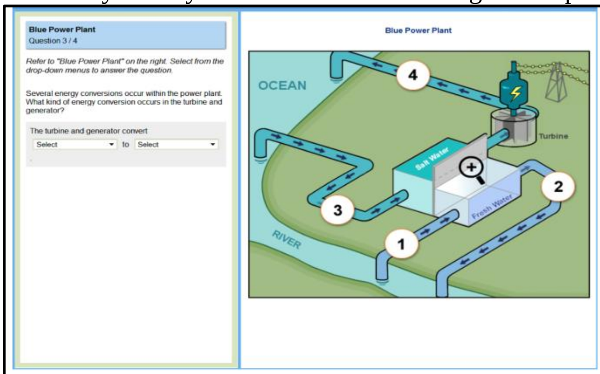
Figure-1. Sample Science Item in Physical Systems / Content Knowledge / Interpret Item Group



Students must apply their understanding of how water moves through the power plant presented in the diagram to identify *Location 2* and *Location 4* as containing water molecules from the river.

Item Number	CS639Q01
Competency	Interpret Data and Evidence Scientifically
Knowledge – System	Content – Physical
Context	Local/National – Frontiers
Cognitive Demand	Low
Item Format	Complex Multiple Choice – Computer Scored

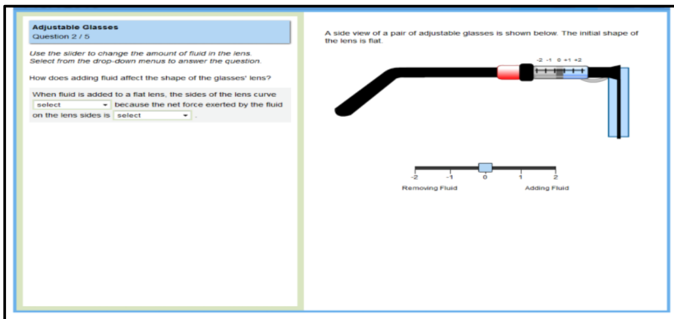
Figure-2. Sample Science Item in Physical Systems / Content Knowledge / Interpret Item Group



Each drop-down menu in this item lists four types of energy: gravitational, potential, kinetic and electrical. Students must correctly interpret the animated diagram and specify that the turbine and generator convert *kinetic* to *electrical* energy.

Item Number	CS639Q04
Competency	Interpret Data and Evidence Scientifically
Knowledge – System	Content – Physical
Context	Local/National – Frontiers
Cognitive Demand	Medium
Item Format	Complex Multiple Choice – Computer Scored

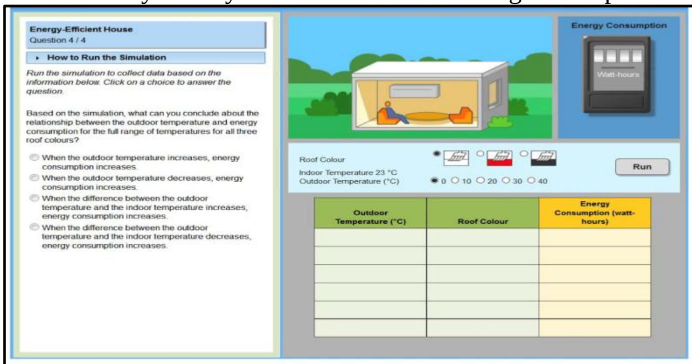
Figure-3. Sample Science Item in Physical Systems / Content Knowledge / Interpret Item Group



The options in the drop-down menus are outward and inward for the first menu and more and less for the second. Using the simulated adjustable glasses, students are asked to determine that when fluid is added to a flat lens, the sides of the lens curve *outward* and then interpret the simulation to specify that this is because the net force exerted by the fluid on the lens is *more*.

Item Number	CS621Q02
Competency	Interpret Data and Evidence Scientifically
Knowledge – System	Content – Physical
Context	Personal – Frontiers
Cognitive Demand	Low
Item Format	Complex Multiple Choice – Computer Scored

Figure-4. Sample Science Item in Physical Systems / Content Knowledge / Interpret Item Group



Students are asked to select a statement about the relationship between outdoor temperature and energy consumption that is supported by the simulation. The correct response is the third option: *When the difference between the outdoor temperature and the indoor temperature increases, energy consumption increases.*

Item Number	CS633Q05
Competency	Interpret Data and Evidence Scientifically
Knowledge – System	Content – Physical
Context	Local/National – Natural Resources
Cognitive Demand	High
Item Format	Simple Multiple Choice – Computer Scored

Differences between averages and standard deviations were computed for this item group in order to see the differences on individual items by using the information in OECD reports.It was clearly observed that participants from U.S. performed lower than the other participants in all of the items in the S_S2_K1_C2 item group. Effect size, as seen in the last column of Table14, shows the differences by using standard deviation scale. Effect size was calculated by dividing differences between averages by standard deviation. For example, effect size belonging to item CS413Q05S was found to be (-0.86) which means achievement level of the U.S. participants is approximately one standard deviation lower than the average achievement level.

