Primary Science Teachers' Perceptions towards STEM Education in Public Schools in Qatar

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Abstract
Understanding teachers' perceptions of STEM education is crucial to ensure the quality of teaching and learning provided for the students in the classrooms. This study aimed at investigating science teachers' perceptions towards STEM education in primary public schools in the State of Qatar in terms of: teachers' knowledge, STEM teaching requirements, impact on students' outcomes. This study followed a sequential explanatory mixed-method approach. Quantitative data was collected by surveying (148) science teachers, while qualitative data was obtained using four focus groups. Results indicated that teachers have relatively high perceptions towards STEM education. However, the findings highlighted the need to increase teachers' understanding and knowledge of STEM disciplines and their approaches to integration.

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1. Introduction

Across the world, governments recognize teachers as the cornerstones for successful and sustainable educational development. Teachers' critical role in preparing students to be global citizens who can compete in this fast-changing world is indispensable. In this vein, there has been a growing interest recently in the fields of STEM (science, technology, engineering, and mathematics) in all over the world and in Qatar specifically (Sellami, El-Kassem, Al-Qassass & Al-Rakeb, 2017).

Over the past decade, STEM education was a global focus consideration in both developed and developing countries (El-Deghaidy& Mansour, 2015). STEM education is enthused by the demand of global workforce and the economy needs to fulfill the deficiency of STEM competent workers. Within the current competitive global marketplace, the four domains of science, technology, engineering and mathematics are crucial parts of education. This highlighted the prominence of STEM education and its impact on developing well-educated skilled work force to push their countries forwards towards economic expansion (Ahmed, 2016). Thus, STEM is the key for shifting countries and nations towards economic growth and sustainable development (Khuyen, Bien, Lin, Lin & Chang., 2020).

STEM is an acronym generated from using the initials of four main disciplines Science, Technology, Engineering, and Mathematics in order to describe education and practices in those fields (McDonald, 2016). STEM is an interdisciplinary cohesive learning paradigm, where integration of these disciplines is the heart of STEM. Thus, STEM removes the barriers between the four fields and introduces them in an authentic context (Hom, 2014). The main goal of STEM education is to encourage school students at an early age to have an interest in STEM subjects, which will increase their opportunities in the job market, and eventually, there will be a return on investment on the overall country's economy.

In the focus of STEM education, The National Research Council (NRC) (2007) stressed on the importance of teaching STEM at elementary level due to the early students' development of both perceptions and knowledge of STEM at that crucial stage. Appleton (2003) pointed out that teachers' attitudes, which resulted from their own perceptions towards STEM can enhance or hinder their interest to teach STEM. Therefore, the sense of transferring such attitudes from teachers to students, may lead eventually that students build negative attitudes towards STEM. Accordingly, the importance of improving knowledge of teachers in teaching STEM is of the same importance of considering and improving their perceptions.

Hence, in order to reach a stage where STEM education acts as an engine to increase STEM schools and teachers; there is a prior need to set a clear definition and description to STEM to avoid any negative attitudes or perceptions that could be associated with it as a term. Consequently, investigating teachers' perceptions towards STEM education will provide correct information that will enrich the opportunity of developing new learning experiences, and correcting misperceptions and wrong beliefs towards the subject matter.

2. Theoretical Framework:

Theoretical framework of STEM education stemmed on both social constructivism theory and instructional practices as shown in figure (1) (Thibaut et al., 2018).

Figure 1. Theoretical framework for STEM education adopted from Thibaut et al. (2018)

In STEM education, the integration is endorsed to support students' constructing new connections and relations between various ideas (El-Deghaidy et al., 2017). According to brain research, developing significant connections between previous and new knowledge and between different disciplines provide a great opportunity to develop schemas that enhance cognitive skills and deepen the learning (Beane, 1996). Consequently, STEM education supports social constructivist approaches in learning, where teachers act as a facilitator for the learning process by scaffolding students' learning (Becker & Park, 2011; Cunningham & Cordeiro, 2006; El- Deghaidy et al., 2017).Holons cooperate with peers in order to organise and reorganise themselves based on mutually acceptable plans. This is for solving any problem or conflict they might encounter from time to time, and ultimately, serving the goals of the larger whole.

2.1 Integration of STEM content

Integration in STEM education advocates building connections between different STEM disciplines. There are two approaches of integration in STEM education: content integration and context integration (Moore & Smith, 2014). Content integration aims at fusing the different disciplines into single curricular unit to focus the main concept from multidimensional content areas, while context integration focus on the content of single discipline and use the contexts from other disciplines as motivating tools to increase the significant of the content (Roehrig et al. , 2012). Accordingly, STEM curricula established on these integration approaches encompass digital formatting, inquiry, problem-based learning, constructivist teaching instructions, interdisciplinary approach and design based learning (Al Basha, 2009). Many research such as (Satchwell and Loepp 2002; Person, 2017; Shahali et al., 2017; Stump et al., 2016) highlight the prominence of explicitly integrating concepts from different STEM disciplines as students can not suddenly integrate concepts via various illustrations and resources on their own. Thus, intended scaffolding for students to construct new knowledge and acquires new skills among different fields must be highly supported (Person, 2017).

2.2 Problem centered learning

Problem-centered learning involves the use of authentic world problems within an engaging context (Thibaut et al., 2018). Problem-centered learning focuses on application and transformation of knowledge in authentic contexts, where problem-solving skills are clearly recognized as an additional outcome (Merrill, 2007; van Merriënboer and Kirschner, 2007). Problem-centered learning encloses both project-based learning and problem-based learning. Both of these approaches are common in using real-life problems, students centered learning, enhancing active learning, but some difference still exists (Ashgar et al., 2012).

2.3 Inquiry based learning (IBL)

Inquiry-based learning is a crucial instructional practice of STEM education. Although it is considered the heart of science education, it is not restricted to this domain and can be implemented in different contexts such as mathematical or technological contexts (Satchwell and Loepp, 2002). It engages students in authentic practices to discover new concepts and build on their prior knowledge to deepen their understanding through engaging hands-on activities (Satchwell and Loepp, 2002). Inquiry-based learning based on constructivism theory, as it enhances knowledge construction through investigational learning (Wells, 2016).

