Alignment of Lebanese National Examinations and TIMSS Advanced Mathematics Study

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Abstract

TIMSS Advanced is an international study that provides information about the educational achievement of students in grade 12 mathematics and physics worldwide. The purpose of this paper was to study the alignment of the Lebanese national exams with the TIMSS Advanced framework in general as well as with TIMSS Advanced items derived from the TIMSS Almanac in particular. This paper then explored the alignment of the average percent correct items of the Lebanese students with the international average for each item. The document analysis method was adopted and the Porter alignment index was calculated each time. The results showed that the alignment index was higher when the grade 12 national exam was compared to the TIMSS framework content and cognitive domains in general than when it was compared to the TIMSS items in particular. The decline in the alignment index may be due to the lack of coherence between item types and domains.

Key words: Alignment- Porter index- TIMSS- National exams- Content domain- Cognitive domain.

الملخص

دراسة تيمس المتقدّمة هي دراسة دولية توفّر معلومات حول الاتجاهات العالمية في دراسة الرياضيات والفيزياء لطلاب الصف الثاني عشر في جميع أنحاء العالم. تهدف هذه المقالة إلى تحليل امتحانات شهادة الثانوية العامة اللبنانية لفرع العلوم العامة من أجل التحقق من مواءمتها مع إطار تقييم دراسة تيمس المتقدّمة للرياضيات في مجالات المحتوى

والإدراك بشكل عام، بالإضافة الى مواءمتها مع أسئلة تيمس المستمدّة من تقويم تيمس بشكل خاص. كما تمّ مواءمة معدّل الإجابات الصحيحة للطلاب اللبنانين ومقارنتها مع المعدّل العالمي لكلّ سؤال. تمّ استخدام أسلوب تحليل الوثيقة واحتساب مؤشر المواءمة بورتر في كلّ مرة. أظهرت النتائج أن مؤشر المواءمة عند مقارنة إمتحان الشهادة الثانوية اللبنانية مع إطار تقييم دراسة تيمس المتقدّمة كان أعلى عند الأخذ بإطار التقييم على مستوى المحتوى والإدراك بشكل عام مما كان عند مقارنته مع أسئلة تيمس بشكل خاص. قد يكون من الممكن الانخفاض في مؤشر المواءمة بسبب الافتقار إلى الاتساق بين أنواع الأسئلة ومجالاتها.

الكلمات المفتاحية: مواءمة- مؤشر بورتر- دراسة تيمس- الإمتحانات الرسمية - مجال المحتوى- مجال الإدراك.

Résumé

TIMSS Advanced est une étude internationale qui fournit des informations sur la réussite scolaire en mathématiques et physique des classes terminales globalement. Le but de cette étude est d'analyser les examens nationaux libanais afin de les aligner avec le cadre TIMSS Advanced en général et ainsi qu'avec les articles de TIMSS provenant de l'Almanach de TIMSS en particulier. Cet article explore ensuite l'alignement des moyens de pourcentage correct des étudiants libanais avec la moyenne internationale pour chaque question. La méthode d'analyse de document a été adoptée et l'indice de l'alignement de Porter a été calculé à chaque fois. Les résultats ont montré que l'indice d'alignement était plus élevé lorsque l'examen national des classes terminales sciences générales a été comparé au contenu cadre TIMSS et aux domaines cognitifs en général que lorsqu'il a été comparé aux questions de TIMSS en particulier. La baisse de l'indice de l'alignement peut être en raison du manque de cohérence entre les types de questions posées et leurs domaines.

Mots clés : Alignement- TIMSS- Indice de Porter- Examens Nationaux - Domaines Cognitif- Domaines Contenu.

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. 2016[a]). 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. 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. 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).

In 2008, TIMSS Advanced results showed that students in Lebanon performed relatively better in geometry and less well in algebra,

and better in knowing and less well in applying and reasoning (Mullis et. al. 2009, p.82). In 2015, students in Lebanon had the highest performance in calculus worldwide but had less achievement in algebra and geometry. They also had relative strengths in knowing and relative weaknesses in reasoning. (Mullis et. al., 2016[a]).Saber report (2013) stated that the results of International large scale assessments (ILSA) have not been disseminated in Lebanon (World Bank, 2013). Little information was known about the TIMSS results and no clear decisions were made based on the results to improve students' achievement levels in grades 8 or 12 in math and sciences.

