

## **TIMSS Advanced Mathematics and Physics 2015- Lebanon Overview**

### **Introduction**

Different forms of assessment are used by nations worldwide and many of them are international. However, the nature of these assessments vary according to their purpose. The purpose of norm referenced assessments is to compare the performance of students to a hypothetical average that is to rank each student with respect to the achievement of others (Huit, 1996). Examples of these tests are GRE and SAT used by universities to select students (Blodgett, 2014). Criterion referenced tests are used to measure the performance of students on a specific body of knowledge against a fixed set of criteria. Examples of criterion referenced tests are TIMSS and PISA that provide important information about the educational achievement of students in a nation compared to their peers of other nations (Center for Public Education, 2006) TIMSS advanced is an international study that provides information about the educational achievement of students in grade 12 mathematics and physics worldwide. It comes along with another TIMSS study that monitors students of grade 4 and 8 in math and science every four years since 1995 (Mullis et. al. 2016a). However, TIMSS Advanced study took place less frequently in 1995, 2008 and 2015. Lebanon participated in the 2008 and the 2015 TIMSS Advanced studies, while it participated in TIMSS study for grade 8 since 2003 and on. Lebanese, Russian and Dutch students performed highest in TIMSS Advanced 2008 amongst the ten participating countries worldwide with averages higher than the scale center point in mathematics. Despite the fact that Lebanese students' average declined 13 points in 2015 from that in 2008, Lebanese and Russian students performed best in 2015. They were the only two countries out of the nine participating countries who had an achievement higher than the scale

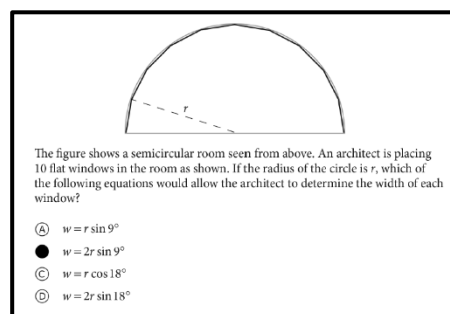
center point in mathematics. Lebanese students who participate in the TIMSS Advanced study are a random sample of grade 12 students enrolled in the general science section in Lebanon and who take an average of 240 yearly instructional hours in mathematics (Mullis et. al., 2016). As for physics, Slovenia, Russia and Norway performed best in 2015. Lebanon scored less than the scale center point with an average lower than six participating countries but higher than Italy and France (Mullis et.al.2016). TIMSS Advanced assessment is distributed in 12 booklets. Booklets 1 till 6 cover the math items while booklets 7 to 12 cover the physics items. These items are either multiple choice or constructed response items.

### Analysis of Mathematics TIMSS Advanced

Analyzing the math exam booklets, it was noticed that mathematics items as aligned with the Lebanese curriculum can be analyzed as follows:

- There are 108 questions in 6 booklets (Booklets 1 to 6).
- 90% of the questions correspond to grades 10 to 12 since the mathematics Lebanese curriculum is spiral so all the items covered in grade 10 are revisited in grade 12 and new topics covering new items are introduced through the years.
- 10% of the items are not familiar to Lebanese students since they cover real life situations while most of the Lebanese curriculum is abstract mathematics and not applied mathematics. An example of such items is shown in figure 1 below.

Fig. 1 A sample item non- familiar with the Lebanese curriculum



The mathematics items were distributed in three mathematics domains Algebra, Calculus and Geometry covering the topics displayed in Table 1 below.

Table 1 Distribution of TIMSS advanced mathematics by content domains

<b>Algebra 35%</b>	
Expressions and operations	Algebraic expressions, arithmetic and geometric series
Equations and inequalities	Using equations and inequalities, and systems of equations and inequalities to solve problems
Functions	
Various representations and properties of functions	
<b>Calculus 35%</b>	
Limits	Limits of functions, Conditions of continuity and differentiability of functions
Derivatives	Differentiate functions, use derivatives to solve problems in optimization and rates of change, Use first and second derivatives to determine slope, extrema, and points of Inflection, use first and second derivatives to sketch and interpret graphs of functions.
Integrals	
Integrate functions, evaluate definite integrals, and apply integration to compute areas and volumes.	
<b>Geometry 30%</b>	
Non-coordinate geometry	Use non-coordinate geometry to solve problems in two and three dimensions
Coordinate geometry	Apply the properties of vectors and their sums and differences to solve problems
Trigonometry	Use coordinate geometry to solve problems in two dimensions Apply the properties of vectors and their sums and differences to solve problems Use trigonometry to solve problems involving triangles. Recognize, interpret, and draw graphs of sine, cosine, and tangent functions. Solve problems involving trigonometric functions.