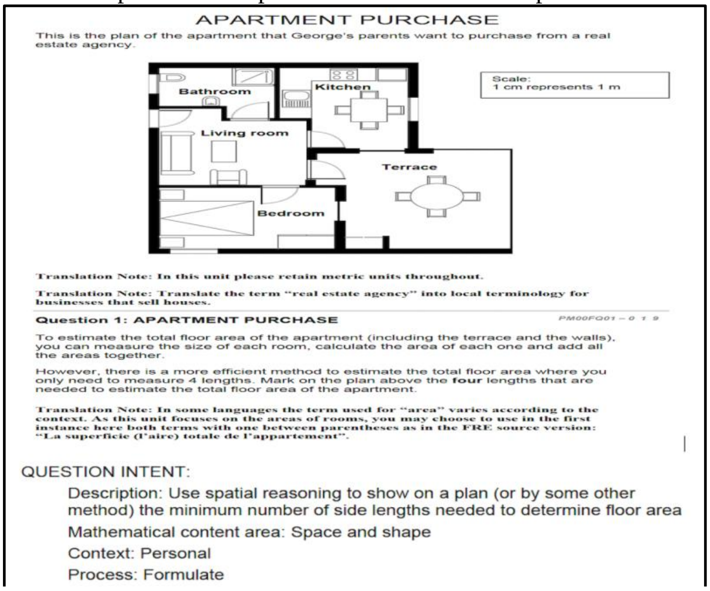
Table 14. Average Scores for Items in Physical Systems / Content Knowledge / Interpret Group.

Item	Average (US)	Average (International)	Difference	SD	Effect Size of the Difference
CS413Q06S	31.02	33.17	-2.15	9.37	-0.23
CS413Q04S	38.69	40.28	-1.58	10.41	-0.15
CS413Q05S	59.05	64.87	-5.82	6.73	-0.86

2.8. Results for Mathematics

Results of the study clearly showed that U.S. students have more difficulties in mathematics assessment comparing to science and reading assessment. Particularly, the U.S. students performed significantly lower than the international average on 5 of the 12 item groups in mathematics(Space and Shape/Employ, Space and Shape/Formulate, Quantity/Employ, Quantity/Interpret, Uncertainty and Data/Formulate). Sample items in these groups can be seen in the following figures (figures-5-9).Data analysis also revealed that while students from 28 countries have performed better than U.S. students on these 10 item groups, students from only seven countries have performed lower than the U.S. students.On the other hand, U.S. students didn't perform significantly higher than international average on any of the 12 item groups in mathematics.

Figure-5. Sample Math Item in "Space and Shape/ Formulate" Item Group


APARTMENT PURCHASE

This is the plan of the apartment that George's parents want to purchase from a real estate agency.

Translation Note: In this unit please retain metric units throughout.

Translation Note: Translate the term "real estate agency" into local terminology for businesses that sell houses.

Question 1: APARTMENT PURCHASE PM00FQ01 – 0 1 9

To estimate the total floor area of the apartment (including the terrace and the walls), you can measure the size of each room, calculate the area of each one and add all the areas together.

However, there is a more efficient method to estimate the total floor area where you only need to measure 4 lengths. Mark on the plan above the **four** lengths that are needed to estimate the total floor area of the apartment.

Translation Note: In some languages the term used for "area" varies according to the context. As this unit focuses on the areas of rooms, you may choose to use in the first instance here both terms with one between parentheses as in the FRE source version: "La superficie (l'aire) totale de l'appartement".

QUESTION INTENT:

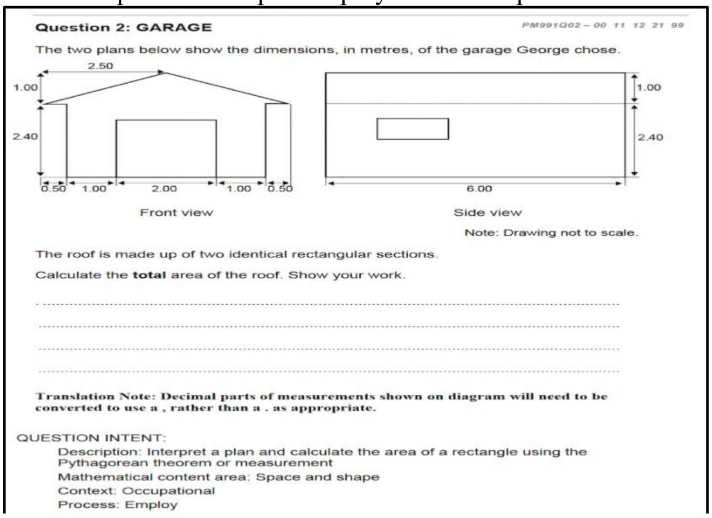
Description: Use spatial reasoning to show on a plan (or by some other method) the minimum number of side lengths needed to determine floor area

Mathematical content area: Space and shape

Context: Personal

Process: Formulate

Figure-6. Sample Math Item in "Space and Shape / Employ" Item Group


Question 2: GARAGE PM991Q02 – 00 11 12 21 99

The two plans below show the dimensions, in metres, of the garage George chose.

