MAHMOUD SYAM
QATAR UNIVERSITY, QATAR

MOHAMED CHABI
QATAR UNIVERSITY, QATAR

MUNEER AL WADI
QATAR UNIVERSITY, QATAR

THE STUDENTS WHO COME TO THE UNIVERSITY ARE WEAK IN MATHEMATICS, WHY AND WHERE IS THE PROBLEM?

Abstract:

Weakness of students in mathematics is a very old problem, discovering the source of this weakness is not an easy mission and needs to check the curriculum, teaching methods, learning process, assessment methods and using the technology in teaching mathematics. In addition, Mathematics is a vertically structured field, secondary stage depends on preparatory stage which depends also on primary stage. Determining the source of weakness depends on the outcomes of each stage by using international tests to be fair with all stages including the first year University students.

In this paper, Authors used four international tests to discriminate the level of students and to investigate their actual performance in the levels; grade 4, grade 8 and first year University students and the end of secondary stage. These international tests are TIMSS for grades 4 and 8, PISA for grade 10, and ACT and ACCUPLACER for first year University students. It is found that the problem starts after grade 8 specially in secondary stage. Teachers, curriculum, teaching methods, lack of using technology, instructional language, using the calculators continuously and lack of communication between the schools and the university are factors affect students' transition from high school to university.

Keywords:

TIMSS, ACT, PISA, ACCUPLACER, Student, School, University, Education System.

1 Introduction

For a long time, the instructors in Qatar University are facing a big problem with students in mathematics, they do not know the exact reason behind the weakness of students in mathematics, and the results of students in Math courses were always weak comparing to other courses. The instructors in the university claim that the students come weak in mathematics from the high secondary schools, the teachers in high secondary schools claim that the students come weak in mathematics from the preparatory schools, and the teachers in Preparatory schools claim that the students come weak in mathematics from the primary schools and so on. No one knows from where the problem started and no one wants to abide the responsibility.

Nine years ago, Qatar University started solving or at least reducing this problem by establishing the Foundation Program, and the studies showed that the results of students who finished Foundation Program in Math courses are better than before. In Foundation Program, we still receive very weak students in mathematics, and up till now we still ask ourselves why? Where is the problem? Who is responsible? Is the weakness because of our current Math education system? If we can determine where is the problem, we can seek for some solutions to reduce it.

The problem can be described by the following example about how to solve real word problem. There are 4 steps to solve this real word problem.

Step 1: Converting the real word problem into pure Math problem

Step 2: Solving the pure Math problem

Step 3: Writing a statement about the real word problem depending on solving the Math problem

Step 4: Interpreting on the real word problem by the above statement.

The authors estimate that about 75% - 85% of mathematics education at grades KG1 – Grade 12 level is focused on step 2. Which means that math education system is focusing on learning students the speed and accuracy in performing the arithmetic operations without connecting them with practical examples from real life.

Mathematics is a very large, vertically structured field and changes over time. During the past 5000 years there has been a steady increasing in mathematics, two powerful changes factors are brain science and ICT and our recent information age has led to a steady increase in the use of math in many different disciplines. Therefore our education system has moved steadily toward the idea that the basic computational numeracy described above is insufficient, students also need to know basic algebra, geometry, statistics, probability, and connect these concepts to real life examples and word problems.

When we evaluate the weakness and strength of any educational system, we should check the six principles of The National Council of Teachers of Mathematics (NCTM), the leading professional society for Prekindergarten – grade 12 Mathematics education in the United States.

1. The Equity Principle: Excellence in mathematics education requires equity--high expectations and strong support for all students.
2. The Curriculum Principle: A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well-articulated across the grades.
3. The Teaching Principle: Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.
4. The Learning Principle: Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge.
5. The Assessment Principle: Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.
6. The Technology Principle: Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning.

