



Science Education Reform in Qatar: Progress and Challenges

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Science education reform in Qatar has had limited success. In the Trends in International Mathematics and Science Study (TIMSS), Qatari 4th and 8th grade students have shown progress in science achievement, but they remain significantly below the international average. Also, in the Program for International Student Assessment (PISA), Qatari students have shown progress in science achievement, but they are again below the international average. To gain insight into what factors limit the students' science achievement, the School Science Teaching Inventory Questionnaire (SSTIQ) was administered to science coordinators and teachers in 24 independent schools in Qatar. The questionnaire results, in conjunction with interviews, indicated that science coordinators and teachers believed that a set of factors was responsible, and that low student motivation was the factor that was most responsible. Low student motivation was due, in part, to textbooks being overemphasized, and inquiry-based and problem-based methods being underemphasized. Based on these findings, recommendations for improving students' science achievement were provided.

Keywords: science education, assessment, achievement, TIMSS, PISA, Qatar

INTRODUCTION

Bringing teacher learning into action where the teacher carries own learning into The status of science education in Qatar is similar in many respects to that in other Arab countries. Only a relatively small percentage of college students enroll in STEM (Science, Technology, Engineering, and Mathematics) programs; most students enroll in programs in business, the humanities, and the social sciences. For example, in Qatar, the percentages of students majoring in finance and economics are growing, while the percentages majoring in chemistry and physics are declining.

The simple truth is that the percentages of students enrolled in STEM programs must increase significantly if Qatar and other Arab countries are to achieve and sustain high, international standards of economic prosperity for its citizens. As Dagher and BouJaoude (2011) explain:

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Advancement in science and technology fields is a critical goal for many Arab states as scientific and technological prosperity are considered crucial for economic and social development. Attaining this goal rests considerably on establishing educational policies that value the acquisition of requisite scientific knowledge and promoting pedagogical practices that support engagement in science. (p. 73)

There is a history of educational policies in Qatar that value scientific knowledge and pedagogical practices. In 1995, the Qatar Foundation for Education, Science and Community Development was founded. Since then, the Foundation has provided significant support and leadership for a research culture engaged in the pursuit of new knowledge, research, and technologies. To prepare Qatari students to participate in this culture, a series of science education reforms were carried out in Qatar.

In 2001, the Qatar education system initiated a reform when the RAND Corporation was commissioned to examine the nation's Kindergarten (K) to Grade 12 education system and to recommend options for building a world-class system that would meet the country's changing needs by considering radical and innovative solutions. In 2003, as part of these recommendations, independent schools started to replace some of the government schools at a rate of 15 to 20 schools per year, distributed over the three grade stages K-6, 7-9, and 10-12. Later, all government schools were converted into independent schools.

In 2004, new curriculum standards were developed by a group of well-known international educational organizations. The standards covered four subjects: science, mathematics, Arabic, and English. The standards were adopted and implemented by the Arabic- English independent schools.

In 2008, Qatar launched an ambitious national strategy called the Qatar National Vision 2030. One of the key goals of this strategy is the diversification of the Qatar economy away from a dependence on oil and gas revenue to an economy based on revenue derived from scientific knowledge and invention. For this transition to take place in a relatively short period of time, a truly exceptional educational system is required (General Secretariat for Development Planning, GSDP, 2008). More specifically, an educational system is required that can produce graduates who will contribute significantly to the scientific and technological economy envisioned in the Qatar National Vision 2030. Without excellence in science education, the Qatar National Vision 2030 will not be fully realized.

Qatar's strategic reforms in recent years have had positive results, but not exceptional results, as indicated by the Trends in Mathematics and Science Study (TIMSS), which compares the achievement of students in participating countries and other education systems. An "other education system" is a portion of a country such as a province or emirate.

