OPEN ACCESS
EURASIA Journal of Mathematics Science and Technology Education
ISSN: 1305-8223 (online) 1305-8215 (print)
2017 13(6):2459-2484
DOI 10.12973/eurasia.2017.01235a

Context of STEM Integration in Schools: Views from In-service Science Teachers

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Received 4 September 2016 ▪ Revised 16 November 2016 ▪ Accepted 30 November 2016

ABSTRACT
This study explores science teachers' views regarding Science, Technology, Engineering and Mathematics (STEM) pedagogy and its interdisciplinary nature. It also seeks to identify teachers' views on the contextual factors that facilitate and hinder such pedagogy in their schools. Qualitative methodologies were used through focus group discussions and an interview protocol. From the specific contextual issues that were highlighted in the findings, was teacher self-efficacy, pedagogical-knowledge, issues related to establishing a collaborative school culture and familiarity to STEM education among school administrators, students and parents. Findings expressed teachers' concerns of their under-preparedness to enact STEM practices and illustrated that engineering is the least mentioned discipline to be integrated with science. The study ends with recommendations that could lead to develop a professional development model to enact STEM education in schools based on valuing partnership with universities and industries as a necessary step for enacting a STEM integrated model.
Keywords: in-service teachers: interdisciplinary learning; science: STEM education

INTRODUCTION

The integration of Science, Technology, Engineering and Mathematics, known as STEM education, is a growing area in developed and developing countries (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2010). In the United States, for example, the Next Generation Science Standards [NGSS] acknowledges the importance and value of integrating the main disciplines identified in the acronym STEM and therefore engineering and technology are now integral parts of science literacy (National Research

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State of the literature

- There is variation and sometimes confusion on what is meant by STEM and its educational practices. There is a wide continuum of what STEM could mean starting from the emphasis on one discipline only to a range of multidisciplines and even beyond that to transdisciplines.
- Teachers and school context should be part of planning for any new educational reform
- Partnerships add value to education especially when community and state-of-the-art go hand in hand.

Contribution of this paper to the literature

- This is the first study in the Arab region on STEM education and therefore the first step entailed identifying teachers' perspectives of STEM education and how they perceive the contextual factors in order to implement STEM education
- Similar to previous studies that investigated STEM education, teachers in the context of this study had conflicting views on the role of various disciplines within the integrated experience. Technology and engineering where the ones which teachers doubted the most on how to integrate with science.
- Outcomes of this study contribute to the literature with its main findings and with recommendations to transfer from a silo science context to that of a STEM integrated model.

Center [NRC], 2012). By taking a look at its origins, STEM seemed to evolve out of the American government policy in the early 1990s, specifically from within the National Science Foundation [NSF], which used the acronym SMET. This then changed to STEM in 2001. STEM education evolved in the United States mainly to resolve various issues in the workforce as there was a noticeable decline in the number of students joining the various STEM disciplines and specific careers (NRC, 2011). In the Arab region, it has to be noted that there is a major concern with the low quality of education (United Nations Development Programme, 2014) in addition to issues related to the rise of unemployment rates. There is an escalated number of those who are unemployed representing about 30% in most Arab countries. There is also a mismatch between the outputs of the educational systems and the needs of the job market. The problem is illustrated further with the 40% unsatisfied employers complaining about the lack and limited knowledge and skills of their employees: mostly in how to deal with multi-faceted problems and how to devise creative and integrative solutions (Meagher, 2016). In a report by the World Bank in 2008, it turned out that education in the Arab countries is not preparing students with the necessary skills needed for the 21st century. With such issues facing education in the Arab region, this paper seeks to focus on STEM education as a means to providing for quality education. With teachers seen as the main driving force in the field, teachers' perceptions are specifically taken into consideration.

Theoretical Framework and Literature Review

From the concepts found in the literature that relate to the focus of this study are 'multidisciplinary' and 'interdisciplinary learning', where in some cases both are used interchangeably. Multidisciplinary learning refers to 'additive knowledge' where various disciplines are combined together yet each discipline is independent and separable to the others (Park & Mills, 2014; Park & Son, 2010). Whereas an interdisciplinary learning approach is where disciplines are integrated and boundaries are blurred. Through such approach, learners need to go through various cognitive skills. From these skills is 'synthesis' to make meaningful connections to process knowledge to produce interdisciplinary meaningful understanding. Boix Mansilla, Miller, & Gardner (2000) proposed a definition for interdisciplinary understanding,

> *The capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement—such as explaining a phenomenon, solving a problem, or creating a product—in ways that would have been impossible or unlikely through single disciplinary means. (p. 219)*

Whereas Spelt, Biemans, Tobi, Luning, Mulder (2009) defined 'interdisciplinary' as the "capacity to integrate knowledge of two or more disciplines to produce cognitive advancement in ways that would have been impossible or unlikely through single disciplinary means" (p.365) through the application of complex cognitive skills.

From the above, 'interdisciplinary learning' can be perceived as a radical restructuring of the whole learning process. This happens through constructing a model of an integrative education based on modern pedagogical and curricula design methodologies (Crampton, Ragusa, & Cavanagh 2012). This represents a big leap to traditional subject-based silo teaching which is gaining more and more attention (Czerniak,Weber, Sandmann, Ahern, 1999).

In terms of the value and impact of what such a radical structure of learning can provide, there has been documented research which claim its benefits as a means to provide for quality learning and linkage to the real-world context (Erdogan, Navruz, Younes & Capraro, 2016; Hernandez et al., 2014). Becker and Park (2011) explored through a meta-analysis of 28 studies the effect of integrative approaches on student achievement. Results were in favour of interdisciplinary learning. Moreover, interdisciplinary learning impacts lifelong learning habits, academic skills, personal growth (Jones, 2009) and development of knowledge management skills (Biasutti &EL-Deghaidy, 2012). In a study including 35 Estonian science teachers through the analysis of their concept maps, they seemed to agree that there is benefit of the interdisciplinary approach in making learning interesting, purposeful and meaningful (Mikser, Reiska, Rohtla & Dahnke, 2008).

In an attempt to present the various forms of STEM education, Bybee (2013) presented nine different perspectives to STEM education ranging from STEM as a single reference discipline to a STEM transdisciplinary programme. It could be concluded from the continuum presented by Bybee that STEM has at its core an 'interdisciplinary nature' that focuses on authentic problem solving. In this study, STEM education aims to shift teaching practices from traditional lecture-based teaching into those that are inquiry, project-based and problem-based learning as a means to present integrated, meaningful learning experiences that could include two or more of the four main disciplines identified in STEM education. Within such interdisciplinary philosophy, deep conceptual understanding and what is termed 21st century skills could be developed (Biasutti & EL-Deghaidy, 2014). Despite the increased interest in STEM education, Breiner, Johnson, Harkness, & Koehler, (2012) claim that advocates have struggled to conceptualise its instructional practices. By a review of the literature, with an emphasis on STEM pedagogical implementation, there seems to be a struggle in incorporating all four disciplines (Atkinson & Mayo, 2010) as there is still a constant focus on integrating just science and mathematics.