We can look to these principles as one unit, if anyone is ignored this will effect of the educational process. These principles can be described as in the following diagram

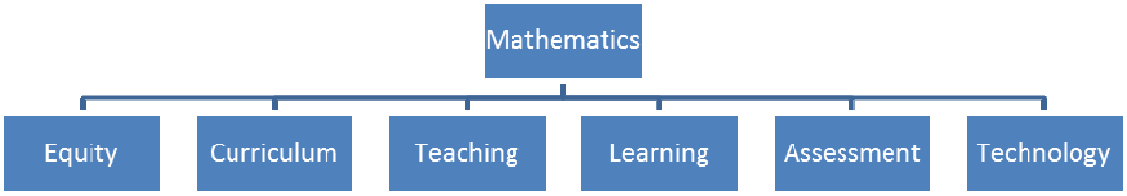

Figure 1: the six principles of The National Council of Teachers of Mathematics (NCTM)

In addition, the standards for school mathematics should describe the mathematical understanding, knowledge and skills that students should acquire from Pre KG through grade 12. Each standard should consists of two or four specific goals that apply across all the grades and these standards should be divided into content standards and process standards.

1.1 TIMSS[1]

For the past 20 years, TIMSS (Trends in International Mathematics and Science Study) has measured trends in mathematics and science achievement at the fourth and eighth grades. It has been conducted on a regular 4-year cycle since 1995, making TIMSS 2011 the fifth assessment of mathematics and science achievement trends.

In general, participating countries use TIMSS in various ways to explore educational issues, including: monitoring system-level achievement trends in a global context, establishing achievement goals and standards for educational improvement, stimulating curriculum reform,

improving teaching and learning through research and analysis of the data, conducting related studies, and training researchers and teachers in assessment and evaluation. TIMSS results are disseminated through reports and via the web through a well-documented international database for within and across country research.

1.2 American College Testing (ACT)

The ACT is a national college admissions examination that consists of subject area tests in: English, Mathematics, Reading, and Science. The ACT Plus Writing includes the four subject area tests plus a 30-minute Writing Test. The ACT includes 215 multiple-choice questions and takes approximately 3 hours and 30 minutes to complete, including a short break (or just over four hours if you are taking the ACT Plus Writing). Actual testing time is 2 hours and 55 minutes (plus 30 minutes if you are taking the ACT Plus Writing).[2]

The ACT Mathematics Test is a 60-question, 60-minute test designed to measure the mathematical skills students have typically acquired in courses taken by the end of 11th grade. The test presents multiple-choice questions that require you to use reasoning skills to solve practical problems in mathematics.[3]

The ACT test is composed of six content areas: pre-algebra, elementary algebra, intermediate algebra, coordinate geometry, plane geometry, and trigonometry.

1.3 ACCUPLACER[4]

ACCUPLACER is a suite of computerized tests that determines the students' knowledge in math, reading and writing as they prepare to enroll in college-level courses. ACCUPLACER is used to identify students' strengths and weaknesses in each subject area and to help them improve their skills through interactive online learning tools. The results of the assessment, in conjunction with the academic background, goals and interests, are used by academic advisors and counselors to place students in the appropriate college courses that meet their skill level.

The ACCUPLACER math section consists of a 17 questions arithmetic, a 20 questions college level mathematics, and a 12 questions elementary algebra subsection in which all the questions are multiple choice ones.

1.4 PISA[5]

The Program for International Student Assessment (PISA) is a triennial international survey which aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students. Since the year 2000, every three years, students from randomly selected schools worldwide take tests in the key subjects: reading, mathematics and science, with a focus on one subject in each year of assessment, the focus of PISA 2012 was mathematics.

The students take a test that lasts 2 hours. The tests are a mixture of open-ended and multiple-choice questions that are organized in groups based on a passage setting out a real-life situation. A

total of about 390 minutes of test items are covered. Students take different combinations of different tests. They and their school principals also answer questionnaires to provide information about the students' backgrounds, schools and learning experiences and about the broader school system and learning environment.