State of the literature

- Qatari students' science achievement on the TIMSS and PISA tests is significantly below the international average despite the progress achieved following education reforms and implementation of new curriculum standards.
- Students' science achievement is related to their science attitudes, enrollment in science programs, and pursuit of science-related carriers. A decline in students' attitudes towards studying science has led to a "swing away from science" in Qatar.
- There is a need to gain insight into what factors are responsible for limiting Qatari students' science achievement on the TIMSS and PISA tests.

Contribution of this paper to the literature

- This study addressed the need to improve Qatari students' science achievement, science attitudes, enrollment in science programs, and pursuit of science-related careers.
- This study examined Qatari students' TIMSS and PISA science achievement, and used the SSTIQ and interviews to gain insight into what factors science coordinators and teachers believed were responsible for limiting students' science achievement.
- What is learned from this study is useful to educators in other countries with similar circumstances who wish to improve the science achievement of their students and the economic conditions of their countries.

Between TIMSS 2007 and TIMSS 2011, the science achievement of both 4th graders and 8th graders in Qatar increased more than 30%. This represented significant progress. Despite this progress, however, in both TIMSS 2007 and TIMSS 2011, the achievement of Qatar 4th graders and 8th graders fell well below the international TIMSS scale average science score of 500.

In 2011, the science score of Qatar 4th graders was 394 and the score of Qatar 8th graders was 419. Not only were these science scores of Qatari students less than the international average, they were significantly less than those of students in some neighboring countries, such as the United Arab Emirates. It should be noted that differences in population size and diversity makes direct comparisons between countries difficult. Nevertheless, the Qatar National Vision 2030 implies that Qatari teachers and students should aspire to attain science achievement that meets or exceeds that of regional neighbors and the international average.

It is vitally important that science curricula are well designed, teachers' methods are effective, and students have positive attitudes toward science and science-related careers (Osborne, Simon, & Tytler, 2009; Potvin, & Hasni, 2014). What is worrying, however, is that recent studies paint a picture of a Qatari educational system that is not supporting students' attitudes toward science and science-related careers. The science attitudes of Qatari students are not as strong as those of students in many economically developed countries. The results of recent studies (Said, Summers, Abd-El-Khalick & Shuai Wang 2016, M. Summers, Abd-El-Khalick, Said, & Culbertson, 2014; Said & Friesen, 2013), together with the results of international TIMMS and PISA tests, support this view.

The Qatari students' science achievement on the TIMMS and PISA tests is not the only indication of Qatar's limited success in reaching its science education goals. Enrollments in science programs at Qatar University (see Figure 1) indicate a sharp decline in the last fifteen years, which has resulted in the suspension of three science programs (Qatar University statistics 2008, 2009, 2012).