It should be noted that interdisciplinary learning is a radical approach compared to most current teaching practices (Mikser et al., 2008). Therefore, teachers need to understand the philosophy behind it before enacting such pedagogies in their daily practices (Fulton & Britton, 2011). In a study by Brown, Brown, Reardon, and Merrill, (2011), it was concluded that teachers who were surveyed on their understanding of STEM education believed that it is important yet had no clear view of how to enact its practices in class. This supports the need for more studies on teachers' perceptions and expectations as a major milestone before seeing STEM in action. Vasquez, Comer, and Sneider, (2013) concluded that STEM education is not a curriculum by itself, but it is an approach for teachers to organise and deliver instruction in a way that helps students apply their knowledge with their peers in meaningful situations. This approach is supported by the recognition that real-life problems are not found in separate disciplines. With an emphasis on the need to establish effective STEM instruction, NRC (2011) stressed on including "a coherent set of standards and curriculum; teachers with high capacity; a supportive system of assessment and accountability, adequate instructional time; and equal access to quality STEM learning opportunities" (p. 25).

This study is based on the STEM integration research framework where teachers act as facilitators to expose students to meaningful learning experiences that enrich their deep content understanding in the STEM disciplines and then establish connections to everyday life experiences. Ultimately, the STEM integrated framework builds on developing new models of teaching that foster such integrated meaningful learning experiences. Science teachers need to be able to offer learning opportunities that provide their students with authentic learning through provoking their understanding of the various concepts in the various STEM disciplines when working with others and applying their knowledge and skills to solve problems creatively. For this to happen, teachers need guidance and training to be prepared for such requirements. Part of their preparedness is to examine teachers' views on STEM education (Han, Yalvac, Capraro & Capraro, 2015) and the necessary skills, beliefs, knowledge, and experiences teachers need to enact such integrated instruction. Therefore, it is required that before getting science teachers to embark on enacting STEM pedagogical practices in their schools, is to start by exploring their views on the contextual factors of STEM integration as an indication of their mind set of being intellectually and emotionally prepared and willing to enact the interdisciplinary nature of STEM in their science classes. This study seeks to examine teachers' perceptions as part of the initial step before asking them to implement such practices in class.

The conceptual framework that governs this research is based on the social-constructivist framework. Constructivism stresses on helping students form deeper understandings in order that they see the 'big' picture. There is also emphasis on presenting a curriculum that is relevant to students to help increase their interests and motivation (Czerniak et al., 1999). Through constructivism, there is emphasis on how people learn and the complexities surrounding learning are taken into consideration, especially with a view of teachers as learners (EL-Deghaidy, Mansour, & Al-Shamrani, 2015).

Integration is promoted as a way to help students make these connections among ideas. Advocates also state that curriculum integration is supported by sociocultural reasons especially since traditional curriculum is not linked to students' everyday life and far from addressing their daily needs and problems. Meaningful connections formed between prior and current knowledge and between disciplines can help establish schemas which helps with cognitive skills and results in deep versus surface learning according to brain research (Beane, 1996**).** Therefore, STEM education could be seen as a means that support a constructivist approach in learning as teachers facilitate and scaffold students' meaningful learning (Becker & Park, 2011; Cunningham & Cordeiro, 2006).

Context of STEM Education in Saudi Arabia

Science and mathematics in Saudi Arabia are taught from the first grade through the tenth grade as compulsory subjects for all students (primary through middle school) in gender segregated schools in compliance with cultural principles (Alahmad & Alshehri, 2010). In the eleventh and twelfth grades (secondary stage), students are taught science and mathematics only if they choose the scientific track. As in most countries, in primary and middle schools, science is introduced as a separate subject where science classes and textbooks include biology, chemistry and physics content. At the tenth grade it starts to branch out to specific subjects - biology, chemistry, physics and geology (Ministry of Education [MoE], 2014) with limited opportunities for students to make connections across these disciplines all together. According to statistics, in Saudi Arabia the science discipline is well known to be a masculine one leaving out the arts discipline to female students (Corporate Planning and Policy Directorate, 2010). This is similar to other countries even those across Europe (van Langen, Rekers-Mombarg, & Dekkers, 2006). According to cultural norms, specific disciplines and careers are well known for males rather than females especially in fields of medicine and engineering. In Saudi Arabia, greater efforts are being made to increase female enrolment in disciplines thought to be only for males (Organisation for Economic Co-operation and Development [OECD], 2012). With these ideas being brought to the forefront of the government, STEM education seems to find a place to fulfil gender equity. Recently, there has been collaboration between PCS Edventures (PCSV) and Tatweer T4EDU. The former is a company with over twenty years of experience in experiential education. Its main focus is to develop and deliver a learning framework to facilitate non-formal STEM education that links informal STEM education experiences to the formal classroom experience. The latter, T4EDU, is an educational initiative that aims to bring about change in teaching and learning in Saudi Arabia. The main aim of this collaboration is to introduce Saudis to science clubs at a young age to increase their motivation to pursue studies and careers in science disciplines, especially the females. The expected impact of such projects is to have a positive effect on the country in addition to opening up career opportunities for individuals (Person Middle East, 2014). As for teacher education, programmes are discipline-oriented, each in their silos. Science and mathematics teachers are usually prepared through either a four-year programme at the Faculty of Education or through a two-year Intermediate College. Teachers, in general, are prepared to teach science as a silo discipline in a centralised education system where they implement science curricula and instructional recommendations mandated by the MoE through a top-down system (Mansour, EL-Deghaidy, Al-Shamrani, & Aldahmash, 2014).