2.4 Design based learning

Design based learning refers to the application of technological or engineering design (Thibaut et al., 2018) . One of the main goals of STEM education is engaging students in actively engineering challenges. Engineering challenges offer students an opportunity to learn more about process and practices of engineering design, and to expanding their understanding of various concepts through different disciplines (Guzey et al., 2016; Hernandez et al., 2013; Shahali et al., 2016). Thus, engineering design practices empower students' knowledge of different STEM disciplines, as it builds clear connections between content knowledge, abstract knowledge and application (Riskowski et al., 2009).

2.5 Collaboration learning

STEM education involves the contribution of collaboration and teamwork. STEM education guarantees that students can learn by fun, which will actively engage them in learning process within their cooperative groups (Land, 2013). According to NRC (2011), effective STEM education should focus on students' interest and their previous experience to build on it. Thus, STEM education support students' active participation within their groups via using various practices such as inquiry, problem solving, constructivist teaching approach and performance based (Land, 2013).

3. Literature Review

3.1 Teachers' Knowledge of STEM Education

In the current study, the first domain to investigate is teachers' perceptions towards STEM education knowledge. Knowledge is an examining situation that focuses on recalling, and recognizing of information related to a specific concept (Chan, Yeh & Hsu, 2019). Additionally, Thomson (1998) defined knowledge as individual awareness and familiarity of concepts, ideas, thoughts or objects of specific information. In general, many scholarly research papers focused on the importance of teachers' knowledge to deliver effective teaching and learning (Chan et al., 2019; Guerriero, 2017; Verloop, van Driel, & Meijer, 2001). In same vein, Allen, Webb, & Matthews, 2016; Saxton et al., 2014; Srikoom et al., 2017 highlighted the prominence of teachers' knowledge needed for an effective STEM teaching. Effective STEM teaching was described as a group of teaching practices that is based on teachers' knowledge such as; implementation of students centered pedagogies and engaging the students in various inspired contexts (Chan et al., 2019).

In the current study, STEM knowledge covered different dimensions of teachers' information, such as: a) characteristics nature of STEM education, b) goals of STEM education, and c) instructional practices of STEM.

3.2 STEM Teaching Requirements

STEM education in the focus of this study founded on constructivism theory and integration paradigm practices. In both, teachers are considered facilitators for the learning environment and process, where they provide students with authentic learning opportunities to enrich their learning experiences via deepen their understanding of STEM content disciplines (EL-Deghaidy, Mansour, Alzaghibi, & Alhammad, 2017). Moreover, teachers help students in constructing the relations between different disciplines and real-life while working collaboratively within their teams and applying their knowledge in real-life problems to invent creative solutions.

Consequently, teachers and students are crucial elements in identifying STEM teaching requirements. One of the vital elements of STEM teaching requirements is changing teaching instructions to shift students from knowledge recipients to knowledge producers via immersing students in inquiry-based, practical, project-based, and problem-solving practices that will improve their logical, creative, and critical thinking skills (Alsmadi, 2020). Hence, there is a need to improve students' 21st century and life skills; as there is a necessity to train students on various skills such as problem solving, analytical thinking, creative thinking, making decisions, entrepreneurship, teamwork and communication. Therefore, all these practices require teachers' awareness and readiness for various STEM teaching requirements (Alsmadi, 2020).

3.3 Impact of STEM Education on Students' Outcomes

NRC (2014) conducted literature review regarding STEM education impact on students' learning outcomes. As a result, they reported the significant influence of STEM education on both students and teachers (Kanadlı, 2018). Moreover, NRC (2014) emphasized that learning outcomes of STEM education for students do include, improvement in academic achievements, develop their 21st century skills, increase students' number enrolled in STEM fields' courses, development of STEM workforce, and increase in the interest of STEM, in addition to elevating the ability to express understanding between different STEM disciplines. On the other hand, NRC (2011) specified that the learning outcomes for educators is evident in the effective implementation of instructional strategies, which will increase engagement of students in inquiry and design based learning, and the improvement of STEM pedagogical content knowledge.

Additionally, STEM education enhances the development of various students' skills such as life, psychomotor, problem-solving, critical thinking, engineering and design, inquiry and 21st century skills (Kanadlı, 2018). MoNE (2013) stated that life skills involve analytical thinking, creative thinking, decision-making, entrepreneurship, teamwork and communication. Whereas they defined 21st century skills to encloses of communication, collaboration, critical thinking, problem solving, creative thinking, decision-making, and metacognition (Çepni & Ormancı, 2018). The significance of acquiring these skills will reflect on both cognitive and personal development of students, which will adapt them more to challenges in their professional lives in the future (Ontario, 2016).

3.4 STEM Education in Qatari context

The State of Qatar has occupied broad paces in shifting its society into regional educational hub via reform of its full educational system (GSDP, 2012). In late 90s, there was huge dissatisfaction with the educational system in the State of Qatar, which was highlighted in the low-quality outcomes of the Qatari students and their academic achievement, attending college and meeting successful standards of labor market. Consequently, the leadership assigned RAND Corporation to evaluate the education system from kindergarten through grade 12 and to design reform plans to help in qualifying Qatar to meet its need and to be aligned with global standards (Brewer et al., 2007). Subsequently, as per Qatar National Vision 2030, the State of Qatar targeted specific goals to be achieved by year 2030 to shift from hydrocarbon economy dependence to the knowledge-based economy where STEM field is a major focus of these plans (Sellami et al., 2017).

Several studies such as (GSDP 2011; Shediac & Samman Sellami et al., 2017; Abdulwahed et al., 2013) reported shortage of qualified Qatari citizens in STEM fields. Currently, the workforce relies mainly on the foreign experts rather than Qatari nationals (Sellami et al., 2017). Similar to the Arab Gulf states, the State of Qatar countered this insufficiency by hiring qualified workers from all over the world (Sellami et al., 2017). On the other hand, there is great focus highlighted from educational reforms on the importance of STEM education as a foundation asset for constructing the future of Qatari knowledge society (Oxford Strategic Consulting, 2015, 2016; Sellami et al., 2017; Barnett, 2015; Wiseman et al., 2014).