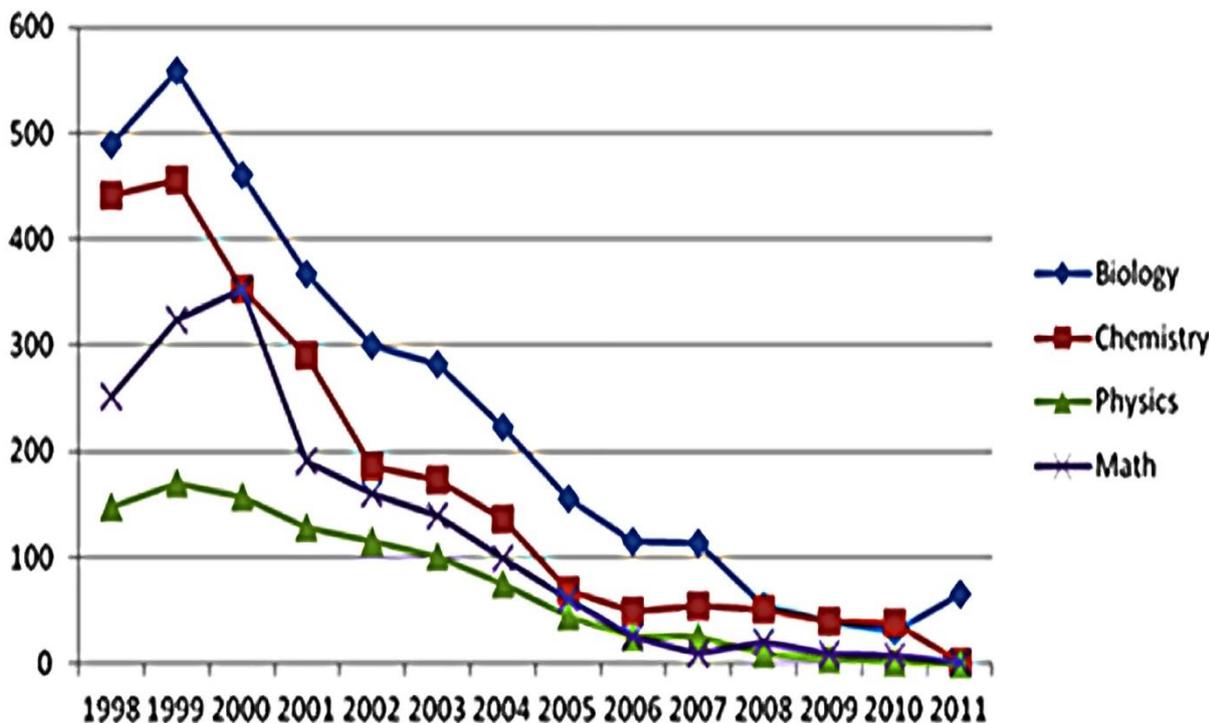


Figure 1. The enrollment in science and mathematics programs at Qatar University between the years 1998 and 2011 is depicted. These data are from Qatar University statistics 2008, 2009, and 2012.

Data for the enrollments in the three science programs and the mathematics program at the Qatar University reveal the scope of the problem and the long-term decline in student numbers. Figure 1 represents Qatar University's enrollment trends over more than a decade. The figure reveals a decline in enrollment in the science programs, ranging from a decrease of 77% for biology to a decrease of 100% for physics. In contrast, the number of students enrolled in finance and economics at the university has increased 478% over the same period. This has led to the suspension of enrollment in some of the science programs (Qatar University Data, 2008, 2009, and 2012). This situation is very alarming to instructors, educational administrators, and national policy makers: The current state of affairs is likely detrimental to the large investments currently being deployed to nurture scientific research and development in Qatar.

Students' science attitudes affect their interest in science-related careers. A decline in students' attitudes towards studying science has led to a "swing away from science" in many countries (Osborne, Simon, & Collins, 2003). In Qatar, this decline appears alarming and untenable.

One of the key challenges to achieving the goals of the Qatar National Vision 2030 as stated in the Qatar National Strategy Development 2011-16 policy paper is: "Raising the achievement of Qatari students at all levels, especially in math, science and English and, through that, increasing educational attainment of Qatari students" (GSDP, 2012a, p.124). In addition, the Qatar Third National Human Development Report stated that "declining enrollment in science and mathematics needs to be reversed especially at the tertiary level to better fulfill the needs of knowledge-based economy industries" (GSDP, 2012b, p. 52). Furthermore, an analysis of the current situation of the Qatar education system shows that it still faces challenges affecting both supply and demand for education, training, and the labor market: "The challenges include: (1) the underachievement of Qatari students in math, science and English language at all levels, and (2) weaknesses in educational administration and the preparation and development of teachers" (Qatar Supreme Education Council, 2012, p.8).

This study provides an overview of the science achievement of Qatari students in the TIMSS. The TIMSS data are examined to compare the Qatari students' achievement with international standards. The Qatari students' knowledge and skills are reflected in their answers to questions about different aspects of science domains required by curriculum standards. The domains include knowledge, application, and reasoning. This study also provides an overview of Qatari students' science achievement on another international test, the Program for International Student Assessment (PISA). Qatari students' achievement on the TIMSS and PISA are compared.