When it comes to implementation and teacher practices in schools after finalising teacher educational programmes, it is noticed that classroom teaching is mostly done independently as teachers prepare and deliver their lessons individually. This in itself sets the tone for a certain school culture of how teachers work and how they interact together within and across disciplines. It is not common that science and mathematics teachers sit together to identify crosscutting content or skills. Accordingly, the three possible models of instruction of an interdisciplinary curriculum (parallel, cross-disciplinary and infusion) do not exist in current practices (Consortium of National Arts Education Associations, 2002). As for the practical side of science teaching, most schools, in general, are equipped with science labs where students can carry out hands-on activities. There is, however, no precise organisation or pre-set requirement plans for students' visits to the labs. Having said that, it is commonly perceived that labs are not utilised as expected or required by the curriculum. Considering technology and engineering as components of STEM education, they are implicitly introduced in the science textbooks. In some parts of the textbooks technology/engineering- oriented activities or investigations are presented as enrichment content more than essential parts of the lesson. For example, some additional enrichment activities in science lessons could require students to design certain artefacts (e.g. a lesson on Archimedes law requires students to design a ship where this could be linked to engineering design processes). Nonetheless, teacher guidebooks designed by the Ministry of Education do not provide specific guidelines of how to interactively conduct such activities. This leads to leaving teachers unsupported and possibly will choose to leave out such activities.

RESEARCH METHODS

Research Problem and Questions

It is common practice throughout many Arab nations that subjects such as science and mathematics are taught separately as ‘silos’ through a discipline-based approach with limited connections to real life situations. For teachers to shift from their comfort zones of teaching in the 'silos' and introduce an integrated STEM education model into their schools, several aspects should be taken into consideration. These include teachers' deep content knowledge, strong belief in innovative teaching strategies (that has at its core student centred teaching), interdisciplinary learning to building bridges across subjects, and the development of strong teacher teams that are able to create a culture of success in schools through professional communities. There are claims that the number of mathematics and science teachers with hands-on experience working in STEM education is limited and teachers may also lack educational background in STEM pedagogies according to a report finding by the National Science Foundation. The report indicates that 30% of science middle school teachers lack in-field training (NSF 2012, cited in Casey 2012).

In order to promote STEM education, this study seeks to identify teachers' views regarding STEM education. It also seeks to identify their views on STEM's interdisciplinary nature and the factors that facilitate or hinder such form of instruction in their schools. The research questions focus on the following:

- What are teachers' views on STEM education?
- What are the contextual factors that facilitate and hinder science teachers to enact STEM integrated pedagogies?

Participants

Participants of this study were middle school Saudi science teachers in local educational districts in the capital city Riyadh. These districts were chosen because they are part of the partnership programme governed by the educational centre sponsoring this study. All teachers involved were science middle school male teachers who agreed to participate on a voluntarily basis and signed a consent form, approved by the Institutional Review Board (IRB). A total of 21 teachers were involved in the study. All teachers had a bachelor degree in science education and at the time of this study none of them had previous training nor attended PD workshops on STEM education. The average years of teacher's experiences are illustrated in **Table 1**. Teachers were recruited through their schools as illustrated below. Participating schools were drawn from a total of 418 middle schools in Riyadh. Teachers were involved in focus group discussions that focused on various items relevant to teachers' views and understanding of STEM education. There were also questions related to the contextual factors that either facilitate or hinder the implementation of STEM practices in the classrooms (Appendix 1). Groups of teachers were formed for the focus group interview as shown in **Table 1**.

After the focus group interviews, two teachers showed interest and agreed and committed to participate in a follow-up in-depth interview according to the protocol illustrated in Appendix 2. This was mainly due to the limited time teachers could afford to spend on the study. The two teachers were given pseudo names and a brief description of each is as follows: 'Mohammed' is a science teacher with 14 years of experience who teaches grade

Table 1. Group distribution of teachers in focus groups

Group	Number of teachers	Average years of teaching experience
1	4	8
2	4	10
3	4	6.25
4	5	10
5	4	16.25

8 in School 1. 'Ahmed', has been a science teacher for five years and teaches grade 9 in School 2. In general, it was made clear from the start of the study that teachers' responses would be kept anonymous and that participating teachers could withdraw from the study at any point. Details of the research instruments and means of data collection are in the section below.

Research Instruments and Data Collection

The authors opted to administer a combination of qualitative instruments. These instruments were used consecutively to strengthen the quality of evidence that would help identify how teachers perceive STEM education and code their perceptions using a grounded theory approach to data analyses (Patton 2002). Qualitative instruments have the flexibility and capacity to probe the perceptions and views of teachers in-depth. Hence, the qualitative data was used to help unfold the contextual factors that facilitate or hinder teachers from applying such innovative interdisciplinary practices in class. Details of each instrument can be found as follows:

- Focus group: The aim of the focus group was to discuss science teachers' familiarity with and views on STEM education. This was mainly to explore their views on how to enact STEM practices in the future in their schools. It also aimed to identify what teachers perceive as contextual factors that could facilitate or hinder STEM practices if they were to initiate the implementation of STEM education in their schools. The authors contacted the local educational district which then sent invitations to middle school administrators for teachers to participate on a voluntarily basis. In the invitation, it stated the expected time needed and teacher incentives. The incentives were mainly presented through awarding participating teachers with certificates from the MoE. This was to acknowledge attending a STEM focus group discussion, voicing their views on science classroom practices, and being the first to know of an innovative teaching and learning approach presented through STEM education in Saudi Arabia. Twenty-one teachers, each from a different school, showed interest and commitment to be involved in the focus groups. Transportation for all teachers was provided to encourage their participation. Teachers during the focus group were randomly assigned to a group on their arrival at the local district office, where the focus group took place, into five groups. Once a group was completed with all its expected number of members one of the authors met with the teachers to explain the aim of the research and the aim of the focus group. Teachers in each group were asked to discuss together and share their views after each question and then reach consensus to present their collective response after selecting a spokesperson. Each focus group lasted for a little over an hour to cover all aspects of interest to the researchers.

- Semi-structured interviews: These were used to discuss teachers' views of the contextual challenges and factors that have an impact on the enactment of STEM education practices in science classrooms in the Saudi educational system, in depth. The starting point for the interview was to comment, ask and reflect on what was mentioned and documented in the focus group interviews. Teachers were then asked to discuss the science lesson plans. The questions focused on their views on STEM education through the context of interdisciplinary learning. The questions went further to identify the difficulties teachers see in enacting such an approach and the factors that they perceive as facilitating such enactment. Finally, teachers were asked about the impact they see in implementing this approach in the science classrooms on the students and their career choices. An interview with the two participating teachers was carried out using the interview protocol in Appendix 2. These interviews lasted for about 45 minutes each.