Correspondingly, MOEHE attempts to achieve the strategic goal to raise the percentage of secondary school students enrolled in STEM specialized fields by developing the vision of Qatar Science and Technology Secondary School (QSTSS) which was open in 2018. Moreover, the project of QSTSS has been finalized in accordance to its operational plan by the announcement of receiving the international accreditation from the “Advanced” organization and the inauguration of grade 11 starting of the academic year 2020- 2021 (Al-Khater, 2021). In addition, there has been an opening to the first technical school for girls, and there is an intention to open two extra schools for STEM for both gender in the near future (Al-Khater, 2021). Lastly, the Education Affairs Sector of the MOEHE revealed the launch of new initiative for horizontal expansion of the STEM education in public schools via the implementation of various STEM programs in primary, preparatory, and secondary schools.

Therefore, to accommodate this new initiative for horizontal expansion of STEM education in public schools in the State of Qatar, investigating science teachers’ perceptions towards STEM education in primary public schools will be an initial step for providing useful information to enrich the effective STEM implementation in the future.

4. Research Problem

Qatar contributed in the Trends in Mathematics and Science Achievement (TIMSS) for four years (2007, 2011, 2015 and 2019) to gain a clear insight of students’ knowledge and skills in Science and Mathematics. TIMSS 2019 reported that there is an improvement in the average achievement across the assessment years in both subjects for grade four students. However, the results of TIMSS 2019 highlighted that Qatar’s performance is still below the average level compared to other countries (Mullis, Martin, Foy, Kelly & Fishbein, 2020).

As per the summary of education report for the academic year (2017-2018), it is highly recommended to raise students’ outcomes in Math, Science and English. Additionally, the report called for the alignment between students’ outcomes and teaching instructions, which pointed out the crucial necessity to improve the instructional methods to enhance students’ abilities and their higher order thinking skills (School Evaluation Department-Evaluation Affairs Sector, 2018). Therefore, MOEHE in Qatar sustains professional development opportunities for teachers to keep them compatible with most effective and updated instructional methods and improve their performance, which will be reflected on students’ outcomes in general and on students’ achievement in international exams as TIMSS in specific.

To this end, MOEHE adopted the initiative of STEM education in Qatar. STEM education causes a fundamental transformation in classrooms. It shifts them into creative, integrated disciplines nature, and converted the teacher’s role to facilitator of learning process who guides students towards exploration, investigation, problem solving and enhance their motivation to think critically to develop different creative solutions for real life challenging problems (Ahmed, 2016). Furthermore, findings from previous literature indicated that teachers’ practices in STEM education are strongly affected by their perceptions, which arose from their level of understanding of integration between STEM disciplines and demanding teaching requirements (El-Deghaidy & Mansour, 2015; Ambo Saedey, Al-Harthy &Al Shehemy, 2015; Wang, Moore, Roehrig& Park, 2011). Therefore, assessing teachers’ perception of STEM education will provide valuable input for developing new learning experiences, and sustaining STEM deployment (Khuyen et al., 2020). In a similar vein, there are several studies on science teachers' perception in different regions of the world; however, most of the studies published in MENA region were conducted on KSA. Thus, there is still an urgent need for more research work on this topic using different approaches in the Arab region in general and in Qatar in specific.

Therefore, the current study fills a gap in STEM education research field, generally in MENA and Arab region and in Qatar specifically, as it targets to investigate primary science teachers' perceptions towards STEM education in primary public schools in the State of Qatar.

5. Research Questions:

This research study aimed to answer the following research question:

What are science teachers' perceptions towards STEM education in public primary schools in Qatar?

This question will be answered through the following sub-questions:

i. What are science teachers' perceptions of STEM education knowledge in Qatari public primary schools?
ii. What are science teachers' perceptions of STEM teaching requirements in Qatari public primary schools?
iii. What are science teachers' perceptions of the impact of STEM education on students' outcomes in Qatari public primary schools?

6. Materials and Methods:

Research design: The design of this research study applies the descriptive methodology. Precisely, an explanatory sequential mixed method approach. This design is composed of two distinguishable phases; quantitative (QUAN) followed by qualitative (QUAL) (Creswell et al., 2003). The first phase focuses on the data collection and analysis of the quantitative input to reach a generic understanding to the research questions. Subsequently, the second phase expands to analyze the collected qualitative data, which explores in depth the respondents' views on the results of the statistical quantitative data. Thus, results of both phases are complementary to each other (Creswell 2003).

In the current study, the first part of the research is the survey that aims to collect quantitative data about the perceptions of science teachers towards STEM education in primary public schools in the state of Qatar. The second part is collecting qualitative data using the focus group interviews to provide further explanation to the questionnaire results. A web- based survey was sent to all the public primary schools in the state of Qatar with an invitation for the science teachers in their schools to respond to the survey. 148 teachers responded, which represents approximately 36% of total science teachers in public primary schools in Qatar. Subsequently to analyzing the quantitative data, a purposive sampling technique used in qualitative data collection (QUAL) to deepen the information on the addressed topic, using a small number of cautiously selected participants (Teddlie & Yu, 2007). Thus, the members of the four focus groups (Sample 2) were selected from respondents of survey (Sample 1) based on two criteria: receiving STEM related professional development training and teaching experience ranging from six to fifteen years or more.

6.1 Questionnaire Respondents

The number of questionnaire respondents (Sample 1) was 148 science teachers, which represents approximately 36 % of the total number of science teachers in public primary schools in the state of Qatar. The demographic data of the respondents is included in the first section of the questionnaire (Appendix 2). The demographic data included the gender, teaching experience, educational background, highest degree obtained, country of highest degree obtained, specialty, Demographic data of the respondents was analyzed using descriptive statistical analysis as shown in Table (1).