The roof is made up of two identical rectangular sections.

Calculate the **total** area of the roof. Show your work.

Translation Note: Decimal parts of measurements shown on diagram will need to be converted to use a , rather than a . as appropriate.

QUESTION INTENT:

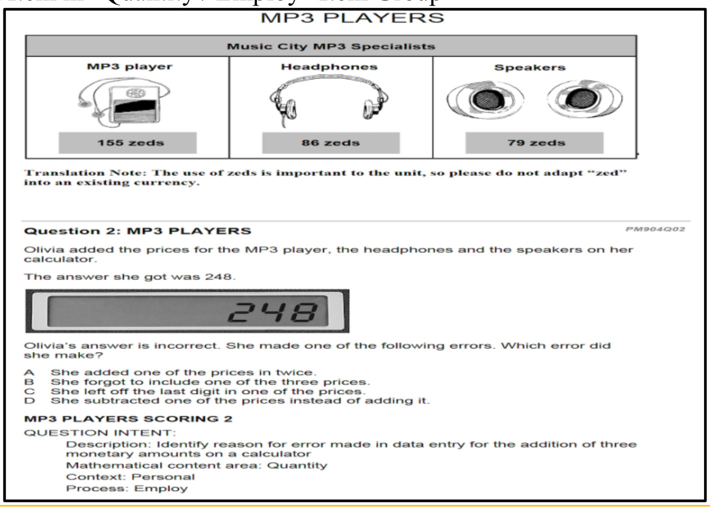
Description: Interpret a plan and calculate the area of a rectangle using the Pythagorean theorem or measurement

Mathematical content area: Space and shape

Context: Occupational

Process: Employ

Figure-7. Sample Math Item in "Quantity / Employ" Item Group


MP3 PLAYERS

Music City MP3 Specialists		
MP3 player	Headphones	Speakers
155 zeds	86 zeds	79 zeds

Translation Note: The use of zeds is important to the unit, so please do not adapt "zed" into an existing currency.

Question 2: MP3 PLAYERS PM904Q02

Olivia added the prices for the MP3 player, the headphones and the speakers on her calculator.

The answer she got was 248.

Olivia's answer is incorrect. She made one of the following errors. Which error did she make?

A She added one of the prices in twice.
B She forgot to include one of the three prices.
C She left off the last digit in one of the prices.
D She subtracted one of the prices instead of adding it.

MP3 PLAYERS SCORING 2

QUESTION INTENT:

Description: Identify reason for error made in data entry for the addition of three monetary amounts on a calculator

Mathematical content area: Quantity

Context: Personal

Process: Employ

Figure-8. Sample Math Item in "Quantity / Interpret" Item Group

Question 3: MP3 PLAYERS PM904Q03

Music City has a sale. When you buy **two or more** items at the sale, Music City takes **20%** off the normal selling prices of these items.

Jason has 200 zeds to spend.

At the sale, what can he afford to buy?

Circle "Yes" or "No" for each of the following options.

Items	Can Jason buy the items with 200 zeds?
MP3 player and the headphones	Yes / No
MP3 player and the speakers	Yes / No
All 3 items – the MP3 player, the headphones and the speakers	Yes / No

MP3 PLAYERS SCORING 3

QUESTION INTENT:

Description: Decide whether a known monetary amount will be sufficient to purchase a selection of items at a given percentage discount
Mathematical content area: Quantity
Context: Personal
Process: Interpret

Figure-9. Sample Math Item in "Uncertainty and Data / Formulate" Item Group

FAULTY PLAYERS

The *Electrix Company* makes two types of electronic equipment: video and audio players. At the end of the daily production, the players are tested and those with faults are removed and sent for repair.

The following table shows the average number of players of each type that are made per day, and the average percentage of faulty players per day.

Player type	Average number of players made per day	Average percentage of faulty players per day
Video players	2000	5%
Audio players	6000	3%

Question 1: FAULTY PLAYERS PM00EQ01

Below are three statements about the daily production at *Electrix Company*. Are the statements correct?

Circle "Yes" or "No" for each statement.