Qatar and other Arab countries have experienced extensive educational reforms in the past three decades. But, "the extent to which these reforms have affected the quality of science education has not been systematically explored" (Dagher & BouJaoude, 2011, p. 74). The purpose of this study was to explore the effects of these reforms in Qatar and to gain insight into what factors science coordinators and teachers believed were responsible for limiting students' science achievement on TIMSS and PISA. In order to gain this insight, the School Science Teaching Inventory Questionnaire, SSTIQ, (Said & Friesen, 2013; Said, Abd-El-Khalick, Summers, Culbertson, & Friesen, 2013) was administered to teachers and science coordinators in independent schools in Qatar. The questionnaire, in conjunction with interviews, provided information about the teachers' beliefs, so that recommendations can be made to improve the science achievement of Qatari students.

What is learned in this study will be useful to educators in other countries, with similar economic circumstances, who wish to improve the science education performance of their students. Many other countries have a history of science

education reforms and goals, which are similar in some respects to those of Qatar (Alpaslan, Yalvac, & Loving, 2015). In summary, this study was designed to address the following research questions:

(1) What is the status of Qatari students' performance in science in both the TIMMS and PISA, and what progress has been achieved, over different cycles of these tests, as a consequence of science education reform?

(2) In the opinion of Qatari science coordinators and teachers, what factors have limited the science education achievement of Qatari students and how can their achievement be improved?

Methods

To address the preceding research questions, data were analyzed from the international tests of TIMMS (2007 and 2011) and PISA (2006, 2009, and 2012). In addition, data were collected from a total of 92 science coordinators and teachers in 24 Qatar schools by means of the School Science Teaching Inventory Questionnaire (SSTIQ), which has been found to be reliable and valid in related studies (Said & Friesen, 2013; Said, Abd-El-Khalick, Summers, Culbertson, & Friesen, 2013).

TIMSS

The Trends in International Mathematics and Science Study (TIMMS) and the Program for International Student Assessment (PISA) are periodic international assessments of students' educational achievement. The participating students come from a diverse set of educational systems (i.e, countries or regional jurisdictions of countries). The systems are diverse in terms of geography, economic development, population size, and population diversity. The assessments are carried out to provide policy makers with information to improve educational outcomes.

TIMSS collects data on educational achievement, in mathematics and science, from students at the fourth and eighth grades. At each grade level, the scale center point of 500 is set to correspond to the mean of the overall achievement distribution. TIMSS is conducted every four years. Qatar participated in the most recent 2007 and 2011 cycles.

PISA

PISA is administered every three years to 15-years-old students. The PISA tests are designed to assess how well students are prepared intellectually for their full participation in society. PISA sets six proficiency levels (in science and mathematics) and calculates the percentage of students for each country who achieve each proficiency level. PISA also assesses reading skills in addition to science and mathematics. PISA is intended to assess knowledge and skills acquired by students nearing the end of compulsory education. Similar to TIMMS, the data are analyzed and the reports published internationally. Qatar participated in the recent three cycles of 2006, 2009, and 2012.

School Science Teaching Inventory Questionnaire (SSTIQ)

To gain insight into the factors that science coordinators and teachers believed limited science achievement on TIMSS and PISA, and led to declining enrollment in university science programs, a section of the School Science Teaching Inventory Questionnaire, SSTIQ, (Said & Friesen, 2013; Said, Abd-El-Khalick, Summers, Culbertson, & Friesen, 2013) was administered to science coordinators (n = 30) and teachers (n = 62) in 24 Qatar schools (8 primary, 8 preparatory, and 8 secondary

schools). The questionnaire provided information about the science coordinators' and teachers' beliefs, so that recommendations can be made to improve the science achievement of Qatari students.

Science coordinators and teachers in these schools responded to SSTIQ Likert-type items that asked them to rate (on a 1 to 5 scale where 1 = very low and 5 = very high) the relative importance of 12 factors that are among those often cited as influencing students' science achievement (e.g., Lam & Lau, 2014). In addition to responding to the SSTIQ, a sample ($n = 48$) of the teachers, whose schedules permitted, were interviewed by means of individual semi-structured interviews, following procedures described by Patton (2002).