Table 1. Descriptive statistical analysis of demographic data.

	Demographics	Frequency	Percentage
Gender	Male	18	12.2%
	Female	130	87.8%
Educational Background	Bachelor	117	79.1%
	Higher Diploma	11	7.4%
	Master degree	19	12.8%
	Doctoral	1	0.7%
Country of highest degree	Qatar	70	47.3%
	Others	78	52.7%
Teaching Background	Less than 5 years	17	11.5 %
	6 to 10 years	43	29.1 %
	11 to 15 years	50	33.8 %
	More than 16 years	38	25.7 %
Specialty	Biology	39	26.4 %
	Chemistry	42	28.4 %
	Physics	16	10.8 %
	Geology	7	4.7 %
	Others	44	29.7 %

The above table (1) shows that the respondents included (18) male teachers (12.2 %) and 130 female teachers (87.8 %). Most of the teachers hold a bachelor's degree (79.1%), while (7.4%) hold a higher diploma, (12.5%) hold a master degree and only one teachers hold a doctoral degree (0.7%). (47%) of the respondents got their highest degree from Qatar while (53%) got it from another countries.

In terms of teaching experience, (33.8%) of the sample respondents have teaching experience from 11 to 15 years, (29.1%) of the sample have experience from 5 to 10 years, (25.7%) of them have teaching experience 16 years or more and (11.5 %) of the sample have less than 5 years teaching experience.

In relation to specialty, the sampled respondents is (28.4%) Chemistry, (26.4%) Biology, (10.8%) physics, (4.7%) Geology and (29.7%) mentioned other specialty such as Mathematics, Statistics, Biomedical, and Engineering.

6.2 Focus group respondents

In addition to their years of experience (6 to 15 years or more) of teaching in Qatar public schools, the focus group interviewees (Sample 2) were selected based on their receipt of STEM related professional development program such as QUEMTA or any other STEM related training. Sample (2) as shown in table (2) included four focus groups, each group consists of three teachers. The teachers are from different school locations. Those teachers are knowledgeable on the focus topic of the study, its practices and challenges that might hinder its implementation in in public primary schools.

Table 2. Demographic characteristics of focus groups respondents

Focus Group number	Teacher code	Gender	Teaching experience
1	F1	Female	6 years
	F2	Female	6 years
	F3	Female	12 years
2	H4	Female	7 years
	H5	Female	15 years
	H6	Female	10 years
3	M7	Male	11 years
	M8	Male	17 years
	M9	Male	14 years
4	I10	Female	13 years
	I11	Female	18 years
	I12	Female	9 years

6.4 Research instruments

In the current study, two main instruments were employed for collecting data; a web-based survey and focus group interviews. In reference to "Research Methods in Education" for Louis Cohen, Lawrence Manion, Keith Morrison, the main privilege of using different instruments is to enrich the focus study with more reliable data (broader and deeper) than a single instrument would yield.

i. *Teacher's Survey*

Survey is a common tool that offers benefits of standardized and open responses to a variety of topics for a large sample or population. More than that, other common advantageous aspects of surveys are their low cost, high-reliability and validity, quickness and practicality in completion (Cohen et al., 2018). Thus, an online survey (consisting of two sections) was created to collect quantitative data.

- Section 1: This section enclosed five items including demographic data such as gender, teaching experience, educational background, country of highest degree, major,
- Section 2: This section comprised 36 items classified into four main domains. The study domains comprised of a scale ranging from one to five, where (1) reflected an opinion of "strongly disagree" and (5) is "strongly agree". The items adopted and modified from various studies in multiple countries, such as Al Anzi & Al Gabr (2017) in the Kingdom of Saudi Arabia (KSA), Khuyen et al. (2020) in Vietnam. Additionally, Al Basha (2018) in the United Arab Emirates (UAE), all items were adjusted appropriately for context in Qatari public schools.
- **The first domain:** Teachers' perceptions about STEM education's knowledge. It consists of fourteen items. These are designed to examine teachers' perceptions about STEM characteristics features, main concepts and its instructional practices.
- **The second domain:** Teachers' perceptions towards STEM teaching requirements. It included eleven items. These items examine teachers' perceptions of requirements of STEM implementation in science classes.
- **The third domain:** Teachers' perceptions of the impact of STEM education on students' outcomes. This domain consists of eight items, these items examine perceptions' of science teachers of the impact of STEM education on enhancing 21st century skills such as critical thinking, problem solving and decision making, in addition to measuring the impact of STEM education on students' learning outcomes.

Teacher's Survey Reliability and Validity

Reliability:

The internal consistency coefficient (Cronbach's Alpha) reflects the reliability of a questionnaire. As per Cohen et al. (2018) whenever the value of the Cronbach's alpha increases; the internal reliability becomes stronger. Cronbach's Alpha values ranged from (0.883) to (0.960), which indicate high internal reliability between the questionnaire items and between the items within each domain as shown in table (3) (Cohen et al., 2018).

Table 3. Cronbach's alpha to measure reliability for research domains

Indicator	Cronbach's Alpha
Teachers' perceptions of STEM education knowledge.	0.966
Teachers' perceptions of STEM teaching requirements.	0.969
Teachers' perceptions of the impact of STEM education on students' outcomes.	0.960

Validity:

To declare the content of the survey, the survey was checked by five university professors from Qatar University, American University in Cairo and Exeter University, in addition to four professional development specialists (Math & Science specialty) from the National Center for Educational Development in Qatar University. They all recommended some modifications regarding the language and to test one idea or concept within each item. Further modification was applied to the survey accordingly to the feedback and recommendations.

Moreover, Constructed validity was tested using confirmatory factor analysis as shown in table (4). It determines the interrelationships between variables to specify if those variables can be gathered into a smaller set of underlying factors.