Focus Group and Interviews Analyses and Findings

Responses from the focus group and individual interviews were audio recorded and transcribed. This allowed for thematic analyses of the data. At the end of each focus group an abridged transcript was prepared. Throughout this transcript, there were comments directly linked to the questions asked throughout the focus group interview in addition to the researcher's oral summary that took place at the end of each focus group. In presenting the findings, a specific coding was allocated according to the theme and its relevance to each research question. After looking at the findings and results from the analyses, the researchers decided that they have reached to what is known by 'theoretical saturation' through redundant information. There was no need to add any additional focus group interviews to what was already available. The thematic analysis of the data resulted in the identification of seven main themes:

1) STEM as interdisciplinary, 2) STEM as linked to life (local/international), 3) careers in science, 4) PCK and STEM education, 5) STEM school culture 6) factors facilitating the implementation of STEM, and 7) factors hindering the implementation of STEM education.

Each of the five focus groups represents a case where the main findings are related to each theme (see **Table 2**). This illustrates the similarities and differences across all participants of the focus groups. A cross-case analysis was then performed to identify commonalities across the five different cases. Two main themes that represent the two research questions are presented in the following sections:

Table 2. Major patterns that emerged from the five focus groups

Theme	Focus Group	Example of Patterns
1. STEM as interdisciplinary	1.	1. Interdisciplinary happens between two subjects where engineering and science integrate together 2. Integration is facilitated by the inclusion of real life examples, use of technology, developing thinking skills
	2.	1. The core in interdisciplinary is mathematical skills 2. Technology is most feasible to integrate with science
	3.	1. The priority in Interdisciplinary is lesson content and achieving lesson objectives 2. Integrating mathematical skills and use of technological tools help facilitate subject integration
	4.	1. The priority in Interdisciplinary is the nature of the lesson and student age range 2. Both Mathematics and Technology could be integrated easily with Science 3. Integration can be facilitated according to the relevance of type of objectives and students' foundational knowledge
	5.	1. Priority in the integration is presenting knowledge faster and easier, practicing students to reach logical answers and analytical views. 2. Integration between science and math is mostly possible
2. Stem as linked to life	1.	1. The use of robots in industry and regionally in electric metro. 2. Industries found in the local community could help promote STEM through partnerships with the schools where students carry out field trips to such places (i.e. cement & dairy company)
	2.	1. Partnerships with corporates and industries to be used in field trips and projects such as Recycling plastic products and producing geometric shapes out of them. 2. Designing water dams in Egypt using different measurements to produce energy 3. Design buildings to produce alternative forms of energy using wind and solar energy
	3.	1. Teaching topics such as 'Water cycle', Traffic, and Air pollution
	4.	1.Speed cameras that are fitted on the main roads
	5.	1. Roads in Riyadh city and billboard temperature screens
3. 21st century skills and Careers in Science	1.	1. Identifying student career aspirations in science
	2.	1. Increasing the number of field visits and requesting students to carry out research inquiry 2. Development of thinking skills and problem solving skills
	3.	1. Provide for extensive information and resources in the field or topic that students want to learn more about 2. Develop students' research and collaborative skills and focus on linking topics to real life situations
	4.	1. There is a need to identify students' interests to stimulate such interest that could impact career choices in the future 2. Allow students to apply their knowledge in real life situations
	5.	1. The use of scientific experiments, field trips, research and the use of samples that help identify students' talents and discover their career paths.
4. PCK and STEM education	1.	1. Teachers need training to implement STEM in their practices 2. Professional development institutions have a great impact on teachers' PCK
	2.	1. Teachers need to know more about STEM as they lack this. Also there is no teacher guidebook
	3.	1. Teachers would need to know more about STEM and how to shift from a teacher-centered approach to a student- centered and free discovery that aligns with the course objectives. 2. From the institutions that could help develop teachers' PCK are the research centers and libraries in addition to factories and engineers through field visits.
	4.	1. Teachers need to know how to manage a positive dialogue amongst students 2. Present professional development programs that train teachers on implementing STEM lessons where they can discuss the main difficulties and issues that teachers might face with their application.
	5.	1. Discovery learning and problem solving are key to any teacher teaching STEM

Table 2 (continued). Major patterns that emerged from the five focus groups

Theme	Focus Group	Example of Patterns
4. PCK and STEM education	1.	1. Teachers need training to implement STEM in their practices 2. Professional development institutions have a great impact on teachers' PCK
	2.	1. Teachers need to know more about STEM as they lack this. Also there is no teacher guidebook
	3.	1. Teachers would need to know more about STEM and how to shift from a teacher-centered approach to a student- centered and free discovery that aligns with the course objectives. 2. From the institutions that could help develop teachers' PCK are the research centers and libraries in addition to factories and engineers through field visits.
	4.	1. Teachers need to know how to manage a positive dialogue amongst students 2. Present professional development programs that train teachers on implementing STEM lessons where they can discuss the main difficulties and issues that teachers might face with their application.
	5.	1. Discovery learning and problem solving are key to any teacher teaching STEM
5. STEM school culture	1.	1. All stakeholders, from parents, organizations, and teachers, collaborate to develop the learner 2. Collaboration taking place amongst teachers and the support provided from administrators, educational mentors at school as communities of learners in addition to face-to-face and distance training on STEM curricula and teaching
	2.	1. Having peer support and exchange of experiences through class visits and extended dialogue 2. Increase the amount of professional development training specifically on how to implement STEM practices in the class through detailed guidelines that fit with the current science curriculum 3. Link the science curriculum with technology and mathematical skills
	3.	1. Having group discussions, with assessments that include skills and research skills rather than just content in addition to formative assessment while going through group dialogue 2. That the school administrator provides for the facilities needed with a new role of the educational mentor and professional development on STEM lesson implementation and curricular design whether in workshops or blended learning
	4.	1. Students work on projects to design a flying bird as they plan and use engineering design. Teacher's role will be to guide and assess progress 2. Schools need to provide for time to divide working hours and assess artistic skills in addition to content
	5.	1. Teachers give each other support whether emotional or physical and the role of the school is to help develop such a culture of support and guidance to each other 2. Have PD specifically in STEM and technology to help illustrate discipline integration
6. Factors facilitating STEM implementation	1.	1. What facilitates the implementation is the availability of resources and a great reduction of the course content 2. Making use of science institutions in the community
	2.	1. The acceptance of students to this new teaching approach and the availability of resources 2. Having parents aware of what STEM is in order to encourage their children to such integrated learning 3. Integration can be facilitated by teacher belief in STEM education
	3.	1. An ideal learning environment with an optimal number of students and state-of the-art facilities with trained and motivated teachers
	4.	1. Provide smart boards and facilities that could be used to apply STEM education and teacher guidebooks in addition to motivating teachers through various incentives
	5.	1. Direct collaboration between schools and universities where partnership could be established 2. STEM integration can be facilitated by helping students accept such integration through designing a stimulating learning environment with real-life examples