The last reform for the Lebanese curriculum was implemented in 1997. National examinations for third secondary students (grade 12) were initiated according to the new curricula in 2001. The characterization of the Lebanese official examinations that was issued in 2001 tended to stereotype the national examinations (Osta, 2007). However, Saber report (2013) claimed that there are limited systematic mechanisms in place to ensure the quality of the national examinations (World Bank, 2013).

Theoretical Framework

Curriculum alignment is defined as the agreement between a set of content standards and an assessment used to measure those standards (Case et. al., 2004). Osta (2007) developed a qualitative and quantitative framework for alignment of the Lebanese curriculum to the national grade 9 exams in Lebanon.

Document analysis is a systematic procedure for reviewing or evaluating documents (Bowen, 2009). Its aim is to analyze and synthesize data contained in documents.

The Porter index analyzes the extent of alignment between two frequency tables after which an index is calculated ranging between 0 and 1, this index shows the extent of alignment between the two frequency tables (Fulmer, 2010).The extent to which the national exams are aligned with the TIMSS framework reflects the performance of Lebanese students in TIMSS Advanced. A curriculum alignment has been implemented for the TIMSS framework with all the mathematics

curricula of the participating countries (Mullis et. al.,2016 [b]). The results showed that there are only six TIMSS items which are not covered in the Lebanese curriculum. However, this alignment did not take into consideration the classification according to content and cognitive domains.

The purpose of this research is to analyze the Lebanese national mathematics exams for the General Science section in grade 12 and explore their alignment with the TIMSS Advanced framework in terms of mathematics content and cognitive domains.

The research questions addressed in this study are:

1. To what extent are the Lebanese national exams aligned to TIMSS framework in terms of mathematical cognitive abilities?
2. To what extent are the Lebanese national exams aligned to TIMSS framework in terms of content?
3. To what extent are the Lebanese national exams aligned to TIMSS items in terms of type and domain?
4. When TIMSS Advanced 2015 items are analyzed, to what extent is the Lebanese students' achievement aligned to the international achievement in cognitive and content domains?

In order to answer these questions, a qualitative analysis of a sample of official exams according to the framework developed by Osta (2007) was employed and the alignment index defined by Porter (2002) was calculated. The national general science math test items were categorized according to the TIMSS framework content and cognitive domains.

Literature Review

Four familiar aspects of the curriculum were discussed in educational research, the intended, enacted, assessed and learned curriculum. (Porter & Smithson, 2001). The intended curriculum is the set of written documents, while the enacted curriculum refers to the instructional acts and procedures implemented in the classroom, whereas the assessed curriculum refers to the achievement tests and the learned

curriculum is the content that students have learned as well as the level of proficiency offered by test scores (Porter & Smithson, 2001, p.3). Two aspects of curriculum alignment were studied by Case and Zucker (2005), vertical and horizontal alignment. Horizontal alignment is the degree to which an assessment matches the corresponding content standards for a subject area at a particular grade level while the vertical alignment is the alignment of different parts of an entire educational system. Nixon and Barth (2014) critiqued the focus on the ranking of nations and considered it less informative than an assessment which concentrates on cognitive domains which could yield better inferences for curriculum designers and policy makers in a certain country. Web's (2009) research aimed at studying the alignment of state's curriculum standards and assessments for different grade levels. Two of the criteria addressed in the study were the content alignment and the degree of item complexity. The results showed that the percentage of the reasoning level did not increase across grade levels. Rather, it remained constant or even decreased in transition from one grade level to a higher one. As for content, it was noticed that most of the objectives did not meet the curriculum standards. On the other hand, Osta (2007) concluded that there is lack of alignment between the Lebanese official exams and curriculum objectives which creates discrepancies between the intended curriculum and the implemented curriculum. Osta used the document analysis approach to analyze both official grade 9 exams (brevet exams) and model tests prepared by the Center for Educational Research and Development in Lebanon in their alignment to the Lebanese curriculum across the topics covered (Plane geometry, analytic geometry and algebra) and the mathematical abilities (procedural knowledge, conceptual understanding and problem solving). The results showed that the test items were fairly divided between the topics with the highest percentage given to plane geometry. As for the mathematical abilities, each ability was manifested in a particular topic, problem solving addressed mainly in geometry, the procedural knowledge in algebra and conceptual knowledge in sets. However, conceptual knowledge was rarely detected in the official and model tests.