2 Investigating the students' performance from different grades and first year of university in international tests.

To investigate the student's performance we focused on the student's results in grades 4, 8 and first year of university. International exam (TIMSS) is accredited for grades 4 and 8, international exam PISA is accredited for 9 (students with 15 years old) and international exams ACT and ACCUPLACER are accredited for first year university students. Since we have the results of all students in the population, authors considered the sample to be equal to population. In this paper, the results of students in Qatar University are considered and compared to the average of all countries that applied these tests. One of the research problems is to determine from where the weakness of students in mathematics started. Is it during the grades KG – 4, or during the grades 5 – 8 or during the grades 9 – 12.

The applicant to the College at Qatar university that have Foundation Program requirements should complete the ACCUPLACER / ACT exam which is used to place students in the appropriate Math levels. The colleges that required Foundation Program requirements are: Science, Education "Only for Sciences and Mathematics Concentrations in Secondary Education", Engineering and Pharmacy. Our main focus is how students performed in ACCUPLACER/ACT for Academic 2013-2014, we collected and analyzed students' results. In addition, we have studied how students performed in PISA (2012) and in TIMSS (2011).

The results of students in Qatar are compared to the international averages and during different years. TIMSS center point is 500, PISA center point is 494, ACT center points are 21 for partial exemption and 24 for full exemption and ACCUPLACER center points are 82 for partial exemption and 95 for full exemption.

2.1 Some statistics about the international tests

2.1.1 TIMSS

Overview of TIMSS 2007 and 2011 International Benchmarks are defined as the following:

Fourth Grade
Advanced : Apply understanding in relatively complex situations and explain reasoning.
High : Apply knowledge and understanding to solve problems.
Intermediate: Apply basic knowledge in straightforward situations.
Low : Have some basic mathematical knowledge.

Eighth Grade
Low : Some knowledge of whole numbers and decimals, operations, and basic graphs.
Intermediate: Apply basic knowledge in a variety of situations.
High : Apply knowledge and understanding in a variety of relatively complex situations.
Advanced : Reason, draw conclusions, make generalizations, and solve linear equations

Note that trends at TIMSS International Benchmarks, TIMSS reports achievement at four points along the scale as international benchmarks: Advanced International Benchmark (625), High International Benchmark (550), Intermediate International Benchmark (475), and Low International Benchmark (400).

Country	Average
Top: Hong Kong SAR	607
TIMSS Center Point	500
Qatar	296
Lower: Yemen	224

Tab.1 : Distribution of Mathematics Achievement TIMSS 2007 4th Grade

Country	Average
Top: Chinese Taipei	598
TIMSS Center Point	500
Qatar	307
Lower : Qatar	307

Tab.2 : Distribution of Mathematics Achievement TIMSS 2007 8th Grade

Country	Average
Top: Singapore	606
TIMSS Center Point	500
Qatar	413
Lower: Yemen	248

Tab. 3 : Distribution of Mathematics Achievement TIMSS 2011 4th Grade

Country	Average
Top: Korea, Rep. of	613
TIMSS Center Point	500
Qatar	410
Lower : Ghana	313

Tab. 3 : Distribution of Mathematics Achievement TIMSS 2011 8th Grade

Note that the average of fourth grade and the average of eighth grade participants had very low performance in Qatar in comparison to the TIMSS center point of average 500 " Performance average of twenty-seven countries".