The achievement of Lebanese students across content domains showed advancement in Calculus and Geometry over all other countries while Russian Federation which provides their students an intensive course in mathematics outweighed Lebanon in Algebra only. Table 2 shows the achievement of countries participating in TIMSS Advanced across content domains.

**Table 2.** Achievement in Mathematics TIMSS Advanced across Content Domains

Country	Overall Advanced Mathematics Average Scale Score	Algebra (37 items)			Calculus (34 items)			Geometry (30 items)		
		Average Scale Score	Difference from Overall Advanced Mathematics Score		Average Scale Score	Difference from Overall Advanced Mathematics Score		Average Scale Score	Difference from Overall Advanced Mathematics Score	
Russian Federation 6hr+	540 (7.8)	556 (9.0)	16 (3.9)	🟢	513 (8.0)	-27 (2.3)	🟡	560 (8.4)	20 (3.2)	🟢
‡ Lebanon	532 (3.1)	525 (4.0)	-6 (3.6)		544 (3.9)	12 (2.8)	🟢	526 (3.7)	-6 (2.3)	🟡
‡ United States	485 (5.2)	478 (5.0)	-7 (1.7)	🟡	504 (6.0)	19 (2.9)	🟢	455 (5.7)	-30 (2.6)	🟡
Russian Federation	485 (5.7)	495 (6.3)	10 (1.9)	🟢	459 (5.9)	-26 (1.2)	🟡	500 (5.8)	15 (1.0)	🟢
† Portugal	482 (2.5)	495 (2.7)	12 (1.5)	🟢	476 (2.6)	-6 (1.4)	🟡	464 (3.2)	-18 (1.5)	🟡
France	463 (3.1)	469 (2.9)	7 (1.8)	🟢	466 (3.2)	3 (1.8)		441 (3.7)	-22 (1.3)	🟡
Slovenia	460 (3.4)	474 (3.5)	14 (1.1)	🟢	437 (4.4)	-23 (2.0)	🟡	456 (4.0)	-4 (1.4)	🟡
Norway	459 (4.6)	446 (4.1)	-13 (1.6)	🟡	463 (5.3)	4 (1.5)	🟢	473 (4.6)	14 (2.0)	🟢
Sweden	431 (4.0)	422 (4.1)	-9 (1.2)	🟡	438 (3.9)	7 (1.5)	🟢	430 (3.7)	-1 (1.4)	
Italy	422 (5.3)	414 (5.1)	-8 (2.2)	🟡	433 (5.2)	11 (2.7)	🟢	413 (5.7)	-9 (3.2)	🟡

Table 3 shows the distribution of Mathematics TIMSS items across the three cognitive domains:

knowing , applying and reasoning along with the percentage of their occurrence.

**Table 3.** Distribution of TIMSS advanced mathematics by cognitive domains

Knowing 35%	
Recall	Recall definitions, terminology, notation, mathematical conventions, number properties, and geometric properties. Recognize entities that are mathematically equivalent (e.g., different representations of the same function). Carry out algorithmic procedures (e.g., determining derivatives of polynomial functions, and solving a simple equation).
Recognize	
Compute	
Retrieve	
Retrieve information from graphs, tables, texts, or other sources.	
Application 35%	
Determine	Determine efficient and appropriate methods, strategies, or tools for solving problems for which there are commonly used methods of solution. Generate an equation or diagram that models problem situations and generate equivalent representations for a given mathematical entity, or set of information. Implement strategies and operations to solve problems in familiar mathematical concepts and procedures.
Represent/Model	
Implement	
Reasoning 30%	
Analyze	Identify the elements of a problem and determine the information, procedures, and strategies necessary to solve the problem. Link different elements of knowledge, related representations, and procedures to solve problems. Determine the appropriateness of alternative strategies and solutions. Make valid inferences on the basis of information and evidence. Make statements that represent relationships in more general and more widely applicable terms.
Integrate/Synthesize	
Evaluate	
Draw conclusions	

Generalize	Provide mathematical arguments, or proofs to support a strategy, solution, or statement.
Justify	

The results of achievement over cognitive domains displayed in Table 4 showed advancement of Lebanon over all countries in knowing but not in applying and reasoning where Lebanon ranked second after Russia. Here, we note again that Russian students participating in TIMSS Advanced undergo an intensive course in mathematics.