Table 2 (continued). Major patterns that emerged from the five focus groups

Theme	Focus Group	Example of Patterns
7. Factors hindering STEM implementation	1.	1. Lack of adequate locations for carrying out experiments 2. Time limitations 3. Lack of teacher development 4. Lack of proper educational settings including cramming content knowledge
	2.	1. Lack of recourses 2. Deficiency in teacher preparation and training especially in Mathematical skills and integrating technology 3. No clear teacher guide to help out
	3.	1. Lack of resources and school facilities 2. Teachers' frustration and burnout due to the difficulty of the content and not having proper school facilities
	4.	1. Teachers not knowing about other disciplines 2. There is great emphasis on content coverage 3. Lack of proper facilities 4. Large number of students in class
	5.	1. Students' low levels in skills in general including the use of technology 2. Teachers have limited teaching abilities in STEM as they lack skills to integrate subjects 3. Difficulty to integrate subjects in the same grade 4. Students are not prepared for such integration 5. Curricula from different subjects are not linked together

1) Teachers' views on STEM education 2) Contextual factors that facilitate and hinder enacting STEM integrated practices in science classrooms.

Through the use of cross-case analysis, the main themes identified in the findings were visited. This was to identify major similarities across the five groups involved in the focus groups and from the two teachers; these were exemplified with selected verbatim quotes as in the following sections that also helped in the triangulation of findings using different sources.

Science Teachers' Views on STEM Education

To identify teachers' views on STEM education, several aspects were raised whether in the focus group data analysis and/or through administering the interviews to the two teachers. These were, the concept of 'Interdisciplinarity', STEM as linked to life, the development of 21st century skills and career aspirations in science, teachers' pedagogical content knowledge, and STEM school culture.

Concept of interdisciplinarity. It seems that teachers involved in the focus groups perceived that integration could happen between two subjects rather than a spectrum of disciplines. From their selected disciplines, two groups identified science and technology, one group identified science and engineering, and another group identified the integration between science and mathematics. Only one group identified three disciplines; these were science, mathematics and technology. Engineering was the least mentioned discipline and it seems that there were no clear ideas of how such integration could take place amongst the various disciplines. 'We see that the best integration possibility taking place is between science and mathematics. This seems obvious and realistic (Teacher A, Focus group 5)'. From the two teacher interviews there were similar findings that align with those from the focus group. Mohammed referred to the disciplines that could be integrated through his science integrated lesson plan on earthquakes. There was no clear reference to engineering, although the expected outcome would have been designing an apparatus to measure shock waves. From the main disciplines he stated was technology, yet from Mohammed's point of view technology was actually limited to the use of the Internet and search engines. The following is a quotation on his view on the concept of Interdisciplinarity: 'I think that students' level of engagement and involvement in a science integrated lesson with disciplines such as mathematics and technology helps in their learning and such enrichment helps meet their needs and interests'. Ahmed's response to the same point included getting students to write a report on ships and the role ships have in transferring goods and linking Saudi Arabia to other countries around the world. It was obvious that he appreciated integrating language skills, specially writing skills with learning science.

> *Yes, this [topic] could be linked to math where students make various calculations in addition to what this concept has in terms of its application to everyday life. This could be measuring the density of liquids and how it varies from one type of liquid to the other. I suggest that this could also be used in industrial fields as well. (Ahmed, personal communication, April 22, 2014).*

Partnerships. Partnerships with industries and universities were included in teachers' responses. Such partnerships were seen as opportunities for valuable field visits where ideas of interdisciplinary projects could be developed and teachers can get ideas for their STEM lessons and experiences for their students. They were seen as locally and regionally useful for developing students' interest in STEM disciplines and careers through direct interaction with the STEM community in their daily life. From the focus groups, teachers emphasised the significance of establishing partnerships between schools and informal science learning centres such as exhibitions and museums to capitalise on both teachers' and students' experiences with STEM careers. 'There is the Mishkate exhibition for alternative energy that could act as a great resource for students' learning through fun hands-on activities. Taking students to such places is surely an added value to their learning (Teacher C, Focus group 2)'. There was also reference to academic partnership between schools and universities as the latter are seen as the powerhouse for knowledge and expertise. Teacher E, focus group 5 stated that 'partnerships with universities could help fill some gaps that we have in our content and pedagogical knowledge and help us manage to deal with the challenges that we could face in implementing STEM lessons in class with our students'.

Twenty-first century skills. As for the 21st century skills and aspirations for future careers in science, thinking skills, collaboration, problem solving, and research skills could all be useful for careers in science.

> *For future careers in science it is the skills that students should develop in their schooling years that matter the most. What science curricula are doing so far with these skills needs a different set of teachers' efforts. We are talking now about how students think critically, how they can create something new. These things are what is needed for the future. (Teacher D, Focus group 3).*

Mohammed mentioned that linking learning to real-life was his aim as this will also direct students to develop their attitudes towards science and therefore to careers as well.

Pedagogical content knowledge of STEM education. It was obvious that teachers through the focus groups identified the need for pedagogical content knowledge that would help implement STEM education. Reference to teachers' deficiencies and well-developed professional development were found across all five groups.

> *The lack of training and even teacher educational preparation in such innovative pedagogy surely requires that teachers receive some professional training to prepare us for teaching in STEM. This could be through training centres or universities. We require more on discovery learning and problem solving that are key to STEM teachers. (Teacher D, Focus group 5).*

During the interview, Mohammed mentioned that the lesson objective was much more difficult to achieve as both teachers and students were not prepared to teach and learn in an integrated hands-on manner. In terms of identifying resources that teachers refer to during their classroom practice preparation, Ahmed's resources were stated as documentary channels on the Television and school textbooks that are over emphasised in the Saudi system, as they do in many other Arab countries.

> *I learnt the use of active learning strategies through professional development programmes. I expect to find the same support to use this innovative integrated approach to science teaching. The emphasis is given to content in the textbooks; teachers expect some guidance, even though the teacher's guide that we rely on frequently. (Ahmed, personal communication, April 22, 2014).*

STEM school culture. In schools, it was apparent that STEM education required a different culture than that in non-STEM schools. The STEM school culture requires collaboration among stakeholders and building a collaborative and supportive STEM community. To note, such practice is far from the norm in Saudi schools. Having gone through a teacher education programme with a certain disciplinary focus and then teach with no links to other disciplines makes STEM education unique in what it offers and requires from teachers to change in a school culture. In this STEM school culture, the exchange of experience and constant dialogue between teachers and the administrator were highly emphasised.