2.1.2 PISA

In mathematics performance among PISA 2012 participants, at national and regional levels Qatar has improved performed from 2006 to 2012 but it still below OECD average

Rank	**Mean score in PISA 2006**		**Mean score in PISA 2009**		**Mean score in PISA 2012**	
Top	Chinese Taipei	549	Shanghai, China	600	Shanghai,	613

					China	
OECD average	OECD average	494	OECD average	494	OECD average	494
Qatar	Qatar	318	Qatar	368	Qatar	376
Lower	Kyrgyzstan	311	Kyrgyzstan	331	Peru	368

Tab.5: Student Performance in Mathematics-PISA 2006, 2009 and 2012

2.1.3 ACCUPLACER

Score	APLA	APEA	APCL
20 to 30	582	277	126
31 to 40	149	145	131
41 to 50	93	140	163
51 to 60	60	123	152
61 to 70	36	151	93
71 to 80	36	106	49
81 to 90	12	152	15
More than 91	12	590	13
Total	980	1684	742

Tab.6: ACCUPLACER results in Qatar university for academic year 2013/2014

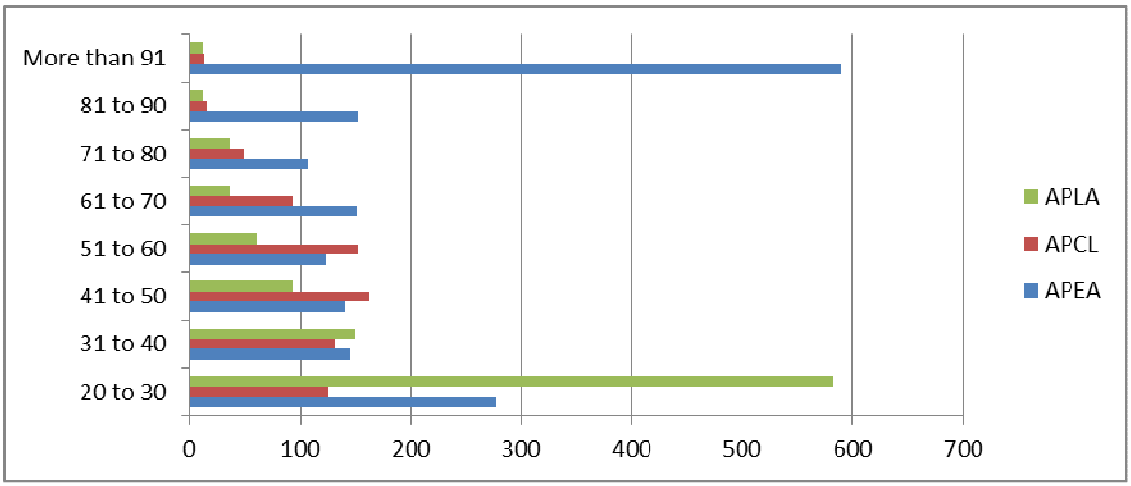

Figure 2: ACCUPLACER results in Qatar university for academic year 2013/2014

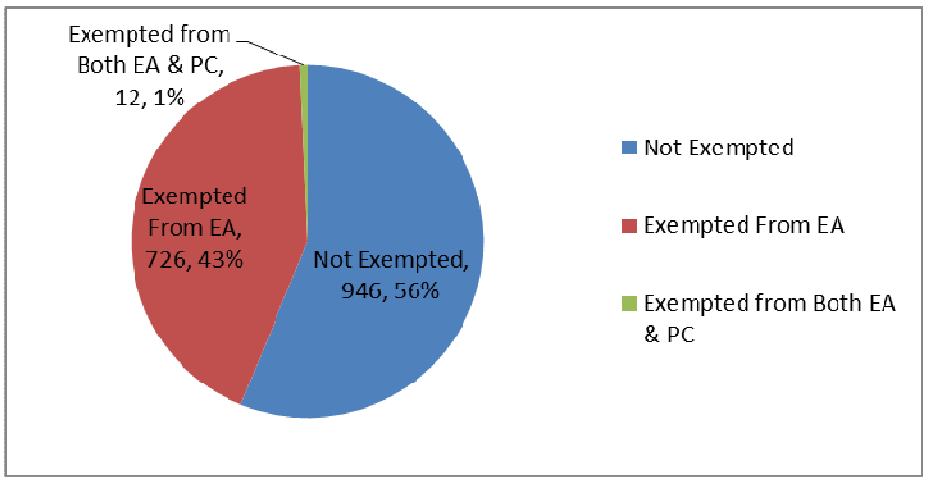

Figure 3: Exemption from foundation courses at Qatar university

Only 1 % of students who took the ACCUPLACER test were exempted from both EA & PC courses and only 43% of students who were exempted only from EA. Most of students who scored less than 30 in "Arithmetic" ACCUPLACER scored very poorly in the Midterm Exam and their average score did not exceed 10% in the midterm Exam. ACCUPLACER results confirm that students results in Midterm and confirmed that students were not well prepared for the course

