

Exploring Saudi Arabian Teachers' Changing Understandings of STEM Education

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Abstract

In 2016, the Kingdom of Saudi Arabia (KSA) developed a bold plan, 'Vision 2030'. This plan seeks to establish a strong foundation for future economic prosperity based on a transformational shift from the current natural resource-based economy to a knowledge economy (Wiseman, Abdelfattah & Almassaad, 2016). In addressing these reforms, the KSA Ministry of Education has engaged a number of global universities to design and implement teacher professional learning for KSA educators to build the new knowledge and skills needed to innovate the traditional curriculum. The Faculty of Education, Monash University, was engaged in this initiative, designing a 44 week program exploring technologies and pedagogies of STEM education and the implications for KSA schools. The cohort of 25 technology, mathematics and science Saudi educators experienced many STEM learning opportunities, including 17 weeks immersion in STEM education classes in Australian schools. The program was intended to positively impact teacher professional growth, evidenced by a change in participant thinking about understandings of STEM education. The intensive nature and duration of the professional learning program presented a unique opportunity to map changes in teacher thinking. This research seeks to capture such change using a mixed methods approach (anonymous surveys and regular focus group meetings). Of particular interest are the development of personal confidence with STEM teaching and the changing understanding of the interdisciplinary nature of the subject. Initial survey data reveals the vast majority of the KSA educators report a limited understanding of STEM education and low levels of self-confidence in teaching STEM classes.

Keywords: STEM education, teacher thinking, professional learning

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Introduction

Education in the Kingdom of Saudi Arabia (KSA) is currently undergoing a period of unprecedented change as the pressures of globalisation challenge traditional cultural norms, gender stereotypes, identity and labour markets. Since 1950, the government export revenue has been increasingly reliant on the sale of its extensive reserves of oil and natural gas which are estimated at present (Dudley 2018) to comprise between 16% and 18% of the world's total proven remaining reserves. Initial oil exploration was undertaken in the 1940's by the Arabian American Oil Company (ARAMCO) and a shifting mix of American and Saudi interests followed with changing profit sharing arrangements. In 1988, the industry was completely nationalised through a buyout by the Saudi Royal family establishing the State owned Saudi Arabian Oil Company (Saudi Aramco). Saudi Aramco remains the most profitable company in the world, valued between \$1.2 to \$2.6 trillion dollars and earning more than twice that of its nearest rival company Apple Inc. in 2019. More recently Saudi Aramco has released a prospectus offering 0.5% of its shares to private investors with the potential to be the largest public share offering in history.

Following a sustained downturn in the export price of crude oil between 2014 and mid-2015, there was growing concern within the country of the continued dependence on petroleum revenue, which at the time contributed more than 90% to its total export income (CEIC 2016). With the downturn of traditional markets in America and Europe, and softening prices in Asia, the KSA Gross Domestic Product per capita fell by 2.8% between 2016 and 2017 (CEIC 2016). In response to the uncertainty around KSA's future economic prosperity, 'Vision 2030' (Khan, 2016) was announced in 2016 by the Crown Prince and Chairman of the Saudi Council of Economic and Development Affairs, Mohammed bin Salman bin Abdulaziz Al-Saud.

The KSA economic blueprint, Vision 2030 is wide ranging with no less than 96 objectives, the majority of which are designed to stimulate social, educational and economic changes that will ultimately reduce the KSA's continued dependence on petroleum revenue (Moshashai, Leber, & Savage, 2018). The reforms, as these take effect, are projected to reduce the excessively high public sector spending and grow new opportunities within the private sector for establishing manufacturing markets and stimulating technology innovation. Fiscal commentary at the time of the Crown Prince's announced reforms was widely supportive of the proposals, advocating that the KSA's economic prosperity relied increasingly on educating and skilling its citizens to play a more active role in building a knowledge based economy (Nurunnabi, 2017).