Table 4. Confirmatory Factor analysis

	First domain	Second domain	Third domain	Communalities
1	0.777			0.603
2	0.787			0.620
3	0.733			0.537
4	0.792			0.628
5	0.798			0.637
6	0.886			0.786
7	0.881			0.776
8	0.890			0.792
9	0.863			0.746
10	0.819			0.671
11	0.861			0.741
12	0.898			0.806
13	0.875			0.766
14	0.873			0.761
15		0.748		0.559
16		0.875		0.766
17		0.897		0.804
18		0.779		0.606
19		0.902		0.813
20		0.926		0.858
21		0.902		0.814
22		0.922		0.850
23		0.930		0.865
24		0.865		0.749
25		0.889		0.790
26			0.895	0.800
27			0.914	0.836
28			0.907	0.823
29			0.912	0.832
30			0.858	0.735
31			0.785	0.616
32			0.908	0.824
33			0.907	0.823

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8	0.890			0.792
9	0.863			0.746
10	0.819			0.671
11	0.861			0.741
12	0.898			0.806
13	0.875			0.766
14	0.873			0.761
15		0.748		0.559
16		0.875		0.766
17		0.897		0.804
18		0.779		0.606
19		0.902		0.813
20		0.926		0.858
21		0.902		0.814
22		0.922		0.850
23		0.930		0.865
24		0.865		0.749
25		0.889		0.790
26			0.895	0.800
27			0.914	0.836
28			0.907	0.823
29			0.912	0.832
30			0.858	0.735
31			0.785	0.616
32			0.908	0.824
33			0.907	0.823

i. Teacher's Focus groups Interview

Teacher's focus group is the second phase of this study to collect the qualitative data. As indicated in Cohen et al. (2018), the dynamics of how participants were interacting in the focus group is significant as it leads to a collective view on the topic under study. The focus group protocol was adopted from El-Deghaidy & Mansour (2015) focus group interview. The final form of the focus group questions was developed after conducting, analyzing and interpreting the survey. A total number of four focus groups interviews (N=4), in which each group consists of three participants accepted to be interviewed. All the participants that agreed to be interviewed received a consent form to be signed and returned back via email.

6.5 Data collection & Analysis

The first stage of analysis was for the quantitative data collected using the web-based survey as mentioned previously. The researcher used different methods of statistical analysis while working on the generated data using the Statistical Package of the Social Sciences (SPSS). A descriptive analysis was used for section one of the survey to describe the demographic data of the participants and in the three domains of section two to interpret the science teachers' perceptions.

The second stage of analysis was for focus group interviews, which has been digitally recorded, followed by a transcript, which formed the initial data source. The transcribed interviews facilitated the provision of summary patterns and themes. As a follow-up, the researcher used the thematic analysis method to specify those themes and patterns in the qualitative data.

7. Findings and Results

In the description of teachers' perceptions towards STEM education, the researcher used the means and standard deviation of 148 teachers' responses. To interpret the perceptions' level, the researcher classified the means into three levels as shown in table (5). This was done by computing the difference between the highest and the lowest point (5-1=4), then dividing the range by three (4÷3= 1.33). The below table (5) show the items in descending order.

Table 5. Perceptions' level according to the means

Weighted Average	Result interpretation
1 - 2.33	**Low**
2.34 - 3.67	**Moderate**
3.68 - 5	**High**

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Overall, the descriptive statistics comparison of the four domains (Table 6) shows that means for all domains is around (4) which means that teachers' perceptions is high in the four domains. Teachers' perceptions of STEM teaching requirements showed the highest mean of (M= 4.12) and a standard deviation of (SD= 0.61). Conversely, Teachers' perceptions on STEM knowledge recorded the lowest with a mean of (M= 4.08) and a standard deviation of (SD= 0.64). Whereas teachers' perceptions of Impact on students outcomes gained mean values of (4.10with standard deviation of (0.62).

Table 6. Descriptive statistics comparison of the four domains

Domains	Min	Max	Mean	S.D.
Teachers' perceptions of knowledge about STEM education.	2	5	4.08	0.64
Teachers' perceptions of STEM teaching requirements.	2	5	4.12	0.61
Teachers' perceptions of the impact of STEM education on students outcomes.	2	5	4.10	0.62

7.1 Teachers' perceptions of STEM education knowledge.

Sub-question 1: What are the science teachers' perceptions of STEM education knowledge in Qatari public primary schools?

7.1.1 Quantitative Results (Survey)

The first domain of the survey covers fourteen statements related to STEM education knowledge. Findings illustrated in table (7) show that the overall teachers' perceptions of STEM education knowledge is high with an overall mean value (4.08) and standard deviation of (0.64). Interestingly, the two statements "STEM enhances students' thinking to generate innovative solutions to real life problems" and "Problem based learning is an important element in teaching STEM" got the highest mean with value (4.18) and standards deviation of (0.75), (0.73) respectively. On the contrary, the statement related to the ability of teachers to combine optionally any of STEM domains content knowledge in the current curriculum to create STEM lessons got the lowest mean with value of (3.87) and highest standard deviation of (0.89).

Table 7. Descriptive Statistics of Teachers' perceptions of STEM education knowledge.

Statement	Min	Max	Mean	S.D.
The concept of STEM ed ucation is defined as teaching the knowledge, skills, and logical thinking related to STEM careers.	1	5	4.02	0.81
STEM education is a connection between subjects within authentic context to enhance students' learning.	1	5	4.08	0.85
Teachers can *optionally* combine science, technology, engineering, and mathematics knowledge in the current curriculum to create STEM lessons.	1	5	3.87	0.89
The term "technology" in STEM is *NOT* solely restricted to the use of technological tools in the classroom, such as comp uters, projects, and cameras.	2	5	3.99	0.83
STEM helps in connecting scientific concepts and knowledge in an interdisciplinary paradigm.	2	5	4.00	0.73
STEM helps students build scientific explanations and evaluate solutions.	2	5	4.16	0.74
STEM enhances students' thinking to generate innovative solutions to real life problems.	2	5	4.18	0.75
Problem based learning is an important element in teaching STEM	2	5	4.18	0.73
STEM aims at linking knowledge to global problems such as global warming and saving energy.	2	5	4.13	0.79
STEM allows the diversity of educational context through multiplicity of educational outcomes.	2	5	4.05	0.74
STEM employs a variety of strategies to solve scientific problems with flexibility.	2	5	4.10	0.72
STEM removes barriers between subjects and provides flexibility upon integrating new information.	2	5	4.14	0.70
STEM allows using different methods and approaches to achieve tasks.	2	5	4.13	0.71
The term "technology" in STEM is *NOT* solely restricted to the use of technological tools in the classroom, such as computers, projects, and cameras.	2	5	4.14	0.72
Total	2	5	4.08	0.64