2.1.4 ACT

In ACT test about 91% who were not exempted from any of the two courses EA or PC and only 5% who have been exempted from EA. ACCUPLACER and ACT results confirm that students results in Midterm and confirmed that students were not well prepared for the course

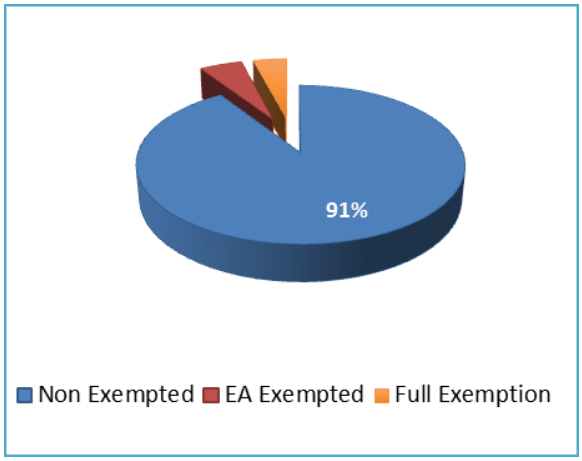

Figure 4: ACT Results in foundation program at Qatar university 16th Nov 2013

Type	Number
Non Exempted	424
EA Exempted	24
Full Exemption	19
Min	1
Max	35
Average	13.302

Tab.7: ACT Results in foundation program at Qatar university 16th Nov 2013

2.2 Discussing the statistics of the international tests

2.2.1 Discussing TIMSS results

Starting with grade 4, it is noticed that the results of students in Qatar is less than TIMSS center point in years 2007 and 2011, but it includes trends in mathematics achievement over time for participants from previous TIMSS assessments in 2007 to TIMSS assessments in 2011. Achievement results also are appeared for mathematics content and cognitive domains.
Here it is important to take in consideration the age of students and low awareness about this test, they were not care about these tests.
Also for grade 8, , it is noticed that the results of students in Qatar is less than TIMSS center point in years 2007 and 2011, but it includes trends in mathematics achievement over time for participants from previous TIMSS assessments in 2007 to TIMSS assessments in 2011.
The result of Qatar's students in grade 8 is better relatively than the result of Qatar's students in grade 4, because the students are more awareness and they can solve in a good way more than grade 4. In 2011 both grade 4 and grade 8 are closer to the TIMSS center point more than in 2007. The averages of Qatar results for grades 4 and 8 with respect to TIMSS center point in the year 2011 are 82.6% and 82% respectively.

2.2.2. Discussing PISA results

It is noticed that the results of students of Qatar in PISA is less than OECD average in years 2006,2009 and 2012, but it includes trends in mathematics achievement over time for participants from previous PISA assessments in 2006 to 2009 till 2012. The averages of Qatar results in PISA with respect to OECD average in years 2006, 2009 and 2012 are 64.3% , 74.5% and 76.1 respectively.

2.2.3 Discussing ACCUPLACER results

Only 1 % of students who took the ACCUPLACER test were exempted from both EA & PC courses and only 43% of students who were exempted only from EA. Most of students who scored less than 30 in "Arithmetic" ACCUPLACER scored very poorly in the Midterm Exam in first year of their university and their average score did not exceed 10% in the midterm Exam. ACCUPLACER results confirm that students were not well prepared for the first year of university.