Promoting educational change through teacher leadership

Given the acknowledged urgency for education and social reforms (Wiseman, Abdelfattah & Almassaad, 2016), the KSA Ministry of Education actively engaged several reputable tertiary educational providers in Australia and internationally to design and implement a number of customised teacher professional learning programs. Most programs have focused on building the leadership capacity of participating KSA teachers by assisting them to explore opportunities for desired educational change. The Faculty of Education, Monash University, successfully tendered with such a program; Building Leadership for Change through School Immersion (BLCSI). This program

has now been offered twice, the first program in 2017 involved 50 Saudi teachers for 30 weeks and the following program in 2018, involved 24 Saudi teachers for 39 weeks. Both programs catered for generalist teachers with a focus on building professional knowledge, leadership and pedagogy through a mix of presentations from leading educational researchers, and expert school practitioners. Importantly, each program provided in excess of 13 weeks of immersion in either Australian Primary or Secondary school settings.

In 2019, following the success of these two programs, the KSA approached the Faculty of Education, Monash University, to offer a longer 44 week program catering for 20 generalist Saudi teachers. In addition, the Faculty was invited to design a parallel program for 25 Saudi teachers with a focus on STEM Education. The intention of this additional program was to build Saudi teachers' understanding of STEM education, in particular the potential benefits for student learning and development. The outcomes from this program are the basis of this research study. All three researchers bring reputable knowledge of STEM education through their extensive experience in the design and delivery of Monash Graduate Certificate Courses in STEM Education and multi-day professional learning programs offered by the Faculty of Education, Monash University, for Australian Primary and Secondary STEM teachers.

The Kingdom of Saudi Arabia educational context

The experience of a teacher in KSA is predominantly a solitary one enacted mostly between themselves and their class with few opportunities for professional collaboration. Classroom instruction is customarily teacher centred and didactic in nature with an emphasis on strict adherence to National set curriculum and content coverage in State prescribed textbooks.

Two of the researchers have previously been involved in both Monash University BLCSI programs in 2017 and 2018. These experiences have provided each with rich insights into the complex nature of the KSA's education systems, culture and social norms and the challenges the Saudi teachers face in attempting to introduce system wide change across their schools on return. Schooling in the KSA occurs in gender segregated schools with same gender teachers, in strict adherence with cultural principles. Many of the KSA teachers from earlier programs have frequently acknowledged their teaching experience is, as El-Deghaidy & Mansour report, "*classroom teaching... (is) mostly done independently as teachers prepare and deliver their lessons individually*" and that "*it is not common for teachers across disciplines to sit together and identify cross-cutting content or skills*" (El-Deghaidy & Mansour, 2015). Anecdotal discussions with BLCSI teachers suggest that these findings, although once widely enacted across most schools in the KSA, are now beginning to be challenged with the introduction of new pedagogies in many of the larger schools in city centres. However, many of the current 2019 program teachers acknowledge that such frequent and routine professional isolation poses major challenges for their introduction and integration of STEM Education across classes or year levels in the KSA schools.

The KSA Ministry of Education's interest in STEM Education appears largely motivated by the expected economic benefits of a future workforce proficient in 21st

century skills and capabilities. These outcomes have been widely promoted in numerous western government industry and education reports over the last decade (West 2012; Freeman, Marginson, & Tytler, 2014). In 2013, a position paper released by the Australian Government's Office of the Chief Scientist (Chubb, 2013), proved instrumental in fostering a ground swell of Government interest and debate in Australia around STEM education. In this paper, the then Chief Scientist, Professor Ian Chubb, argued the importance of encouraging future Australian students into STEM disciplines in order to skill them to play vital roles in economically beneficial STEM industries (Head, 2014). In many countries this position continues to drive Government policy perspective, where education focused on STEM Education is accepted as one of the most beneficial methods of building human capital for labour market readiness, productivity, and innovation (Ramirez, Luo, Schofer & Meyer, 2006). Building teacher capacity to implement effective STEM education is vital to achieving such intentions. There is a need to learn more about how teachers develop deeper understandings about STEM education and how they use this knowledge to reconsider their practice to enhance learning opportunities for students in school based STEM education programs.

Methodology

This study explores the impact of intensive professional learning in changing Saudi Arabian teachers' attitudes towards, and understandings of, STEM education. Particular attention was paid to how the teachers conceptualised STEM Education and their understandings about how STEM Education could be implemented within the constraints of the KSA curriculum. The following research questions form the basis for this study;

1. What are the KSA teacher understandings of STEM Education when they commenced the BLCSI STEM program?
2. What changes occur in participants' attitudes and knowledge about STEM Education over the duration of the BLCSI STEM program?