> *Teachers need support before asking them to make changes to their teaching to what STEM requires. We cannot do things on our own; having the administration and help from other teachers in a collegial manner is what is needed. This could really*

> *turn things at school to a community where all hands are one. (Teacher A, Focus group 3).*

For the teachers who participated in the two interviews, emphasis was on finding support from other teachers and from school administrators. Ahmed referred to such collaboration as '...joint construction of knowledge with other instructors……we get institutional support in our PD programs to form better practices but we have not received that for STEM integration'.

Contextual Factors that Facilitate or Hinder STEM Education Practices

There were a number of factors included across the focus groups that could be identified as a response to the second research question as stated above. These factors could be categorised into internal and external factors. The former relates to teachers' beliefs, capacity and pedagogical knowledge and skills, while the latter relates to administrative support, collaboration amongst teachers, resources/facilities, science curriculum content, class capacity, time issues, student and parent awareness of what STEM is, and the existence of a teacher guidebook and professional development. Time, resources and lack of teachers' preparedness seemed of concern amongst the focus groups as these points were mentioned as external factors that could hinder the implementation of STEM in class. Teachers felt that they had internal barriers to using and enacting STEM practices in the class. These became clear in the responses that mentioned the lack of knowledge of different disciplines while others cited that the educational teacher programmes and professional development programmes lacked reference to STEM education. One of the groups specifically referred to teacher beliefs as an internal factor.

> *How can we teach STEM lessons without even being confident in this new approach? A teacher should stand in his class knowing everything… he cannot be shaken or not confident in himself. The only way we see this happening is if he receives training that increases his self-confidence and efficacy. (Teacher C, Focus group 1).*

Nonetheless, external factors were highly emphasised from the focus groups, particularly the lack of resources. 'We also see that it is not possible to ask the teacher to teach STEM lessons without the facilities and technology in class. If there were enough facilities teachers' practices would surely change' (Teacher B, Focus group 1). 'There is no clear teacher guidebook as to how to make links possible to the different disciplines. Teachers on their own cannot do such a thing as they do not have the capacity or the training to do so'. (Teacher A, Focus group 5).

As for the teachers involved in the two interviews, there was explicit reference to a lack of planned and organised professional development programmes. It was therefore left to the need to replace this with self-learning due to not having a formal means to professional development with this innovative strategy, as in the following quote: 'I had to learn about this topic through accessing the Internet since there was no support from other teachers, school administrators or training programmes'. (Mohammed, personal communication, April 22, 2014).

One of the main factors that Mohammed mentioned in his interview was the 'science curriculum'. Its content is dense and therefore students do not enjoy it at all. As a teacher, Mohammed perceived the curricula as an obstacle. Having to work in an integrated setting would just overload the teacher, especially since school textbooks are the main source of teachers' information. (Mohammed, personal communication, April 22, 2014). He also mentioned the mechanical means of assessment that seems to measure only lower levels of students' cognitive ability. For him, a change to this type of assessment seemed necessary. When Ahmed was asked about internal and external factors that impact classroom practice decisions, Ahmed listed a few. Among them was time limitation, number of students in class, the overloaded content packed in the curriculum, and the lack of various resources and facilities. For teachers to be ready to teach in such an integrated approach, they need to have the experience to do so. For Ahmed, it was clear that without such experience and support, teachers could be integrating disciplines on a very surface and superficial level. Since teachers are so attached to textbooks and teacher-guides, reforming these was also a main factor to get teachers able to implement an integrated science lesson for better learning. (Ahmed, personal communication, April 22, 2014).

DISCUSSION AND IMPLICATIONS

Teachers' Views of STEM Interdisciplinary Teaching and Learning

The findings of the study showed that all teachers expressed concerns that they are underprepared to use STEM applications with their students in the classroom. Lack of teachers' preparation to implement STEM practices may explain their views of interdisciplinary teaching and learning across STEM subjects. The majority of the teachers who participated in the study believed that 'technology' is hardware (e.g. computer, laptop, camera, I-pad, etc.) and is a core element for the integration of STEM in the classroom. This showed that teachers did not have sufficient understanding of the 'T' in STEM. It also showed that science teachers might not have an adequate understanding of the nature of science and technology and the interaction between these two disciplines, when and if integrated. Also none of the teachers mentioned engineering as an element for STEM interdisciplinary learning even if they had mentioned some practices that have some designed-based features (e.g. the train, electric doors, flying birds and planes). Johnson and Cotterman (2013) expressed their recent concerns in regards to 'engineering' being left out of a STEM pedagogical model. A clearer idea of what the 'E' and 'T' refer to seemed necessary, so in this regards Malpas (see Malpas 2000 in Harrison 2011) defined them by:

> *Technology is an enabling package of knowledge, devices, systems, processes and other technologies, created for a specific purpose. The word technology is used*

> *colloquially to describe a complete system, a capability, or a specific device. Engineering is the knowledge required, and the process applied, to conceive, design, make, build, operate, sustain, recycle or retire, something of significant technical content for a specified purpose; – a concept, a model, a product, a device, a process, a system, a technology (p. 18).*

Regarding this view on interdisciplinary teaching and learning, Wang, Moore, Roehrig, and Park, (2011) argue that the majority of science and mathematics teachers lack knowledge and experience of teaching engineering and STEM integration. The Roberts review (Roberts, 2002) noted that teachers' subject knowledge and teaching style are vital factors, but it is often their enthusiasm and motivation that captures pupil's interest and motivates them to study a subject. This current study showed that teachers did not have sufficient interdisciplinary experiences nor the pedagogical knowledge and skills that could help them implement STEM integrated learning in their classroom. But also teachers did not feel confident to use STEM practices that require multidisciplinary knowledge. All the teachers across the five focus groups expressed a need for STEM professional development programmes to provide them with opportunities and connections on how to use STEM integration to teach their subjects. However, the dynamic nature and complexity of STEM disciplines make professional development a challenging task (Baker-Doylea & Yoonb, 2011).