2.2.4 Discussing ACT results

In ACT test about 91% who were not exempted from any of the two courses EA or PC and only 5% who have been exempted from EA while 4% who have been exempted from both EA and PC. ACT results confirm that students were not well prepared for the first year of their university study.

3 A case study to determine the reasons behind students' weaknesses in mathematics when they come to the university:

To investigate the reasons of students' weakness in mathematics when they come to the university, authors asked some teachers in high secondary schools in state of Qatar through a questionnaire to investigate their opinions about these reasons. The questionnaire consisted of 15 questions and was distributed by the beginning of Spring 2014 semester. The questions of the questionnaire focused on some categories like; equity, motivation, curriculum, schools environment, teaching methods, instructional language, using calculators, using technology, assessment methods and communications between university and schools.

3.1 Study Hypotheses

Hypothesis 1: There is an equity and strong support for all students in the school and teachers motivate their students to like math.

Hypothesis 2: The curriculum is a coherent and well-articulated across the grades.

Hypothesis 3: teaching methodologies followed by schools in Qatar are effective.

Hypothesis 4: current assessment methods used in schools students are receiving higher mark than what they deserve.

Hypothesis 5: Lack of using technology based methods in teaching mathematics has negative effects on enhancing students' learning.

Hypothesis 6: Lack of communication between the schools and the university does not help students' transition from high school to university

3.2 Analysis of the Study and the Results

3.2.1 Testing The Hypotheses Of The Study

To test the study hypotheses, we used one sample z-test with level of significant ($\alpha = 0.05$), the null hypothesis H_0: Teachers disagree with the statement and the alternative hypothesis H_1: Teachers agree with the srarement.

By comparing the $p-$ vlaue and the significant level $\propto$:

If $p-$ vlaue $<\propto$ then we reject H_0, otherwise we don't reject H_0

We summarized these tests in the following table:

The hypothesis H_0	Mean	p-value	The Result
There is an equity and strong support for all students in the school and teachers motivate their students to like math.	3.8014	0.004	Reject H_0 So the teachers agree with this hypothesis

Tab.8: Test of the hypothesis 1

The hypothesis H_0	Mean	p-value	The Result
The curriculum is a coherent and well-articulated across the grades	3.7125	0.003	Reject H_0 So the teachers agree with this hypothesis

Tab.9: Test of the hypothesis 2

The hypothesis H_0	Mean	p-value	The Result
teaching methodologies followed by schools in Qatar are effective.	2.7928	0.061	Don't reject H_0 So teachers don't agree with this hypothesis

Tab.10: Test of the hypothesis 3

The hypothesis H_0	Mean	p-value	The Result
current assessment methods used in schools students are receiving higher mark than what they deserve.	4.2275	0.001	Reject H_0 So teachers agree with this hypothesis

Tab.11: Test of the hypothesis 4

The hypothesis H_0	Mean	p-value	The Result
Lack of using technology based methods in teaching mathematics has negative effects on enhancing students' learning	3.9125	0.002	Reject H_0 So teachers agree with this hypothesis

Tab.12: Test of the hypothesis 5

The hypothesis H_0	Mean	p-value	The Result
Lack of communication between the schools and the university does not help students' transition from high school to university	4.6725	0.000	Reject H_0 So teachers agree with this hypothesis

Tab.13: Test of the hypothesis 6

3.2.2 Percentages Of teachers' Responses on Certain Questions

The following table shows the percentages of teachers' responses on certain questions:

The Question	Strongly Agree	Agree	No opinion	Disagree	Strongly Disagree
The curriculum focuses on procedures rather than learning the concepts4	30%	29%	23%	10%	8%

Schools environments promote active learning5	44%	29%	9%	9%	9%
Teachers can determine students' needs and provide the support accordingly7	25%	44%	12%	15%	4%
The used instructional language affects the level of students' understanding8	34%	56%	3%	5%	2%
The use of calculators in the pre-university educational stage reduces students' arithmetic skills9	72%	21%	4%	3%	0%