Nidlovu & Mji (2012) conducted a study that aimed to determine the degree of alignment between the Grade 8 RNCS for Mathematics and the

2003 TIMSS assessment frameworks by means of the Porter index and using the document analysis methodology. Results showed that there was a lack of alignment that called for an urgent attention and intervention from policy makers and curriculum designers in South Africa especially that the discrepancy observed was between the intended curriculum and the implemented one.

Methodology

TIMSS has been designed on a theory of learning (NRC, 2001[b]) that conceptualizes learning as having multiple levels of complexity (Mullis et al., 2009). TIMSS international assessment was designed across domains and at multiple cognitive levels. The domains are Algebra, Calculus and Geometry. The levels are knowing, applying and reasoning. (Mullis et al., 2009). At the knowing level, items are based on remembering facts or procedures. At the applying level, items are mathematics problems that require students to exploit their knowledge in order to answer them correctly. However, at the reasoning level, items are complex multistep problems in unfamiliar contexts (Nixon & Barth, 2014).

The method used in this study is document analysis used in NIdlovu & Mji (2011) and Osta (2007) . The alignment was measured using the Porter (2002) index by the following method: Tables of frequencies for the two documents being compared should be prepared, the ratio of points in each cell with the total number of points in the respective table should be calculated and placed in two new ratio tables with x_{ij} and y_{ij} being the corresponding cells of the two ratio tables. The alignment is calculated using the formula: Alignment $=1-\frac{\sum_{j=1}^{j}\sum_{i=1}^{i}|x_{ij}-y_{ij}|}{2}$. The alignment index ranges from 0 to 1(Polikoff & Fulmer, 2011)

Since all the exams are similar in structure, one national exam (Regular 2006 general science math session) from grade 12 general science was randomly chosen and analyzed in terms of TIMSS content and cognitive domains. Each test item was solved in order to identify the

knowledge content and the cognitive abilities it addresses according to the TIMSS Advanced mathematics framework summarized in tables 1 and 2 and derived from the TIMSS Advanced framework (Mullis et. al., 2016 [a]). Two experts in teaching mathematics solved the items separately and classified their content domain and cognitive domain and then an agreement was made to ensure inter-rater reliability.

Based on data extracted from TIMSS Advanced 2017 items analysis and results (Mullis et. al. 2016), the items were sorted according to their types as multiple choice or constructed response items on one hand and according to the content and cognitive domains they represent on the other hand. The results of Lebanese students by item were listed and aligned with the international results.

Table 1 Distribution of TIMSS advanced mathematics by content domains

Algebra 35%	CD_1
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
Calculus 35%	**CD_2**
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.

Geometry 30%	CD_3
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.

Table 2 Distribution of TIMSS advanced mathematic by cognitive domains

Knowing 35%	
Recall	Recall definitions, terminology, notation, mathematical conventions, number properties, and geometric properties.
Recognize	Recognize entities that are mathematically equivalent (e.g., different representations of the same function).
Compute	Carry out algorithmic procedures (e.g., determining derivatives of polynomial functions, and solving a simple equation).
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.
Represent/Model	Generate an equation or diagram that models problem situations and generate equivalent representations for a given mathematical entity, or set of information.
Implement	Implement strategies and operations to solve problems in familiar mathematical concepts and procedures.
Reasoning 30%	
Analyze	Identify the elements of a problem and determine the information, procedures, and strategies necessary to solve the problem.
Integrate/Synthesize	Link different elements of knowledge, related representations, and procedures to solve problems.
Evaluate	Determine the appropriateness of alternative strategies and solutions.
Draw conclusions	Make valid inferences on the basis of information and evidence.

Generalize	Make statements that represent relationships in more general and more widely applicable terms.
Justify	Provide mathematical arguments, or proofs to support a strategy, solution, or statement.

Results

The structure of a math general science national exam is stable. Despite the fact that the characterization document for the official exams issued from CRDP did not specify the number of parts (Center for Educational Research and Development [CERD], 2017), all the tests consist of six parts. The first part is mainly multiple choice, the second part is mainly analytical 3D geometry, the third, fourth and fifth are respectively a probability problem, a problem about conic sections and another about transformations which may come in any sequence. The last part is always reserved for a calculus problem that acquires 35% of the total grade.