Statement	Is the statement correct?
One third of the players produced daily are video players.	Yes / No
In each batch of 100 video players made, exactly 5 will be faulty.	Yes / No
If an audio player is chosen at random from the daily production for testing, the probability that it will need to be repaired is 0.03.	Yes / No

FAULTY PLAYERS SCORING 1

QUESTION INTENT:

Description: Interpret statistical information involving uncertainty
Mathematical content area: Uncertainty and data
Context: Occupational
Process: Formulate

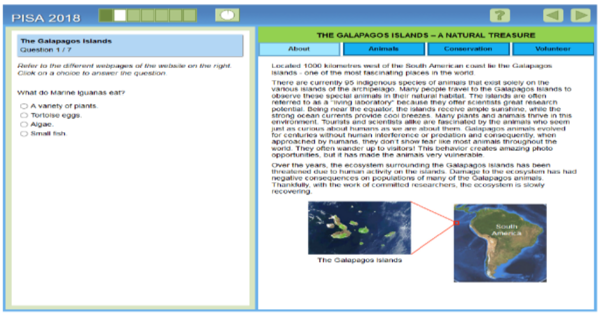
2.9. Results for Reading

Results of the present study indicated that U.S. students performed considerably better on the reading portion of the test when compared to their performance on the mathematics and science assessments. In particular, the U.S. students performed lower than the international average on only one of the 3-item groups in reading (R_L) (Locating Information), although this difference is not statically significant. Sample items in this group can be seen in the following figures (Figures10-12). Data analysis also revealed that while students from 18 countries have performed better than U.S. students on that item group, students from 17 countries have performed lower than the U.S. students.

On the other hand, U.S. students performed significantly higher than international average on the other two item groups in reading (R_U and R_E) (Understanding and Evaluating/Reflecting). As seen in table-13, U.S. students performed higher than international average on only two of the item groups although the differences were not significant.

Figure-10. Sample Reading Item in "Locating Information" Item Group

The Galapagos Islands Released Item #1

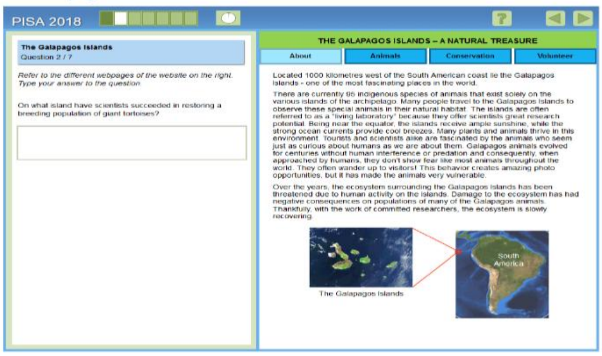


In this item, the answer is not located on the "About" webpage, so the student must search through the different webpages to find the answer. By providing the correct answer, the student demonstrates that he or she has selected the relevant text ("Animals"). Once the correct text has been located, a simple match is made between the content within the section on the Marine Iguana and the options in the stimulus. Thus, while this item encourages engagement with the different webpages, it does not require a deep level of engagement with the relevant text. Here, the answer is (C) Algae.

Item Number	CR571Q13
Cognitive Process	Search for and select relevant text
Response Format	Simple multiple choice
Source Requirement for Item	Multiple

Figure-11. Sample Reading Item in "Locating Information" Item Group

The Galapagos Islands Released Item #2

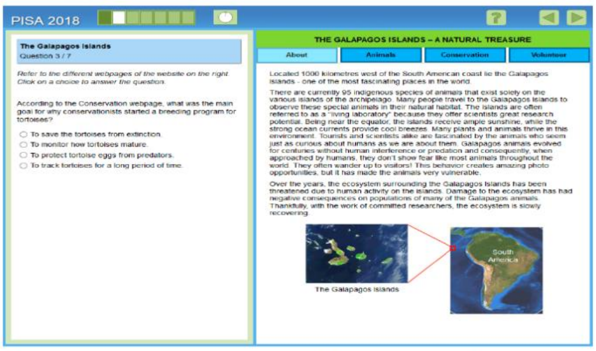


This item is similar to the Released Item #1 in that the student is not given information about where the answer to the question is located. Thus, the student must search among the four webpages and select the relevant text ("Conservation"). Here, the student must provide the answer in their own words, and the coding guide for the item can be found below.

Item Number	CR571Q14
Cognitive Process	Search for and select relevant text
Response Format	Open response – human coded
Source Requirement for Item	Multiple

Figure-12. Sample Reading Item in "Locating Information" Item Group

The Galapagos Islands Released Item #3



This item is a good contrast to the previous two items. In the two previous items in this unit, the item did not explicitly identify the relevant text for the student. Thus, searching for the relevant text was required to complete the item accurately. Here, the item explicitly refers to the "Conservation" webpage. This should be a strong signal to the student that they need to navigate to the "Conservation" webpage to find the answer. Once students are on the correct webpage, they need to match the information in the question stem (started a breeding program for tortoises) and the webpage (launched a breeding program). Option A is also a very close match with what is in the webpage (…to save the rest of the tortoises from extinction). The correct answer is (A) To save the tortoises from extinction. By contrasting this item and the previous two items, one can see the difference between the two cognitive processes of access and retrieve information within a text, and search for and select relevant text.

Item Number	CR571Q08
Cognitive Process	Access and retrieve information within a text
Response Format	Simple multiple choice
Source Requirement for Item	Single

The differences between averages and standard deviations were computed for this item group in order to see the differences on individual items by using the information in OECD reports. Considering this information, it was clearly observed that participants from U.S. performed significantly lower than the other participants in three items in R_L item group. Effect size, as seen in the last column of Table15, shows the differences in a more meaningful format by using standard deviation scale. Effect size was calculated by dividing differences between averages by standard deviation. For example, effect size belonging to item DR420Q02C was found to be (-1.30) which means achievement level of the U.S. participants more than one standard deviation lower than the average achievement level.