**Table 4.** Achievement in Mathematics TIMSS Advanced across Cognitive Domains

Country	Overall Advanced Mathematics Average Scale Score	Knowing (32 items)		Applying (40 items)		Reasoning (29 items)	
		Average Scale Score	Difference from Overall Advanced Mathematics Score	Average Scale Score	Difference from Overall Advanced Mathematics Score	Average Scale Score	Difference from Overall Advanced Mathematics Score
Russian Federation 6hr+	540 (7.8)	538 (8.8)	-2 (2.0)	544 (8.1)	4 (2.0)	541 (7.2)	1 (2.1)
‡ Lebanon	532 (3.1)	543 (4.5)	11 (2.9) 📈	529 (3.8)	-3 (2.8)	527 (3.9)	-5 (2.2) 📉
‡ United States	485 (5.2)	488 (5.7)	3 (2.3)	480 (5.5)	-5 (2.0) 📉	484 (5.3)	-1 (2.2)
Russian Federation	485 (5.7)	478 (6.7)	-7 (1.7) 📉	491 (6.1)	6 (1.7) 📈	484 (5.3)	-1 (1.2)
† Portugal	482 (2.5)	479 (3.0)	-3 (1.6)	476 (2.9)	-6 (1.8) 📉	488 (3.5)	6 (2.2) 📈
France	463 (3.1)	475 (2.7)	13 (2.0) 📈	449 (3.4)	-14 (1.5) 📉	462 (3.1)	0 (0.9)
Slovenia	460 (3.4)	466 (3.5)	6 (1.7) 📈	465 (4.0)	5 (2.1) 📈	442 (4.0)	-17 (1.6) 📉
Norway	459 (4.6)	445 (4.1)	-14 (1.8) 📉	459 (5.1)	0 (2.0)	469 (4.4)	9 (1.4) 📈
Sweden	431 (4.0)	405 (4.7)	-26 (1.4) 📉	434 (3.6)	3 (1.5)	447 (3.9)	16 (2.0) 📈
Italy	422 (5.3)	423 (5.5)	1 (1.9)	425 (5.4)	3 (2.2)	411 (5.9)	-11 (3.1) 📉

## Analysis of Physics TIMSS Advanced

Analyzing the physics exam booklets, it was noticed that the physics items as aligned with the Lebanese curriculum can be analyzed as follows:

- There are 101 questions in 6 booklets (Booklets 7 to 12).
- 14% of the questions correspond to grade 12 General Sciences.
- 50% of the questions correspond to grade 11 Scientific.
- 15% of the questions correspond to grade 10.
- 21% of the questions do not correspond to the Lebanese Curriculum.

Almost 80% of the questions correspond to the Lebanese Curriculum but there is a problem. Our students are not used to the way the questions are asked. They are used to very guided questions and not used to problem situations. They are used to apply knowledge and not to analyze and get to upper levels of thinking. In addition to this, our students aren't used to answer this way (Page 4 – example 3: If you use a calculator in answering one of these questions, you still must describe all the steps you used to obtain your answer. The following illustrates a calculator explanation of Example 3.).

Starting with the equation  $\Delta L = L_0 \alpha \Delta T$ , I used my calculator to get  $\Delta L$ . Then I added that to  $L_0$  to get 10.017m

Our students aren't used to this notation (Page 5 – Selected Physics Formulas:  $v = u + at$  ;  $v^2 = u^2 + 2as$  ;  $s = ut + 1/2.at^2$ ). Instead, they are used to this one ( $v = at + v_0$  ;  $v^2 - v_0^2 = 2ax$  ;  $x = 1/2.at^2 + v_0t$ ).

The physics items were distributed in three physics domains Mechanics and Thermodynamics, Electricity and Magnetism and Wave Phenomena and Atomic/Nuclear Physics with percentages displayed in Table 5 below.

**Table 5.** Distribution of TIMSS advanced physics by content domains

Content Domains	Percentages
Mechanics and Thermodynamics	40%
Electricity and Magnetism	25%
Wave Phenomena and Atomic/Nuclear Physics	35%

The achievement of Lebanese students across content domains showed lowest scores in Mechanics and Thermodynamics and highest in Wave Phenomena. However, in all the three

content domains, Lebanese students scored below the scale center point and lower than six participating countries but higher than France in all the content domains and higher than Italy in Electricity and Magnetism. Table 6 shows the distribution of the physics scores across content domains.