RESULTS AND DISCUSSION

In the following sections, Qatari students' science achievement on the TIMSS and PISA are reported and discussed. In addition, a section of the SSTIQ was administered to Qatari science coordinators and teachers to gain insight into what factors science coordinators and teachers believed were responsible for limiting students' science achievement on TIMSS and PISA. Individual interviews were also conducted with a sample of teachers.

Qatari Students' TIMSS Science Achievement

In TIMSS, at each grade level, the scale center point of 500 is set to correspond to the mean of the overall achievement distribution. TIMSS is conducted every four years. Qatar participated in the most recent 2007 and 2011 cycles.

Between TIMSS 2007 and TIMSS 2011, the increase in overall science achievement was about 34% for Qatari 4th graders and about 31% for Qatari 8th graders (Table 1). This represented significant progress, consistent with curriculum reforms. Despite this progress, however, in both TIMSS 2007 and TIMSS 2011, the achievement of Qatar 4th graders and 8th graders fell well below the international TIMSS scale average science score of 500.

Table 1 summarizes the achievement of Qatari students' for both grades 4 and 8 in science in the two cycles. The table shows the overall science scores and the scores in each cognitive domain: knowing, applying, and reasoning.

In 2011, the overall science score of Qatar 4th graders was 394 and the score of Qatar 8th graders was 419. Not only were these science scores of Qatari students less than the international averages, they were significantly less than those of students in some neighboring countries, such as the United Arab Emirates.

Table 1. Achievement of Qatari students in the TIMSS science cognitive domains

	Grade 4		Grade 8	
	2007	2011	2007	2011
Knowing	304 (2.3)	388 (5.1)	325 (1.7)	418 (4.3)
Applying	283 (2.7)	389 (5.4)	322 (1.5)	420 (3.5)
Reasoning	293 (2.9)	404 (4.4)	*	409 (4.4)
Overall	294 (2.6)	394 (4.3)	319 (1.7)	419 (3.4)

Note. Average scale scores and standard errors (in parentheses) appear in this table. Because the number of items in each domain varies, the overall score, which is based on all the items, is not the average of the domain scores.

* indicates achievement could not be accurately estimated by TIMSS. Data sources are Martin et al. (2008) and Martin et al. (2012)

Qatari Students' PISA Science Achievement

In each of the three cycles of PISA (2006, 2009, and 2012), between 10,000 and 11,000 15-year-old students from 130 to 140 schools in Qatar participated. Various types of schools were represented, including independent schools, Ministry of Education schools (all government schools became independent in 2011-12), international schools, private schools, Arabic schools, and community schools.

A comparison of the three cycles of PISA results was performed in the present study to examine the impact of the Qatar educational reform efforts. Table 2 shows the average score in each year, and the percentage of students at each proficiency level on the science scale in the three cycles. The data in Table 2 are depicted visually in Figure 2.

Table 2. Achievement of Qatari students on PISA and the percentages of these students at PISA proficiency levels

		Score	< Level 1	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
2006	Qatar	349	47.6	31.5	13.9	5.0	1.6	.3	0
	International	500	5.2	14.1	24	27.4	20.3	7.7	1.3
2009	Qatar	379	36.4	28.8	18.8	9.0	4.8	1.3	.1
	International	501	5.5	13.3	23.8	27.5	20.5	8.0	1.4
2012	Qatar	384	34.6	28	19.6	11.2	5.1	1.3	.1
	International	501	4.8	13	24.5	28.8	20.5	7.2	1.1

Note. The ages of PISA students are between 15 years and 3 months and 16 years and 2 months at the beginning of the assessment period. At Level 1, students have such a limited scientific knowledge that it can only be applied to a few, familiar situations; they can present scientific explanations that are simple and follow explicitly from given evidence. PISA scores are scaled so that the international average is approximately 500. Data sources are OECD PISA (2006, 2009).