IV. Discussion and Conclusion

As we examine examples from all around the world, we should consider that fundamental reform movements in curriculum involving revisions and changes have been made for the last couple of decades in the United States at both the national and state levels. International measurement studies such as PISA are indispensable tools to be able to better understand the resulting effects of these U.S. curriculum reforms and changes in long run. From this perspective, results of this study are important to understand the effects of these curriculum reforms by comparing the students' achievement levels in PISAScience, Reading andMathematics tests administered in 2018. Therefore, the aim of this study was to investigate and identify the item groups that reveal statistically significant differences in achievement levels between participants from the U.S. and the participants from the rest of the other countries. For this purpose, PISA items were analyzed by two-level linear hierarchical measurement model.

The PISA test scores did not bring great news about the American education system, as the United States continues to remain under international mean for mathematics and around the international mean for reading and science. On the mathematics section, the U.S. scores significantly below the economically developed countries in Europe and Asia. Compared to previous years the PISA scores on math are still somewhat poor while science and especially reading scores are higher. The consistent finding has been that American high school students perform less well in mathematics than their peers in many other countries. We are not keeping up with our global counterparts, though the world is becoming increasingly interconnected and interdependent. We performed slightly above the OECD average in reading and science (our scores have remained unchanged in almost two decades while our counterparts' scores rose) but performed well below average in mathematics.

Analysis of data showed that almost all student science responses fell within the predicted range. The exception was item group S2_K1_C2, which refers to interpretation of content in physical systems. There were only 3 items in this group. Physical systems refer to content learned in chemistry and physics course work. The content includes the facts, concepts, and basic theories required to understand physical systems. Correct responses required students to interpret information in the context provided. Interpretation involves analysis and evaluation of data, the recognition that scientific evidence is uncertain, and that argumentation is needed to come to a consensus about the meaning of the data. Further, interpretation may require students to make predictions or suggest cause and effect relationships based on data.

In general, students in the United States are required to take three science credits in high school. In some instances, all three of the science courses taken in high school may be related to living systems or earth and space systems, and not physical systems. There are many reasons for this, including the fact that in many states only biology has a high-stakes test requirement (Nolin&Parr, 2013; Momsenet al., 2010). In addition, students may be more familiar with living systems content due to their experiences in elementary and middle school.

Further, courses such as chemistry and physics that are related to physical systems may be taught by out-of-field teachers. Sometimes students rely on memorization of important facts, concepts, and theories in physical systems courses so they lack the understanding required to interpret data effectively. (Dega, 2019; Dewi&Primayana, 2019) Teaching physical systems content in context would benefit student understanding and improve science literacy by relating content knowledge to the real world. Every day, reflective citizens make decisions regarding their personal health and the environment, so they would benefit from learning how to interpret data effectively.

Analysis of data showed that the U.S. students have performed considerably better in reading test comparing to mathematics and science assessments. Particularly, the U.S. students performed lower than international average on only one of the 3 item groups in reading (R_L) (Locating Information), although this difference is not statically significant. Reading literacy, in PISA 2018, is defined as one's capacity to understand, use, evaluate, reflect on, and engage with multiple texts, in a variety of formats, and across disciplines to achieve one's goals; develop one's knowledge and potential; and participate in society (OECD, 2019). PISA assessments in reading have changed to include multiple texts to reflect the "information-rich digital world," reflecting the evolution and growing influence of technology. Reading involves not only the printed page but also digital formats. It requires readers to distinguish between fact and opinion, synthesize and interpret texts from multiple sources, and deal with conflicting information across multiple disciplines. Analysis of data in this study showed that the U.S. studentshave performed considerably better in the reading test compared to mathematics and science assessments.

Literacy research has moved from a content area reading approach to a disciplinary reading approach in which strategies that are distinctive to specific disciplines are used to help students comprehend discipline-based texts (Milojević, 2020; Feng et al., 2019; Wandasari et al., 2019). Content area reading focuses on general comprehension skills and study skills, rather than engaging students into reading like disciplinary experts. Disciplinary literacy emphasizes that literacy and text are specialized and unique across the disciplines (Rainey, Maher and Moje, 2020; Windschitl, 2019). For example, scientists engage in very different approaches to reading than historians, and one can easily distinguish a math text from a literary one. Teaching literacy with a disciplinary literacy approach requires different reading strategies. Disciplinary literacy encourages students to grasp the ways literacy is used to create, disseminate, and critique information in the various disciplines. Students need to be immersed in the language and thinking processes of that discipline, learn the content in each discipline, and understand how and why reading and writing are used in each discipline.