The results showed that there are 41 items in the Lebanese official exam which were classified as 46% knowing, 31% applying and 23% reasoning. On the other hand, they were assorted as 23% algebra, 42% calculus and 35% geometry. The alignment index with the TIMSS classification calculated according to Porter (2002) in each case was 0.89 for the cognitive domain and 0.76 for the content domain. The results are shown in figure 1.

Figure 1 Ratio tables of the National Exam and TIMSS framework by Content and Cognitive domains

National Exam Cognitive Domain	
Knowing	0.46
Application	0.31
Reasoning	0.23

TIMSS Cognitive Domain	
Knowing	0.35
Application	0.35
Reasoning	0.30

P= 0.89

National Exam Content Domain	
Algebra	0.23
Calculus	0.42
Geometry	0.35

TIMSS Content Domain	
Algebra	0.35
Calculus	0.35
Geometry	0.30

P= 0.76

A profound analysis for the items derived from the TIMSS Mathematics Achievement Data Almanac (Mullis et. al. 2016[a]) was implemented taking into consideration the type of items: multiple choice items and constructed response items on one hand and the cognitive and content domain items on the other hand. A cross tabulation of the items in the Lebanese official exam and the TIMSS Advanced across content and cognitive domains was built. The results are displayed in tables 4 and 5. Again, the alignment index was calculated and turned out to be 0.34.

Table 4 Cross tabulation of the Lebanese National Test Items by domain and type of questions

	Cognitive domain International					
Content domain	Multiple Choice items			Constructed Response items		
	Knowing	Applying	Reasoning	Knowing	Applying	Reasoning
Algebra	1	1	1	2	4	0
Calculus	0	1	0	8	5	3
Geometry	1	0	0	6	2	5

Table 5 Cross tabulation of the TIMSS Advanced Test Items by domain and type of questions

	Cognitive domain					
Content domain	Multiple Choice items			Constructed Response items		
	Knowing	Applying	Reasoning	Knowing	Applying	Reasoning
Algebra	16	7	4	3	7	3
Calculus	11	7	9	4	6	7
Geometry	7	9	2	0	3	8

A keener investigation of the TIMSS Advanced results, for each item, was implemented to compare the Lebanese students' performance to that of the international. The percent correct of each item for Lebanon and the international average were extracted from the Mathematics Achievement Data Almanac (Mullis et. al. 2016 [a]). The results are organized in Tables 6 and 7.

Table 6 Cross tabulation of the Lebanese percent correct TIMSS Items by domain and type

	Cognitive domain					
Content domain	Multiple Choice items			Constructed Response items		
	Knowing	Applying	Reasoning	Knowing	Applying	Reasoning
Algebra	72.46	43.77	52.05	39.47	40.61	39.23
Calculus	67.66	53.33	55.66	60.63	23.98	33.79
Geometry	55.67	51.94	34.95	0.00	41.83	36.40

Table 7 Cross tabulation of the International percent correct TIMSS items by domain and type

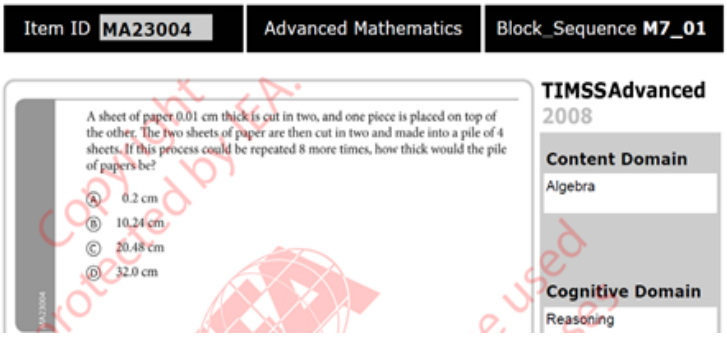
	Cognitive domain International					
Content domain	Multiple Choice items			Constructed Response items		
	Knowing	Applying	Reasoning	Knowing	Applying	Reasoning
Algebra	55.69	40.77	36.43	45.1	30.34	54.73
Calculus	54.64	42.66	46.19	34.18	18.52	19.5
Geometry	50.8	40.49	37.85	0.00	26.43	23.93