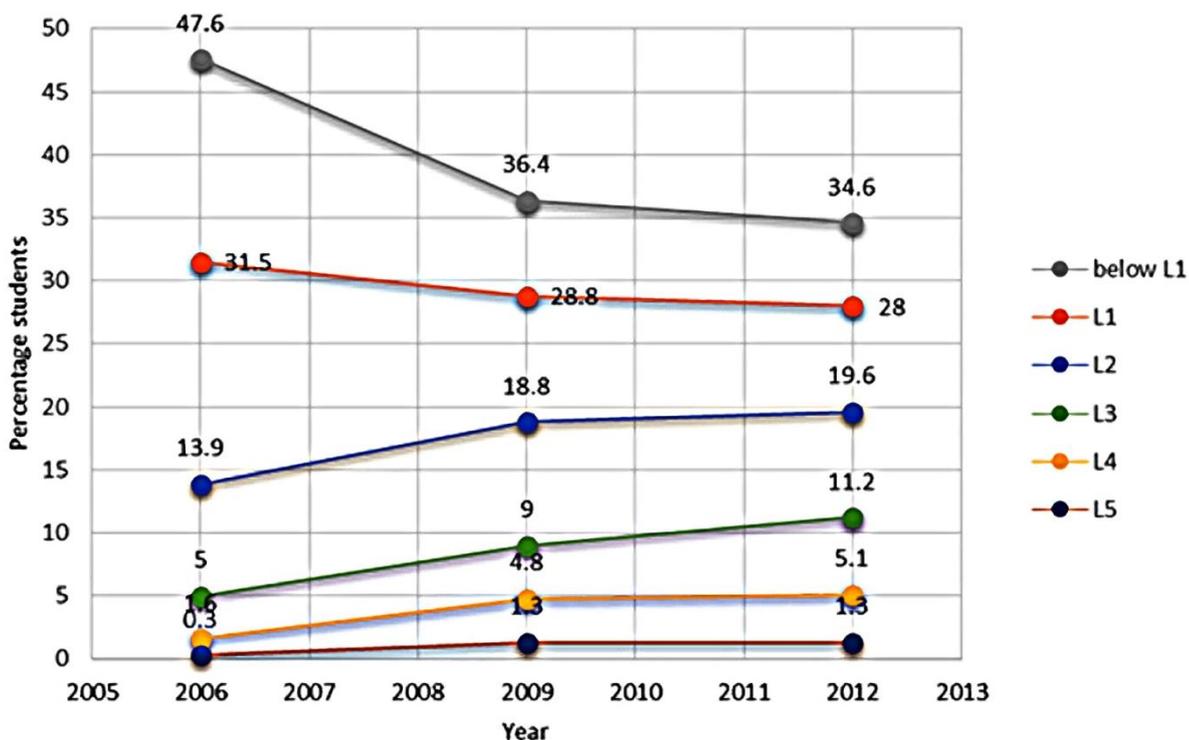


Figure 2. The progress in the achievement of Qatari students in science scores across the three PISA cycles is illustrated. The three numbers on each line represent the average scores on corresponding performance levels.

Qatari students' science achievement scores increased 8.5% from 2006 to 2009 and 1.3% from 2009 to 2012. Qatar's rank among countries changed little during these cycles, however, and Qatar remained well below the international average.

As shown in Table 2 and Figure 2, between 2006 and 2009, there were increases in the percentages of Qatari students' at most proficiency levels. Unfortunately, between 2009 and 2012, the increases were few and offset by decreases, and the lines in Figure 2 tend to flatten out. These findings suggest stagnation in students' science proficiency, which falls short of the new curriculum standards.

In 2012 PISA, the science performance of boys and girls was similar in more than half of the countries assessed. In Qatar, however, as well as in Jordan and the United Arab Emirates, girls outperformed boys significantly (see BouJaoude & Gholam, 2013, for a discussion of gender and science in the Arab states).