The Common Core State Standards (CCSS) highlights that every teacher is a reading and writing teacher in their discipline (Hayden&Eades-Baird, 2020; Lechtenberg et al., 2020). It established disciplinary literacy goals to be introduced in the early sixth and seventh grades and to be mastered by twelfth grade. However, traditional efforts to encourage every content area teacher to be a reading teacher have not been widely accepted by teachers in the disciplines and not effective in raising reading achievement on a broad scale. Disciplinary literacy is often a new and unfamiliar approach to students starting the middle grades. Students struggling to learn to read in the early grade levels can quickly fall behind when reading to learn in the secondary grade levels.

Establishing an appropriate curriculum for teacher preparation is a necessary component for improving disciplinary literacy teaching for middle and high school students. There is also a need for explicit literacy standards for teachers who teach in the disciplines along with sufficient resources to help guide their teaching in varied disciplinary literacy contexts. Lastly, a key component to change includes a literacy curriculum that guides students to better meet the specific demands of reading and writing in the disciplines than has been provided by traditional conceptions of content-area reading.

Mathematics is an area where American students have always struggle (Schoenfeld, 2020; Frederick, 2020; Cuenca-Carlino, Freeman-Green et al., 2016; Barbieri &Booth, 2016). Results of this study suggested that the U.S. students performed significantly below the OECD average. Our productivity is below the OECD average and must be improved. Finland, Germany, Switzerland well outperform the U.S., for example. In a detailed analysis the data revealed that the U.S. students performed significantly lower than international average on 5 of the 12 item groups in mathematics (Space and Shape/Employ, Space and Shape/Formulate, Quantity/Employ, Quantity/Interpret, Uncertainty and Data/Formulate).

Over 30 years of nationwide standardized testing, the mathematics scores of U.S. high school students have barely shifted (Marsh et al., 2018; Woessmann, 2016). The findings of the present study indicate that U.S. students mostly performed lower in the contents of “Space and Shape,” “Quantity,” and “Uncertainty and Data.” Numerous possible reasons can be listed for the failure in so many content areas. One likely reason for students’ limited mastery of quantity, for instance, is that many U.S. teachers lack a firm conceptual understanding of fractions and division. In several studies (Coetzee&Mammen, 2017; Bentle&Bossé, 2018), it has been expressed that the majority of elementary, middle school, high school and even college studentshave problems to generate explanations for solving division problems with fractions. In contrast, most teachers in Japan and China generated two or three explanations in response to the same question Coetzee&Mammen, 2017; Bentley&Bossé, 2018). One reason for the failure in geometry can be explained by student tendency to consider geometrical objects as material objects and specific pictures rather than as theoretical, ideal objects which bear specific properties (Antonini, 2018; Seah&Horne, 2019). This difficulty results to the phenomenon of students trying to solve geometrical problems often relying on the visual perception of the given geometrical figure rather on a mathematical deduction based on the properties of the geometrical objects involved. This is called ‘geometrical figure to figural concept’ difficulty (Fischbein, 1993)

Some other reasons for students’ low performances in mathematics can be listed such as (1) difficulties in formulating situations mathematically, such as representing a situation mathematically, recognizing mathematical structure (including regularities, relationships, and patterns) in problems (Rahmawati&Retnawati, 2019; Jupri&Drijvers, 2016), (2) difficulties in evaluating the reasonableness of a mathematical solutions in the context of a real-world problem (Sawatzki&Sullivan, 2018; Kanthawat et al., 2019), (3) difficulties in understanding nonroutine (uncommon) problems completely(Fortes &Andrade, 2019; Chong et al., 2018; Murphy et al., 2019). In order to better understand and identify specific reasons for this low performance, further qualitative case studies should be conducted with high school students in different achievement levels. More importantly, teacher educators, policy makers and teachers must analyze the quality of the instruction versus the quantity of learning time spent.

Finally, PISA results clearly showed that students from the United States demonstrated learning gains across all three subjects from 2015 to 2018, although the gains were slight and statistically insignificant.

Nonetheless, the gains were sufficient enough to move U.S. reading and science scores above the OECD average. Math scores remained below the OECD average (NCES, 2020). This study clearly identified content and cognitive domains in which the U.S. students have performed significantly lower than international average. Therefore, the results of this study are important for teacher training programs, educational policy makers and teachers to be able to examine and identify possible reasons for these low performances in specific areas.

References

[1]. Afdal, H. W. (2019). The promises and limitations of international comparative research on teacher education. *European Journal of Teacher Education*, *42*(2), 258-275.

[2]. Antonini, S. (2018). Figural concepts in proving by contradiction. *Quadrante*, *27*(2), 115-132.

[3]. Barbieri, C., & Booth, J. L. (2016). Support for struggling students in algebra: Contributions of incorrect worked examples. *Learning and Individual Differences*, *48*, 36-44.

[4]. Bentley, B., &Bossé, M. J. (2018). College students' understanding of fraction operations. *International Electronic Journal of Mathematics Education*, *13*(3), 233-247.