Teachers' views on STEM integration. It is worth mentioning that teacher interviews showed they have a positive attitude towards how STEM integration increases students' motivation to learn science and pursue STEM careers in the future. Raising students' awareness about their future careers seems essential especially if there were a career interest survey that could depict such interest as early as the middle school stage (Kier, Blanchard, Osborne & Albert, 2014). Teachers acknowledged that STEM education could help in promoting 21st century skills including thinking skills, collaboration, problem solving, and research skills that could all be useful for selecting careers in science. Additionally, the findings of the study concur with that of Wang et al. (2011) where they believe STEM integration increases students' interest in learning more about STEM disciplines, because their students have fun when they use STEM applications and activities in the science classroom. A few teachers commented that problem-based learning and project-based learning are very important strategies to teach STEM subjects and introduce STEM issues that related to students' daily life (Erdogan et al., 2016). Wang et al. (2011) explain that interdisciplinary integration begins with a real-world problem. But the majority of teachers in the focus groups reported that they were not able to use these teaching strategies or develop STEM lessons because they did not have sufficient knowledge of the other disciplines such as mathematics or engineering. Williams (2011) argues that STEM integration in the classroom requires science teachers to use integrative approaches to be knowledgeable about the other STEM disciplines but teachers often struggle to instruct through integration. Teachers may become 'regional' over specific subject matter limiting the incorporation of other content. Teachers in this study identified that teaching STEM and linking school science learning with real-life situations are necessary to inspire students to take future careers in STEM fields. The local culture of the students including peers, family, industries, career models, and the use of technology in everyday life can induce students' interests in studying science and understanding STEM and take careers in STEM. Therefore, it is important to take advantage of the local culture and raise awareness of the applications of STEM through science lessons. In this sense, the review by Roberts (2002) argues that the views of parents, teachers, careers advisors and society in general towards study and careers in science and engineering can play a significant role in shaping pupils' choices as to whether to study these subjects at higher levels. There is a need to ensure that science teachers are aware of their pedagogical roles in relation to subject choices and career aspirations, and that they are able to refer students to professional sources of impartial careers information, advice and guidance, including members of staff, regional services and web-based resources. Therefore, it is important to develop STEM activities or projects that can engage teachers, parents and industries or universities in the local areas of the students to understand STEM initiatives but most importantly to raise awareness about STEM careers and subjects. These recommendations are supported by numerous research and reports (see for example: Knezek, Christensen, & Tyler-Wood, 2011; National Science Learning Centre White Paper, 2013; Roberts 2002; Stohlmann, Moore, & Roehrig, 2012; Wang et al., 2011).

STEM as part of the school culture. One of the significant findings of this study showed that school culture plays a key role concerning the implementation of STEM education in schools. The study showed that STEM integration required a different school culture than that in non-STEM schools. The STEM school culture requires collaboration among stakeholders and building a collaborative and supportive STEM community (Basham, Israel, & Maynard, 2010). In this STEM school culture, exchange of experience and constant dialogue between teachers and the administrators are highly emphasised. In this sense, Stoll and Fink (1996) list collegiality as one of ten features of a positive school culture, which includes shared goals and responsibility for success, continuous improvement, lifelong learning, risk-taking, support, mutual respect, openness and humour. Bruce-Davis, Gubbins, Gilson, Villanueva, Foreman, and Rubenstein (2014) used the concept of 'values' to describe a STEM school culture that emphasises shared beliefs, norms and support needed to enact STEM education through establishing a sense of community and student identity. In this study, participants stressed that STEM is not one discipline that science teachers can be responsible to handle by themselves. Teachers need support from other disciplines (e.g. mathematics, technology) and from the school. In this respect, some studies argued that teachers' personal concerns about the content they teach and their school culture are likely to affect their motivation and may act as 'affective filters' or barriers to development, thereby decreasing the likelihood that teachers will engage in activities that demand effort. Such concerns need to be acknowledged if any kind of development or engagement is to take place about STEM (Mansour et al., 2014; Hayes, 1997; Krashen, 1982; Yan 2007).

Challenges of the STEM Integrations

Findings show that all teachers reported common external and internal factors that directly affected teachers' STEM practices and performances. The analysis of the external constraints showed that these constraints generated each other. For example, the lack of equipment availability was related to large class sizes, which in turn influenced the time available for teaching and/or learning STEM. Similarly, there was interaction between the external and internal constraints that negatively influenced teachers' enthusiasm to use STEM activities in their lessons. In addition, contextualized institutional issues including class size, lack of resources, students' concerns about exams, lack of curricula focus on STEM activities and a lack of time acted as external constraints. These external factors interacted with some internal constraints related to teachers' pedagogical content knowledge (PCK), including the lack of pedagogical knowledge about STEM, and the lack of mathematics, technology and engineering knowledge. These contextual external and internal constraints all together could have directed teachers toward adopting teacher-centred pedagogies. In this regard, the findings of this study concur with those of Mansour (2007, 2010, and 2013), EL-Deghaidy (2006) and Johnson, Monk, and Swain (2000), that constraints appear to be cyclical as well as multifaceted, nested, and fluid, that could act as mediating factors which hinder the enactment of pedagogical practices such as an integrated STEM model in the classroom.

Towards Developing Integrated STEM Education in Schools

It is evident that teachers need to develop new conceptual structures when it comes to STEM education. According to Harrell (2010), for teachers to be able to teach integrated STEM they need "professional development experiences, adequate planning periods, and adequate content preparation of teachers with regard to content knowledge" (p. 145). Yet, in-service science teachers note that for STEM integration to take place in schools, certain internal and external factors need to be attended to. For the internal factors, teachers' responses of feeling underprepared to teach using an integrated STEM model echoes previous studies (e.g. Koirala & Bowman, 2003). Teacher self-efficacy has been argued to be of extreme importance for successful teachers (Stohlmann et al., 2012). In this line of argument, Diefes-Dux and Duncan (2007) referred to teachers' lack of confidence and low self-efficacy in mathematics and science in addition to their fear of teaching engineering. This resulted in teachers feeling reluctant to engage in professional development programmes. Teachers' efficacy in their content knowledge could be a factor that teachers perceive as crucial to STEM integration in schools, nonetheless, pedagogical content knowledge in an integrated context is another major requirement. One means to help teachers develop in such areas is through professional development. A major factor that also helps provide for a STEM integrated learning environment, is 'school culture'. Teachers' professional community of learners is an example of such type of culture required for STEM enactment in schools (Bruce-Davis et al., 2014). The NCR (2011) stated that inclusive STEM schools and focus STEM schools are successful because students are provided and exposed to problems that have real-world application which integrate science, technology, engineering and mathematics together. In order to provide for means for science in-service teachers to transfer their teaching practices from focusing on science in its silo into an integrated STEM model, a whole set of contextual factors internal to the teachers and external of them need to be considered. The focus here is on providing science teachers with opportunities to develop their pedagogical content knowledge and self- efficacy in an attempt to overcome teachers' claims of being underprepared for such shift in pedagogical practices. While presenting for this shift, external factors are also required to change. This includes setting a different school culture and valuing different models of partnerships among schools, universities and industries (DePaul, 2013 cited in Chiu, Price, & Ovrahim, 2015). This could be considered as a reform to help support such innovative pedagogies to take place in schools due to the genuine impact such an integrated pedagogy could have on the quality of students' learning and future career choices (see **Figure 1**).