Qatari Students' TIMSS and PISA Science Achievement Compared

Although Qatari students have improved on both the TIMSS and PISA in the past administration cycles, the improvement on the TIMSS was higher than that on the PISA. This is likely due to differences in the ages of the students taking the tests, as well as differences in the characteristics of the tests themselves. TIMSS emphasizes knowledge of scientific content more than PISA, whereas PISA emphasizes knowledge of scientific skills more than TIMSS (De Lange & Schmidt, 2006).

SSTIQ and Interview Responses of Qatari Science Coordinators and Teachers

The science coordinators and teachers (Table 3) rated the SSTIQ factors, indicating how strongly they believed that deficiencies (e.g., a lack of instructional technology) influenced students' science achievement. The mean rating and the standard deviation associated with each factor are reported in Table 4. The coordinators and teachers believed that deficiencies in student motivation limited the students' achievement more than any other factor, and there is support for this essential role of motivation in the research literature (Koballa & Glynn, 2007; Schunk, Pintrich, & Meece, 2008).

It could be argued that the science coordinators' and teachers' ratings were self-serving because they believed that student motivation limited achievement more than other factors, such as practical activities, over which the teachers had greater control (Fiske & Taylor, 1991; Saad & BouJaoude, 2012). And, in fact, the teachers believed that their own professional training played little role in limiting students' achievement, which suggests the ratings could have been self-serving.

But even if the science coordinators' and teachers' ratings were self-serving, these ratings—as indicators of the coordinators' and teachers' beliefs—are still valuable because the coordinators and teachers act based on their beliefs. Based on their beliefs, the coordinators and teachers can potentially enhance or impede learning (Bucholz, & Sheffler, 2009).

The science coordinators and teachers believed that the students had the potential to achieve if the students wanted to. The coordinators and teachers therefore rated

Table 3. Numbers of participating curriculum coordinators and teachers in science areas

Coordinators (n = 30)				Teachers (n = 62)			
General Science	Biology	Chemistry	Physics	General Science	Biology	Chemistry	Physics
10	7	7	6	21	14	14	13

Note. Total respondents were 49 males and 53 females from 24 schools. Some secondary schools have only one coordinator for all science areas. "General Science" includes 4 primary and 4 preparatory schools.

Table 4. Science coordinators' and teachers' beliefs: Ratings of SSTIQ factors that limited Qatari students' science achievement

Limiting Factors	Mean	SD
Student Motivation	4.44	.46
Practical Activities	4.23	.44
Teaching Methods	4.06	.82
Curriculum Framework	3.91	.83
Assessment and Evaluation	3.84	.76
Language of Instruction	3.81	.57
Parents and Family Support intervention	3.71	.69
Curriculum Resources	3.66	.64
Students' Self-Efficacy	3.52	.66
Teachers' Professional Training	3.13	.45
Instructional Technology	3.13	.76
Career Awareness	2.95	.91

Note. SSTIQ responses were on a 1 to 5 scale, where 1 = very low relevance and 5 = very high relevance. The science coordinators and teachers (n = 92) rated the factors in terms of the extent to which deficiencies in the factors limited students' science achievement.

self-efficacy lower than motivation. The problem, as the coordinators and teachers saw it, was not that the students believed they were incapable of learning science. The problem was that the students were simply not motivated to learn science.

Science coordinators and teachers also believed that deficiencies in the area of practical activities strongly limited students' science achievement. But the deficiencies are due to little use and inadequate teacher preparation. During observations of the 24 schools participating in this study, all of the schools were found to have some unused instruments and materials stored in laboratory cabinets and cupboards. Some teachers and lab technicians were unaware of the instruments and materials and, when they were, did not know how to use them.