Tab.14: Percentages of teachers' responses on certain uncategorized questions

Also authors asked the teachers to give a percent (out of 100%) on the following statements, their opinions are summarized in the following table:

The Question	**Grades 1 – 4**	**Grades 5 – 8**	**Grades 9 – 12**	**No opinion**
at what grade level students' weakness in mathematics start to appear?13	10%	22%	66%	2%

Tab.15: Percentages of teachers' agreements on certain statement

4 Conclusions and Recommendations

4.1 Conclusions:

The following conclusions are obtained:

1) The averages of Qatar results for grades 4 and 8 with respect to TIMSS center point in the year 2011 are 82.6% and 82% respectively.

2) The averages of Qatar results in PISA with respect to OECD average in years 2006, 2009 and 2012 are 64.3% , 74.5% and 76.1 respectively.

3) Only 1 % of students who took the ACCUPLACER test were exempted from both Elementary algebra and Pre-Calculus courses and only 43% of students who were exempted only from Elementary Algebra.

4) In ACT test, about 91% who were not exempted from any of the two courses Elementary

Algebra or Pre-Calculus and only 5% who have been exempted from EA while 4% who have been exempted from both EA and PC.

5) 84% of teachers agreed with the statement "There is an equity and strong support for all students in the school".

6) 75% of teachers thought that schools teachers motivate their students to like math.

7) About 80% of teachers agreed with the statement "The curriculum is a coherent and well-articulated across the grades", while 60% of them agree with the statement "The curriculum focuses on procedures rather than learning the concepts".

8) Above 70% of teachers thought that schools environments promote active learning, while 67% of them thought that the teaching methodologies followed by schools in Qatar are effective.

9) About 70% of teachers can determine students' needs and provide the support accordingly.

10) Above 90% of teachers thought that the used instructional language affects the level of students' understanding and the use of calculators in the pre-university educational stage reduces students' arithmetic skills.

11) Above 91% of students are receiving higher mark than what they deserve by the current assessment methods used in schools.

12) 60% of teachers agreed with the statement "Lack of using technology based methods in teaching mathematics has negative effects on enhancing students' learning", while 88% of teachers agreed with the statement "Lack of communication between the schools and the university does not help students' transition from high school to university".

13) 66% of teachers thought that grade level students' weakness in mathematics start to appear at grades 9-12.

4.2 Recommendations:

The following recommendations are introduced:

1) Offering specific training courses and professional development sessions that help school teachers in motivating their students to like mathematics, providing them with some effective methods of teaching, and improving their class management, and training teachers how to understand and react upon specific students' needs. This will contribute to the increase of students motivation and their interest of learning.

2) Following up the curriculum of mathematics courses from grade 1 to grade 12 and making sure that it is a coherent, focusing on learning the concepts rather than procedures, and well-articulated across the grades.

3) Coordination between the high secondary schools and the university in curriculum, methods of teaching, instructional language, using technology to help students' transition from high school to university.

4) Reducing the use of calculators in the pre-university educational stage and activate the arithmetic skills specially in grades 5 – 8.

5) Reviewing the current assessment methods used in schools and giving the students what they Deserve, because this reflect their actual level then the ministry of education can find the solutions for any coming problem.

6) More and more studies must be conducted in future to investigate in depth the reasons of students' weakness in mathematics and introducing practical solutions to reduce or remove this weakness.

7) Activating the role of media and ministry of education to increase the awareness among the society, parents and educators about the importance of mathematics and its application in all other sciences.

8) Integrating mathematics with other subjects to make it perceptible for the students.

9) Increasing the awareness among the students about the international exams like TIMSS, PISA, ACCUPLACER and ACT, and how can they prepare themselves for these exams.

10) This investigation should be replicated in similar Math programs at different Universities in order to compare results and to draw the right conclusions.

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