The alignment index was again calculated and turned out to be 0.9. In spite of the relatively high index and despite the fact that the Lebanese average correct answers was higher than the international average in most of the cells, it is worth noting that Lebanese students had the lowest percentage on unreleased items labeled as "cylinder radius with maximum volume" (Lebanon's average was 18.6% corresponding to 30% as an international average) and "New diameter of soup can" (Lebanon's average was 36.3% corresponding to 40.4% as an international average) while they attained highest percentages on items

labeled as “coordinates of fourth vertex D” (Lebanon’s average was 70.7% corresponding to 54.8% as the international average) and “find a and b for equation given asymptotes” (Lebanon’s average was 55.5% corresponding to 37.7% as the international average) , which shows that Lebanese students had a low performance on items related to real life situations while they performed better on other items irrespective of the content or cognitive domains.

A comparison between a released TIMSS Advanced test item related to real life and an official exam test item is shown in figures 2 and 3.

Figure 2 Item excerpt from TIMSS Advanced 2008



Retrieved from TIMSS (2009) released items.

Figure 3 Excerpt from the Lebanese National 2009 Regular Session

ABCD is a square of side 2 and of center O such that $(\overrightarrow{AB}, \overrightarrow{AD}) = \frac{\pi}{2}\ (2\pi)$.

E and F are the midpoints of [AB] and [BC] respectively and G is the midpoint of [BF].

Let S be the direct plane similitude that transforms A onto B and D onto E.

Let (A_n) be the sequence of points defined by: $A_o = A$ and $A_{n+1} = S(A_n)$ for all natural integers n.

· Let $L_n = A_nA_{n+1}$ for all n.

Prove that (L_n) is a geometric sequence whose common ratio and first term are to be determined.

Calculate $S_n = L_0 + L_1 + \ldots\ldots\ldots + L_n$ and $\lim_{n \to +\infty} S_n$.

Both items represent a geometric sequence whose sum is to be calculated, one modeling a real life situation and the other an integration between sequences and geometry but in a more mathematical sense.

Discussion

The purpose of this paper was to study the alignment of the Lebanese national exams with the TIMSS Advanced framework across content and cognitive domains. The results showed that the Porter index was 0.89 for cognitive domain and 0.76 for content domain. Though these values are greater than 0.5 which may be an indicator of high alignment, it would not be informative enough except if it is compared to other alignments of the same nature. However, Ndlovu &Mji (2012) called for urgent attention from curriculum designers when a Porter index of 0.751 was calculated in order to fill the gap in the misalignment between the South African curriculum that the TIMSS framework for grade 8. Thus, the alignment indices in this study show a misalignment between the Lebanese national exams and the TIMSS framework which needs to be taken into consideration.

The alignment of the Lebanese national exam items versus TIMSS items with respect to the aspect of the item type and domain yielded a Porter index of 0.34. The decline in the alignment index may be due to the lack of coherence across types of questions and domains. This result conforms with Osta (2007) which states that the correlation is higher when it is based on the more global subject strands rather than on the specific details of content.

The alignment of the average percent correct items of the Lebanese students relative to the international average yielded a high Porter index which conforms to the fact that Lebanon ranked second in TIMSS advanced 2015 and it was one of the two countries that scaled above the centerpoint. However, there were certain items in which Lebanon had a very low percentage of correct items as compared to the international average, and most of these items turned out to be related to real life situations.

Conclusion

Results of this study indicated a weakening in the alignment and coherence between Lebanese national exams and TIMSS Framework when specific details were considered with respect to item type and domain. The average percentage of correct answers per item showed more than 90% alignment between the Lebanese students and the international average, but there were specific items in which Lebanese students indicated low performance and most of them were real life situations.

This study has several limitations in the sense that the sample of national exams is small and Porter alignment indices were not that informative. Thus, a larger sample of national exams should be analyzed and critical values for alignment should be investigated. An alignment between the curriculum, the textbook, the instruction and assessment is also recommended in order to bridge the gap between the four aspects of the curriculum. A profound analysis of the TIMSS items should also be implemented and aligned with the different aspects of the curriculum in grades 8 and 12.

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