[5]. Cai, J., Mok, I. A., Reddy, V., & Stacey, K. (2016). *International comparative studies in mathematics: Lessons for improving students' learning*. Springer Nature.

[6]. Chong, M. S. F., Shahrill, M., Putri, R. I. I., &Zulkardi. (2018, April). Teaching problem solving using non-routine tasks. In *AIP Conference Proceedings* (Vol. 1952, No. 1, p. 020020). AIP Publishing LLC.

[7]. Coetzee, J., &Mammen, K. J. (2017). Science and engineering students' difficulties with fractions at entry-level to university. *International Electronic Journal of Mathematics Education*, *12*(3), 281-310.

[8]. Cogan, L. S., Schmidt, W. H., & Guo, S. (2019). The role that mathematics plays in college-and career-readiness: evidence from PISA. *Journal of Curriculum Studies*, *51*(4), 530-553.

[9]. Cooper, G., & Berry, A. (2020). Demographic predictors of senior secondary participation in biology, physics, chemistry and earth/space sciences: students' access to cultural, social and science capital. *International Journal of Science Education*, *42*(1), 151-166.

[10]. Cordero, J. M., Cristobal, V., &Santín, D. (2018). Causal inference on education policies: a survey of empirical studies using PISA, TIMSS and PIRLS. *Journal of Economic Surveys*, *32*(3), 878-915.

[11]. Cuenca-Carlino, Y., Freeman-Green, S., Stephenson, G. W., &Hauth, C. (2016). Self-regulated strategy development instruction for teaching multi-step equations to middle school students struggling in math. *The Journal of Special Education*, *50*(2), 75-85.

[12]. Dega, B. G. (2019). Cognitive diagnostic assessment of students' responses: An example from energy and momentum concepts. *European Journal of Physics Education*, *10*(1), 13-23.

[13]. Dewi, P. Y., &Primayana, K. H. (2019). Effect of learning module with setting contextual teaching and learning to increase the understanding of concepts. *International Journal of Education and Learning*, *1*(1), 19-26.

[14]. Elliott, J., Stankov, L., Lee, J., & Beckmann, J. F. (2019). What did PISA and TIMSS ever do for us? The potential of large-scale datasets for understanding and improving educational practice. *Comparative Education*, *55*(1), 133-155.

[15]. Feng, L., Hodges, T. S., Waxman, H. C., & Joshi, R. M. (2019). Discovering the impact of reading coursework and discipline-specific mentorship on first-year teachers' self-efficacy: A latent class analysis. *Annals of Dyslexia*, *69*(1), 80-98.

[16]. Fischbein, E. (1993). The theory of figural concepts. *Educational Studies in Mathematics, 24*(2), 139-162.

[17]. Fortes, E. C., & Andrade, R. R. (2019). Mathematical creativity in solving non-Routine problems. *The Normal Lights*, *13*(1).

[18]. Frederick, K. D. (2020). *The Outcomes of pre-teaching math lessons to students who struggle in math: A single-subject design approach* (Doctoral dissertation, The Chicago School of Professional Psychology).

[19]. Grabau, L. J., & Ma, X. (2017). Science engagement and science achievement in the context of science instruction: a multilevel analysis of US students and schools. *International Journal of Science Education*, *39*(8), 1045-1068.

[20]. Han, S. W. (2017). From achievement to non-test outcomes in PISA: National trends in stem career expectations. In *The impact of the OECD on education worldwide*. Emerald Publishing Limited.

[21]. Hayden, H. E., &Eades-Baird, M. (2020). Disciplinary literacy and the 4Es: Rigorous and substantive responses to interdisciplinary standards. *Literacy Research: Theory, Method, and Practic*e.

[22]. Hwang, S., & Yeo, S. (2020). Gender differences in Korean elementary students: An analysis of TIMSS 2011 and 2015 fourth grade mathematics assessment. *The Mathematical Education*, *59*(3), 217-235.

[23]. Hwang, J., Choi, K. M., Bae, Y., & Shin, D. H. (2018). Do teachers' instructional practices moderate equity in mathematical and scientific literacy? An investigation of the PISA 2012 and 2015. *International Journal of Science and Mathematics Education*, *16*(1), 25-45.

[24]. Jupri, A., &Drijvers, P. (2016). Student difficulties in mathematizing word problems in algebra. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(9), 2481-2502.

[25]. Kamata, A., Bauer, D. J., & Miyazaki, Y. (2008). Multilevel modeling of educational data. *A. A. OConnell&McCoach, DB (Eds.), 345-388*.

[26]. Kanthawat, C., Supap, W., &Klin-eam, C. (2019). The development of grade 11 students' mathematical literacy on sequences and series using mathematical modelling. In *Journal of Physics: Conf. Series* (Vol. 1157, pp. 1-6).

[27]. Klieme, E. (2020). Policies and practices of assessment: A showcase for the use (and misuse) of international large-scale assessments in educational effectiveness research. In *International Perspectives in Educational Effectiveness Research* (pp. 147-181). Springer, Cham.