The Qatar curriculum standards require teachers to conduct practical activities, such as experiments and demonstrations, with their students, and the use of practical activities is widely recommended by science educators (Fadzil & Saat, 2014). Many of the interviewed teachers complained that their students did not take the practical sessions seriously enough. The students did not place much value on the practical sessions because the sessions counted for little in terms of grades, and the students were very grade conscious. The teachers themselves were part of this problem. The teachers explained that they assigned few practical sessions, and they did not emphasize the sessions when grading, because the national exams which the students took did not involve practical sessions. Thus, the teachers were as grade conscious as their students.

The commitment to scientific inquiry and to lab investigation is a hallmark of contemporary science curriculum standards. Among the major aims of science education reforms is that students should be able to apply inquiry skills in both familiar and unfamiliar situations and communicate the results of their inquiries in scientific ways. For most grades, scientific inquiry requires the students use appropriate materials, handle equipment competently, and identify, develop, and

Table 5. School science coordinators' ratings of the use of various learning strategies in the schools

	Mean	SD
Learning from Textbooks	4.8	.41
Learning from Presentations	3.8	.80
Cooperative Learning	2.8	.71
Problem-based Learning	2.6	.57
Inquiry-based Learning	2.6	.48

Note. The science coordinators (n = 30) responses were on a 1 to 5 scale, where 1 = very low use and 5 = very high use.

make predictions related to research questions and phenomena (Toplis & Allen, 2012).

Unfortunately, some of the schools in Qatar currently employ laboratory technicians who are not sufficiently trained to undertake major tasks required to enhance science teaching consistent with science education reform. In addition, the number of technicians is not adequate to handle the increasing number of students in the schools. In general, both technicians and teachers need more professional development, and this need exists not only in Qatar but regionally (Qablan, Mansour, Alshamrani, Aldahmash, & Sabbah, 2015).

In addition to deficiencies in student motivation and practical activities, science coordinators and teachers also believed that deficiencies in other areas, to a lesser extent, also limited students' science achievement. These included teaching methods, curriculum framework, assessment and evaluation, language of instruction, parents and family support, curriculum resources, students' self-efficacy, teachers' professional training, instructional technology, and students' career awareness. These areas are interrelated and all affect student motivation, the factor that coordinators and teachers believed had the most impact on students' achievement.

Unfortunately, the science coordinators indicated that the students were using relatively passive learning strategies, such as learning from textbooks and presentations, much more than active learning strategies, such as cooperative learning, problem-based learning, and inquiry learning (Table 5). The active strategies are much more likely to increase students' motivation to learn science and, thereby, increase students' science achievement.

CONCLUSION

Significant progress has been made in the science education achievement of Qatari students as a result of curriculum reforms, but the students' scores remain below the international average on the TIMSS and PISA tests. There was little significant progress recently, which suggests a state of stagnation in achievement.

In this study, science coordinators and teachers attributed students' limited science achievement primarily to a lack of student motivation to learn science. That is what the science coordinators and teachers believed. But, they also believed that deficiencies in other factors, such as practical activities, are important because these deficiencies can individually and collectively undermine students' motivation.

The factors examined in this study interact as a system. Deficiencies in one factor, such as students' motivation to learn science, interact with deficiencies in other factors to undermine students' science achievement, as measured by international tests such as TIMSS and PISA. The findings of this study imply that factors directly under the control of science coordinators and teachers—such as practical activities, teaching methods, learning strategies, and instructional resources—should be

coordinated and focused on the goal of increasing students' science motivation and, thereby, their achievement.

Qatar, and other countries with similar circumstances, should focus on increasing students' science achievement by increasing students' motivation to learn science. Questionnaires, such as the SSTIQ, and interviews can play an important role in this process. The findings of this study with science coordinators and teachers should be extended in future studies by arranging for students and parents to respond to questionnaires and interviews, too. The beliefs of all concerned—school coordinators, teachers, students, and parents—should be taken into account to comprehensively understand why Qatari students' science achievement has been limited, what should be done to improve it, and how this knowledge can be generalized to improve students' science achievement in the many other countries that face this challenge.

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