7.1.2 Qualitative Results (focus groups' interviews)

Findings in this section are organized and reported in terms of variances and similarity patterns related to teachers' perception of STEM education knowledge between focus groups. Thematic analysis of the groups' answers, results into four main key findings: integrated disciplines of STEM, general characteristics of STEM education , the relation between teaching STEM and future careers, and instructional practices of teaching STEM.

Variance pattern appeared in the first key finding related to describing STEM education in relation to integrated disciplines. Each group had different description of STEM education in relation to their integrated disciplines. Two groups mentioned that "STEM encloses all the scientific disciplines and Arts", while others stated that "STEM is link between science and mathematical branches only", and they considered the science of engineering as geometry which is one branch of Mathematics, while another group did not mention the engineering at all.

The second key finding is related to general characteristics of STEM education. Mostly, all the respondent groups agreed that STEM is linked to real life where all the scientific concepts are applied to solve various real-life problems. They stated that STEM requires from students a high level of thinking skills to solve these real life problems, and these skills are acquired by practicing rather than teaching. This statement is directly aligned with their agreement that STEM aims at enhancing students' skills to use it in real life situations, which will in turn increase students' motivation to learning.

In the third key finding, there were variance in the respondents' answer to the relation between teaching STEM and future careers. Some groups stated that STEM enhances students' focus on future careers and jobs related to their projects. In addition, one group stated that it is an intention trend to enroll students in STEM schools to qualify them for specialized careers in the future. On the other hand, some groups stated that STEM is not focusing on future careers or professions; yet sometimes it is just referring to them by coincidence and not with an intentional planning.

Finally, the last key finding described the instructional practices of STEM. Focus groups agreed that the main instructional practices of STEM include content integration of the four STEM disciplines, problem based learning, projects and inquiry based learning, 21st century skills, collaboration and teamwork, in addition to application of scientific concepts from different disciplines in real life situations.

7.2 Teachers' perceptions of STEM teaching requirements.

Sub-question 2: What are the science teachers' perceptions of STEM teaching requirements in Qatari public primary schools?

7.2.1 Quantitative Results (Survey)

In the second domain, there was eleven items specified for STEM teaching requirements. Findings demonstrated in table (8) show that the overall teachers' perceptions of STEM teaching requirements are high with an overall mean value (4.12) and standard deviation of (0.61). This means that in average, respondents tend to agree to these statements. The statement related to teaching STEM requires enhancing students' acquisition of communication skills, while handling STEM tasks scored the highest mean of value (4.20) and standard deviation of (0.67). However, the statement related to teaching STEM requires training students on engineering design; scored the lowest mean with value of (3.96) and highest standard deviation of (0.75).

Table 8.Descriptive Statistics of Teachers' perceptions of STEM teaching requirements.

Statements	Min	Max	Mean	S.D.
Teaching STEM requires employing mathematical operations in scientific topics.	2	5	4.01	0.71
Teaching STEM requires using inquiry-based learning.	2	5	4.18	0.67
Teaching STEM requires enhancing students ' acquisition of communication skills while handling STEM tasks.	2	5	4.20	0.67
Teaching STEM requires training students on engineering design.	2	5	3.96	0.75
Teaching STEM requires engaging students in evidence -based discussion.	2	5	4.14	0.72
Teaching STEM requires raising curiosity about natural phenom ena and scientific discoveries.	2	5	4.17	0.69
Teaching STEM requires integrating two or more of STEM fields within one lesson.	2	5	4.09	0.73
Teaching STEM requires training students to search and investigate using various reliable resources from different disciplines.	2	5	4.13	0.69
Teaching STEM requires enhancing students ' abilities to solve problems and scientific thinking.	2	5	4.18	0.65
Teaching STEM requires using technology to integrate multiple STEM fields.	2	5	4.13	0.69
Teaching STEM requires m aking decisions based on data to understand how to refine ideas further.	2	5	4.12	0.67
Total	2	5	4.12	0.61

7.2.2 Qualitative Results (focus groups' interviews)

Findings related to STEM teaching requirements are organized according to the similarities between them. Three main domains for STEM teaching requirements resulted from this structure; STEM teaching requirements for teachers, STEM teaching requirements for students and STEM teaching requirements related to stakeholders. The findings in the three domains showed notable similarities among groups.

Findings in the first domain represents STEM teaching requirements for teachers. All groups mentioned that teachers' awareness, beliefs, perceptions and attitudes of STEM are from the main STEM teaching requirements. In addition to practical training for teachers on various skills and instructions for STEM planning and teaching such as communication skills, inquiry skills, content knowledge and integration of the four main domains of STEM. They also stated that the number of students per teacher should not exceed 10 students for effective implementation.

In the second domain, the key findings emerge in STEM teaching requirements for students. The most common resulted domain was changing students' role from receiver of knowledge to active learner by training them on various skills such as inquiry skills, engineering designs, using data, literacy skills and collaboration. In addition to enhancing their creativity and innovation skills and increasing their awareness and knowledge of STEM and its main disciplines.

On the other hand, the third domain encloses agreement from groups' respondents on the need to increase stakeholders' awareness of STEM and its practices. Furthermore, there is a need of having the MOEHE to provide suitable flexible semester plan with enough time for STEM implementation, in addition to a well-designed integrated curriculum that includes the four main disciplines of STEM. Moreover, the MOEHE needs to provide some physical necessities such as establishing strong infrastructure for schools, tools and facilities.