CONCLUSIONS

This study fills a gap in the research field of STEM education in the Arab region in general and Saudi Arabia in particular, as it seeks to understand the current views that teachers hold toward STEM education and its core interdisciplinary nature. The study findings are to bring a non-Western perspective of science teachers in the context of STEM education. It concludes that the views of Saudi science teachers are still not fully developed regarding interdisciplinary learning especially with the lack of support needed to enact such practices. There is also mixed understanding of the role of various disciplines such as engineering and technology throughout the integrated learning experience. As for the contextual factors, it is seen that school culture and partnerships need to be established to cater for implementing STEM education through professional communities and partnerships with the community and universities.

With such findings, the study can provide recommendations at the policy level to introduce programmes for pre-service and in-service teachers. This could lead to developing a STEM professional development model of what teachers need in terms of pedagogical content knowledge to enact STEM education in class. Future studies could focus on conducting a study to investigate student learning when implementing a STEM integrated lesson in a science classroom. Students' views of STEM integration and the pedagogies their teachers used to help understand science through STEM education could be collected. It would also be necessary to plan school-STEM-based professional development (S-STEM-PBPD) programmes and study science teachers' views of these professional programs. Also explore science teachers' perspectives of the contextual issues that have an impact on putting learning emerging from the S-STEM-PBPD programme into practice. It is also essential for developing effective STEM teacher professional development to identify teachers' professional needs to teach STEM effectively. Teachers made comments about the lack of STEM activities in the science curriculum, so it could be important to carry out content analysis of the science curricula across different educational stages to explore the potential of these science curricula to promote STEM education. In terms of the study limitations, the authors are aware of the limitations when trying to generalise its findings. The main limitation, is that this study was

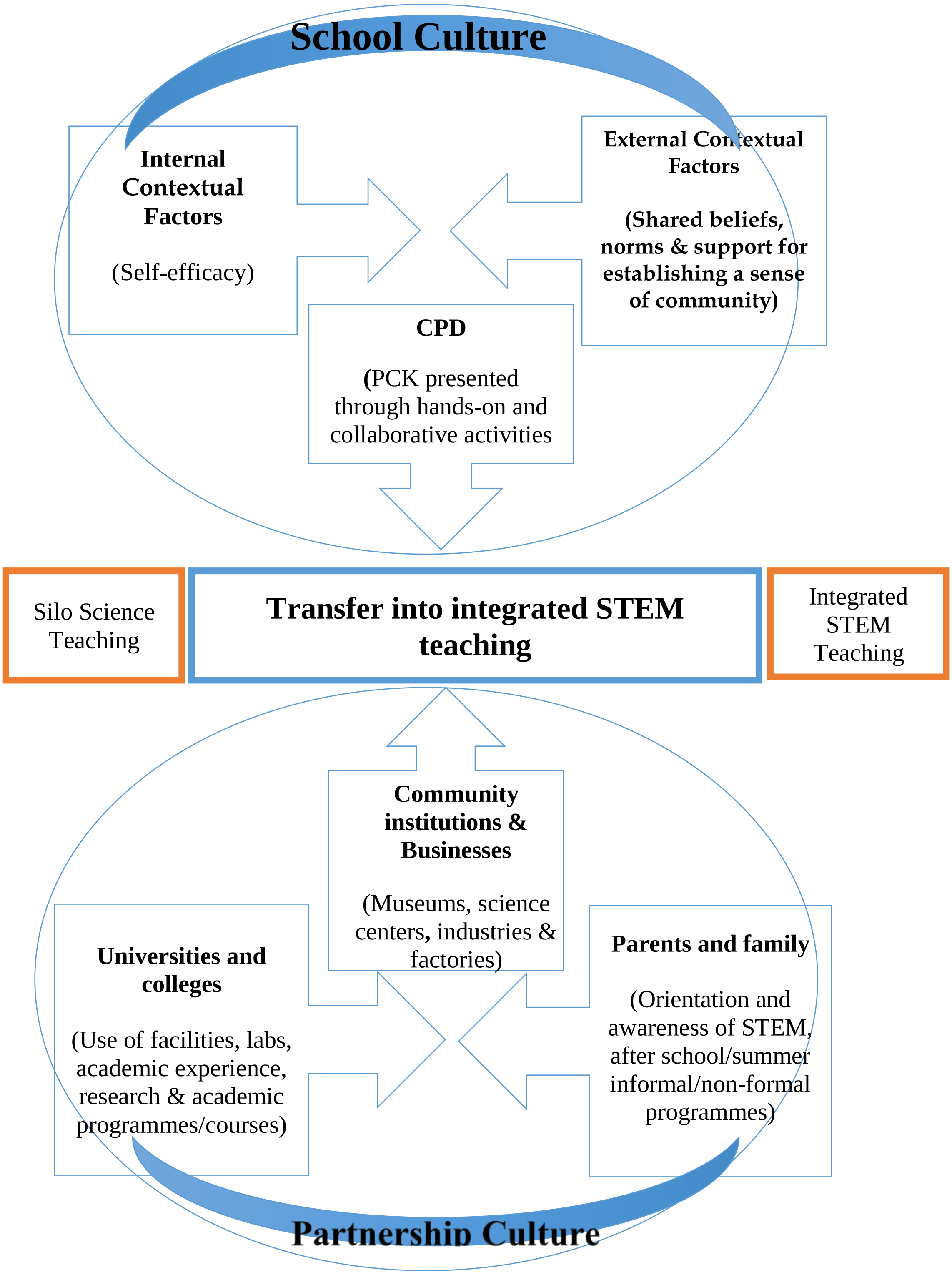

Figure 1. Transfer to a STEM integrated model

only on male science teachers. This limits the voice of female teachers in expressing their views on such contemporarily topic. It should be noted the difficulty of access to female schools and teachers and the concept of interviewing and recording their voices is not that acceptable within the Saudi culture. Another limitation is the number of teachers who were involved in the interviews. Two teachers only were able to participate. Having had more at this detailed stage of eliciting teachers' responses would have helped understand more various views on STEM education and reasons for perceiving certain factors as either facilitating or hindering its implementation. More research is still needed in the Arab region on STEM education to understand more how this integrated model could be implemented in Sadia Arabia and the region.

ACKNOWLEDGEMENT

This research was conducted as part of the professional development for in-service Science and mathematics teachers Research group with support of the Excellence Research Centre of Science and Mathematics Education - King Saudi University, Kingdom of Saudi Arabia.

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