[28]. Kyriakides, L., Creemers, B., & Panayiotou, A. (2020). Developing and testing theories of educational effectiveness addressing the dynamic nature of education. In *International Perspectives in Educational Effectiveness Research* (pp. 33-69). Springer, Cham.

[29]. Lechtenberg, K., Thein, A. H., &Rushek, K. (2020). Challenging hierarchies of reading and text selection in the revised publishers' criteria for the Common Core State Standards. *The Bloomsbury Handbook of Reading Perspectives and Practices*, 258.

[30]. Marsh, H. W., Pekrun, R., Murayama, K., Arens, A. K., Parker, P. D., Guo, J., &Dicke, T. (2018). An integrated model of academic self-concept development: Academic self-concept, grades, test scores, and tracking over 6 years. *Developmental Psychology*, *54*(2), 263.

[31]. Milojević, S. (2020). Practical method to reclassify Web of Science articles into unique subject categories and broad disciplines. *Quantitative Science Studies*, *1*(1), 183-206.

[32]. Momsen, J. L., Long, T. M., Wyse, S. A., & Ebert-May, D. (2010). Just the facts? Introductory undergraduate biology courses focus on low-level cognitive skills. *CBE—Life Sciences Education*, *9*(4), 435-440.

[33]. Murphy, P. E. L., Evans, T., Klymchuk, S., Novak, J., Stephens, J., & Thomas, M. (2019). University STEM students' perceptions of creativity in non-routine problem-solving. *ANZIAM Journal*, *61*, C152-C165.

[34]. Nolin, J. B., & Parr, B. (2013). Utilization of a high stakes high school graduation exam to assess the impact of agricultural education: A measure of curriculum integration. *Journal of Agricultural Education*, *54*(3), 41-53.

[35]. Nortvedt, G. A. (2018). Policy impact of PISA on mathematics education: The case of Norway. *European Journal of Psychology of Education*, *33*(3), 427-444.

[36]. OECD. (2019). *PISA 2018 assessment and analytical framework*. OECD publishing.

[37]. Raudenbush, S. W. (2004). HLM 6: Hierarchical linear and nonlinear modeling. Scientific Software International.

[38]. Raudenbush, S. W., & Bryk, A. S. (2002). Hierarchical linear models: Applications and data analysis methods (Vol. 1),SAGE.

[39]. Rahmawati, F., &Retnawati, H. (2019, March). An analysis of students' difficulties in solving PISA-like mathematical problems. In *Journal of Physics: Conference Series* (Vol. 1200, No. 1, p. 012015). IOP Publishing.

[40]. Rainey, E. C., Maher, B. L., & Moje, E. B. (2020). Learning disciplinary literacy teaching: An examination of preservice teachers' literacy teaching in secondary subject area classrooms. *Teaching and Teacher Education*, *94*, 103123.

[41]. Sawatzki, C., & Sullivan, P. (2018). Shopping for shoes: Teaching students to apply and interpret mathematics in the real world. *International Journal of Science and Mathematics Education*, *16*(7), 1355-1373.

[42]. Schoenfeld, A. H. (2020). Mathematical practices, in theory and practice. *ZDM–The International Journal on Mathematics Education*.

[43]. She, H. C., Stacey, K., & Schmidt, W. H. (2018). Science and mathematics literacy: PISA for better school education. *International Journal of Science and Mathematics Education*, *16*(1), 1-5.

[44]. Seah, R., & Horne, M. (2019). A learning progression for geometric reasoning. In *Researching and using progressions (trajectories) in mathematics education* (pp. 157-180). Brill Sense.

[45]. Sorby, S. A., & Panther, G. C. (2020). Is the key to better PISA math scores improving spatial skills? *Mathematics Education Research Journal*, 1-21.

[46]. Teig, N., Scherer, R., &Kjærnsli, M. (2020). Identifying patterns of students' performance on simulated inquiry tasks using PISA 2015 log-file data. *Journal of Research in Science Teaching*.

[47]. Thien, L. M. (2016). Malaysian students' performance in mathematics literacy in PISA from gender and socioeconomic status perspectives. *The Asia-Pacific Education Researcher*, *25*(4), 657-666.

[48]. Vedder, P. (2020). Measuring the quality of education:An introduction. *Measuring the Quality of Education*, 1.

[49]. Wandasari, Y., Kristiawan, M., & Arafat, Y. (2019). Policy evaluation of school's literacy movement on improving discipline of state high school students. *International Journal of Scientific & Technology Research*, *8*(4), 190-198.

[50]. Windschitl, M. (2019). Disciplinary literacy versus doing school. *Journal of Adolescent & Adult Literacy*, *63*(1), 7-13.

[51]. Woessmann, L. (2016). The importance of school systems: Evidence from international differences in student achievement. *Journal of Economic Perspectives*, *30*(3), 3-32.

[52]. Zhang, W., & Bray, M. (2020). Comparative research on shadow education: Achievements, challenges, and the agenda ahead. *European Journal of Education*, *55*(3), 322-341.