**Table 6.** Achievement in Physics TIMSS Advanced across Content Domains

Country	Overall Physics Average Scale Score	Mechanics and Thermodynamics (39 items)			Electricity and Magnetism (27 items)			Wave Phenomena and Atomic/Nuclear Physics (35 items)		
		Average Scale Score	Difference from Overall Physics Score		Average Scale Score	Difference from Overall Physics Score		Average Scale Score	Difference from Overall Physics Score	
Slovenia	531 (2.5)	541 (2.7)	10 (1.6)	▲	530 (4.3)	-1 (4.5)		511 (4.5)	-20 (3.9)	▼
Russian Federation	508 (7.1)	514 (6.7)	7 (1.6)	▲	515 (8.0)	8 (2.8)	▲	490 (7.5)	-17 (2.1)	▼
Norway	507 (4.6)	503 (4.1)	-5 (1.7)	▼	514 (5.5)	7 (3.8)		507 (5.2)	0 (2.1)	
Portugal	467 (4.6)	489 (4.8)	22 (3.2)	▲	431 (5.8)	-35 (4.5)	▼	456 (6.2)	-11 (5.2)	▼
Sweden	455 (5.9)	455 (6.1)	0 (2.7)		455 (6.0)	1 (2.6)		451 (6.3)	-4 (2.7)	
‡ United States	437 (9.7)	462 (9.6)	25 (3.4)	▲	380 (12.2)	-58 (3.9)	▼	431 (8.7)	-7 (3.0)	▼
‡ Lebanon	410 (4.5)	395 (4.4)	-15 (4.7)	▼	399 (5.2)	-11 (5.9)		431 (6.8)	20 (5.7)	▲
Italy	374 (6.9)	376 (6.4)	2 (2.6)		425 (6.6)	51 (3.7)	▲	329 (7.9)	-45 (2.3)	▼
France	373 (4.0)	327 (5.7)	-46 (3.7)	▼	339 (4.7)	-34 (3.8)	▼	418 (4.5)	45 (2.5)	▲

Table 7 shows the distribution of the physics TIMSS items across the three cognitive domains: knowing, applying and reasoning along with the percentage of their occurrence.

**Table 7.** Distribution of TIMSS advanced physics by cognitive domains

Cognitive Domains	Percentages
Knowing	30%
Applying	40%
Reasoning	30%

The results of achievement over cognitive domains displayed in Table 8 showed that Lebanese students scored highest in Applying and lowest in Knowing and Reasoning. In the three cognitive domains, Lebanon scored lower than six participating countries and higher than Italy and France.

**Table 8.** Achievement in Physics TIMSS Advanced across Cognitive Domains

Country	Overall Physics Average Scale Score	Knowing (30 items)		Applying (41 items)		Reasoning (30 items)	
		Average Scale Score	Difference from Overall Physics Score	Average Scale Score	Difference from Overall Physics Score	Average Scale Score	Difference from Overall Physics Score
Slovenia	531 (2.5)	521 (4.2)	-10 (3.3) ▼	543 (3.8)	12 (3.5) ▲	514 (5.7)	-17 (5.6) ▼
Russian Federation	508 (7.1)	517 (7.5)	9 (2.4) ▲	508 (7.6)	1 (1.3)	493 (6.7)	-15 (2.4) ▼
Norway	507 (4.6)	529 (4.2)	22 (2.9) ▲	484 (5.3)	-23 (1.8) ▼	519 (5.7)	12 (2.8) ▲
Portugal	467 (4.6)	474 (4.7)	7 (3.0) ▲	452 (5.7)	-15 (3.9) ▼	481 (3.9)	14 (2.9) ▲
Sweden	455 (5.9)	452 (6.0)	-3 (2.1)	454 (6.4)	0 (3.0)	450 (6.2)	-4 (3.2)
‡ United States	437 (9.7)	444 (9.8)	7 (3.5)	420 (10.2)	-17 (2.9) ▼	455 (8.8)	17 (3.3) ▲
‡ Lebanon	410 (4.5)	378 (4.7)	-32 (3.6) ▼	433 (5.4)	22 (5.3) ▲	375 (6.2)	-35 (4.1) ▼
Italy	374 (6.9)	367 (6.6)	-7 (4.4)	371 (7.3)	-3 (2.1)	375 (7.3)	1 (3.0)
France	373 (4.0)	375 (3.9)	2 (1.6)	358 (5.6)	-15 (3.4) ▼	397 (4.2)	24 (1.9) ▲

## Conclusion

Lebanon participated in TIMSS Advanced in years 2008 and 2015. In both rounds, Lebanon ranked first in mathematics taking into consideration that the Russian Federation who was considered first in year 2015 gives intensive courses in mathematics to their students. The deficiency in mathematics refers only to the real life based items which are vacant in TIMSS Advanced and are not taken into consideration in the Lebanese mathematics curriculum which is mainly abstract and pure mathematics rather than applied. Moreover, there are some geometry items referring to volumes and lateral areas of solids in TIMSS Advanced that are included but suspended from the Lebanese curriculum. As for Physics most of the items are not taught in grade 12 general sciences in Lebanon and the type of questions are not familiar to Lebanese students who are used to direct applications in physics and not to problem situations. Thus, there is an urgent call for revising the Lebanese curricula in mathematics and physics in order to meet with TIMSS Advanced requirements before the fourth round which is expected in 2023.



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