7.3 Teachers' perceptions of the impact of STEM education on students' outcomes.

Sub-question 3: What are science teachers' perceptions of the impact of STEM education on students' outcomes in Qatari public primary schools?

7.3.1 Quantitative Results (Survey)

The third domain included eight statements related to the impact of STEM education on students' outcomes. Results demonstrated in table (9) show that the overall teachers' perceptions of STEM education impact on students' outcomes is relatively high with an overall mean value (4.10) and standard deviation of (0.62). Remarkably, two statements related to whether "STEM help students acquire critical thinking skills and use of data driven evidence" and "STEM has a positive impact on developing students' creativity" scored the highest mean of value (4.16) and standard deviation of (0.68) and (0.70) respectively. However, the statement stated "STEM prepares students for international standardized assessment such as PISA and TIMSS" scored the lowest mean with value of (3.97) and highest standard deviation of (0.75).

Table 9.Descriptive Statistics of Teachers' perceptions of impact of STEM on students' outcomes.

Statement	Min	Max	Mean	S.D.
STEM helps students acquire skills related directly to STEM careers.	2	5	4.07	0.67
STEM helps students acquire critical thinking skills and use of data driven evidence.	2	5	4.16	0.68
STEM helps students acquire authentic problem solving skills to help in making decisions in the real world.	2	5	4.09	0.70
STEM helps students leverage collaborative learning to execute STEM learning projects.	2	5	4.10	0.71
STEM helps students acquire engineering abilities (define the needs, design, and make a certain product) to make beneficial products.	2	5	4.10	0.73
STEM prepares students for international standardized assessment such as PISA and TIMSS.	2	5	3.97	0.75
STEM has a positive impact on developing students' creativity.	2	5	4.16	0.70
STEM helps students acquire decision-making skills.	2	5	4.11	0.67
Total	2	5	4.10	0.62

7.3.2 Qualitative Results (focus groups' interviews)

The present findings from qualitative analysis is consistent with the quantitative analysis results that confirm the high teachers' perceptions of the impact of STEM education on students' outcomes. Three main key findings emerged and were related to the impact of STEM education on students' affective dimensions, life and 21st century skills, and their impact on students' achievement in international exams.

The initial two key findings show similarities between groups' responses. In the first domain, all groups stated that STEM education would have a great impact on students' development to become independent learners. It will increase students' confidence, motivation and enthusiasm for learning. Another promising finding was the impact of STEM on both students' life and 21st century skills. STEM will develop students' life skills for example creative thinking skills, and 21st century skills such as problem solving, critical thinking, and metacognition skills. In contrast to the previous domains, the third domain showed variances in groups' responses; whereas three groups emphasized that STEM will increase achievement of international exams such as PISA and TIMSS. Only one group stated that STEM is not related because international exams depend more on reading and analytical skills, which need further training of students, rather than skills acquired via STEM.

8. Conclusion

The main purpose of the current study is to examine perceptions of primary science teachers regarding STEM education in Qatari public schools in term of STEM education knowledge, STEM teaching requirements, Impact of STEM on students' outcomes.

What are science teachers' perceptions towards STEM education in public primary schools in Qatar?

Data collected to answer the first question indicate that science teachers in primary public schools in Qatar have relatively high perceptions of STEM education. Overall, there was consistency between quantitative analysis results and qualitative analysis findings to answer the sub questions, which represent the four main domains of the first question in this study. Results obtained agreed with most studies conducted in the MENA region, such as (Al Anzi and Al Gabr, 2017; Al Aitebey, 2018) as they reported high science teachers perceptions' related to STEM education knowledge and STEM teaching requirements. While, Al Basha (2018) specified that STEM education was well perceived by majority of teachers in UAE , and Elayyan & Al Shizawi (2019) and Al Salamat, (2019) indicated high perceptions of science teachers towards integrating STEM in teaching science. However, it was in harmony with few studies conducted in other regions such as (Smith et al., 2015, Park et al., 2016; Khuyen et al., 2020), where they all reported that teachers had high perception for STEM education. To discuss these findings thoroughly, the researcher will discuss each sub-question separately.

8.1 What are the science teachers' perceptions of STEM education knowledge in Qatari public primary schools?

The first sub-question investigated perceived knowledge about STEM education. Bell (2015) and Nugroho, Permanasari, and Firman (2019) findings stressed on the importance of understanding teachers' knowledge of STEM, as it will reflect on their efficacy and practices upon implementing STEM. Results from the quantitative analysis reported teachers' high perceptions related to their knowledge of STEM education. Knowledge of STEM enclosed description of STEM nature, STEM integrated disciplines, STEM and its relation to future careers, and STEM instructional practices. Teachers showed a high level of knowledge related to linking STEM to real-life problems to enhance students thinking skills. This in turn explain teachers' confidence in emphasizing that problem-based learning is a crucial element in STEM instructional practices. On the other hand, teachers were less confident in their integrating STEM disciplines content. This is considered as common results reported in many studies such as (Al Anzi & Al Gabr, 2017; Al Basha, 2018; Smith et al., 2015). These studies agreed that although high perceptions of teachers towards STEM, yet they still showed less confidence in integrating some disciplines such as technology and engineering, and they need to increase their understanding related to integration of these disciplines within their lessons.

Quantitative data was further confirmed by the qualitative data. Teachers showed variance in describing STEM education in relation to integrated disciplines. Some groups well described STEM as their description includes the main disciplines, its integrative nature and some of its practices such as, "STEM is present in any inquiry or topic by linking science, math, engineering and technology. Technology is any used tools such as measuring tools or computers during research. Problem-solving in STEM includes using numbers, data, calculations, units, data analysis, and engineering design." While others stated that "STEM Link scientific information with different Mathematical branches to deepen theses information via engineering or mathematical calculations". Such response shows that teachers consider engineering one of mathematical branches, which reveals their misconception of their engineering concept and their confusion between "engineering" and "geometry" concepts, which have the same term in Arabic. In addition, teachers did not mention integrating technology as a key element in STEM, which means that teachers need to enhance their understanding of integrated STEM disciplines. This result is in harmony with Al Basha (2018) and Madani (2020) findings that highlighted teachers' lack of ability to provide an accurate definition of STEM and their need to further understand disciplines core concept.

Furthermore, Most of the groups were knowledgeable and of high awareness of STEM aims in relation to future careers. This was clarified from their responses such as: "STEM aims to guide students to STEM related careers, I read a report from the Ministry of Commerce in the USA, and they reported that job opportunities for those with specializations related to mathematics and science increased by 17%''. Moreover, teachers stated, "STEM is a worldwide program, it is a trend adopted by society elite, people who aspire to educate their children at a high level, to enroll their children in STEM Schools because it qualifies them for specialized jobs in the future. On the other hand, one group mentioned that STEM only refer to STEM careers rather than directing and guiding students to these fields. They mentioned, "STEM is not directing students to professions, but rather, it just refers to them, for example, while discussing space, teachers imply that this specialty is important for the future, another example refers to the importance of medical professions."

Conversely, respondents' answers showed obvious knowledge of STEM relation to real life, where all the scientific concepts are applied to solve various real-life problems, and how this enhances students thinking skills to solve these authentic problems. They stated that "STEM is linked to real-life problems due to real-life problems it addresses, for example, extinction of animals, global warming, pollution, all solutions are generated by students, which highlights the importance of finding solutions for real-life problems". This result aligns with Drake's (1991) integration theory discussed previously in the literature review. Drake advocated for the transdisciplinary approach in which STEM is connected to real-life applications. Furthermore, focus groups data showed high knowledge and understanding of the main STEM instructional practices: "STEM is based on the 21st-century skills, collaboration and teamwork, finding solutions for real-life problems, critical thinking solving real life problems using the scientific method, integrating and using technology, applying mathematics and different domains of science". This result aligned with the findings of Wang et al. (2011) and Al Basha (2018) who reported that STEM implementation in classes using problem based learning and project-based learning to solve real-life problems is essential to enhance student's skills. The results opposes Madani (2020) study results, which pointed out teachers' imprecision in explaining the main instructional practices of STEM.

8.2 What are the science teachers' perceptions of STEM teaching requirements in Qatari public primary schools?
Teachers' perception of the STEM requirement was the highest among the four domains. Results showed that there is a consistency between both quantitative and qualitative data, which emphasize the presence of high overall teachers' perceptions of STEM teaching requirements. This result is aligned with the results of Al Anzi and Al Gabr (2017), Al Aitebey (2018) study, which highlighted that teachers had higher perceptions of STEM teaching requirements than their perception of STEM knowledge. Qualitative findings pointed out STEM teaching requirements for teachers are increasing teachers' awareness and beliefs of STEM, changing perceptions and attitudes of teachers towards STEM, in addition to the need of practical training for teachers on various instructions for STEM planning and implementation such as inquiry skills, content knowledge, and approaches for integration STEM domains.

On the other hand, key findings emerged in STEM teaching requirements for students are changing students' role from receivers of knowledge to active learners by training them on various skills such as inquiry skills, engineering designs, using data, literacy skills, and collaboration. In addition, findings included enhancing students' creativity and innovation, and increasing their awareness and knowledge of STEM and its main disciplines. Moreover, the most highlighted findings were related to stakeholders, and the need to increase stakeholders' awareness of STEM and its practices as mentioned as "Increase the stakeholders' awareness of MOEHE on STEM education". Stakeholders are also required to provide suitable flexible semester plan, well-designed integrated curriculum, and some physical requirements such as strong schools infrastructure, tools, and facilities.

8.3 What are science teachers' perceptions of the impact of STEM education on students' outcomes in Qatari public primary schools?
Findings in this question showed that the overall teachers' perceptions of STEM education impact on students' outcomes is relatively high, which is aligned with what teachers reported in their interviews. They all confirmed the positive impact of STEM on students' development to as teachers stated, "It will build an independent learner with specified skills that allow him to face various situations and become creative in real practical life". In addition, teachers assured the potential impact of STEM on increasing students' confidence, motivation, and enthusiasm for learning.

Furthermore, a promising finding was the impact of STEM on improving students' life quality and developing 21st-century skills as they mentioned: "STEM will enhance students' abilities in solving problems and design solutions that will be reflected on his mindset'. This result is in harmony with the results of Elayyan and Al- Shizawi (2019) study, which reported that STEM helps to improve students' 21st-century skills, keep pace with modern scientific development.

On the other hand, three of the groups agreed on the impact of STEM on students' achievement in international exams such as PISA and TIMSS. Most of the respondents mentioned, "It will improve students' achievement in PISA and TIMSS as these international exams are based on understanding and applying not on recalling information. STEM will allow students to think, analyse and solve problems". Whereas other groups justify the irrelative relation saying, "International exams depend on reading and analysing skills as most of questions are in essay form. Thus, students should be trained on reading and understanding such questions so they can answer them correctly. Although the different responses in qualitative finding, yet this difference show teachers' awareness and positive perceptions. Whereas they mentioned that literacy skills is a vital element in preparing students and improving their achievement in these international exams. This is highly aligned with the rationalize of changing STEM to STREAM, where the (R) stands for reading and writing and justification for the need to add this disciplines to STEM is the prominence of the literacy skills for effective implementation of integrated curriculum that requires critical thinking and creativity skills.

Overall, consistency of quantitative results and qualitative findings in the three sub-questions emphasized the high perceptions of science teachers towards STEM education. Yet, findings highlighted the need to increase teachers' understanding and knowledge of STEM disciplines and their approaches to allow integration. In addition, there is a necessity for further clarification of the main aims of STEM education and its relation to STEM careers, so teachers can consider it in their planning and implementation of various STEM lessons. Accordingly, this will provide a great opportunity for teachers to change their perceptions regarding the impact of STEM on students' achievement especially in international exams such as PISA and TIMSS. Finally, these findings have important implications in providing STEM teaching requirements, improving teachers' awareness, understanding, and practices, and establishing effective professional development programs.

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