The challenges associated with STEM Educational design, the program cultural context and the lengthy 44 week program duration, were seen by the researchers as providing an invaluable opportunity to undertake a longitudinal study investigating teacher professional growth. Apart from research by El-Deghaidy & Mansour, there appears to be little published educational research investigating STEM Education in the KSA context. For all 25 participating Saudi teachers (7 females and 18 males) English is a second or third language so they were provided with a research explanatory statement translated into their first language, Arabic. All consented to take part in the research in line with research ethics approval granted by the Monash University Human Research Ethics Committee (MUHREC).

The study involved a mixed methods approach with the principal research focus being the evaluation of overall change in the nature of the participants' collective understandings of STEM Education rather than individual changes. The researchers were also keen to identify any key program activities or experiences that participants' felt best helped them to clarify, challenge or improve their STEM Education understandings. Two qualitative data collection instruments were utilised for this study. Baseline data were collected using a written survey (S1) comprising 20 questions in Arabic administered in the first few days of the program. It was deemed

important at this early stage that participants were permitted to use their native language, to ensure that their proficiency in English did not compromise the quality of their responses. All data collected throughout the research was de-identified apart from gender. Data was then translated into English by an external translator and then collaboratively analysed by the researchers.

Following the completion of the initial survey, two focus group (FG) meetings were held at week 20 (FG1) and week 27 (FG2) comprising of separate groups for both males and females consistent with Saudi cultural norms. These discussions groups were conducted in English with common key questions and the participants' comments were recorded, de-identified and transcribed for analysis. Because of the rich and diverse nature of the data collected, the researchers found it helpful to adopt a grounded theory approach to identify a number of emerging themes around which the findings could be aggregated for analysis. The emergent themes to date include; current understandings of STEM Education; challenges and opportunities associated with implementing STEM Education in a KSA context; and, exploring useful pedagogies to enhance STEM Education in a KSA context. Some of these themes will be discussed further in the findings and results section of this paper.

At the conclusion of the program in early 2020 the initial survey will be administered again, (S2) this time in English given the improved English language proficiency of the participants. The completed surveys comments will again be recorded anonymously and compared collectively with the initial survey findings.

Findings and Results

Initial benchmark survey- current understandings of STEM education

An analysis of the initial survey (S1) reveals some insights into the teacher cohorts' background and initial thinking. The vast majority were teachers with between 5 to 12 years experience in schools in either rural or remote areas of the KSA. Only 3 teachers acknowledged having 4 years or less teaching experience. The majority were Computers Science subject specialist teachers with the next most prevalent specialism being Mathematics followed by 2 Chemistry and a single Biology teacher. The predominance of Computer Science subject teachers in the cohort possibly reflects the KSA Ministry of Education's belief that effective STEM Education requires a strong knowledge of computer coding.

When asked to describe what they believed STEM Education means, the dominant view expressed was *"the teaching of science, technology, engineering and mathematics as one subject and in one framework and using teaching methods to integrate these different specialities"* (S1M). Approximately a quarter described it similarly as *"the use of technology in the learning and teaching of a few school subjects and connecting them together"* (S1M). The remainder were less clear with some prepared to state that they, *"Honestly do not know but I have heard before that it involves the programming of robots"* (S1M). In response to the survey question, "What characterises STEM Education and makes it different from other kinds of instructional methods"? a little more than half described it similarly, *"As the integration of four subjects into one unit in an effective way"* (S1M) or *"Involving the use of technology in education"* (S1M). The remaining teachers described it similarly

as a learning that is, “Active, interactive learning through real objects’ (S1M) and involving “a lot of real skills that are connected to real life and the environment” (S1F).

Participants were asked to visually convey their thinking about ‘STEM Education’ by drawing a simple representative diagram which described the relationship between each of the disciplines. The results were diverse with no consistent model appearing to be favoured. This may reflect the cohorts’ limited contact with any such representational models prior to commencing the program. Several images did display a bias towards the importance of Mathematics as evident in the bottom row of Figure 1. However this may be more attributable to the high proportion of mathematics teachers present in the cohort. A frequent justification was “Mathematics is the foundation, and it connects with the other sciences. The other sciences connect directly with each other or through mathematics” (S1F). Another common explanation of this view was “I think that technology is the link between all of them and that math is probably more associated with engineering” (S1M).

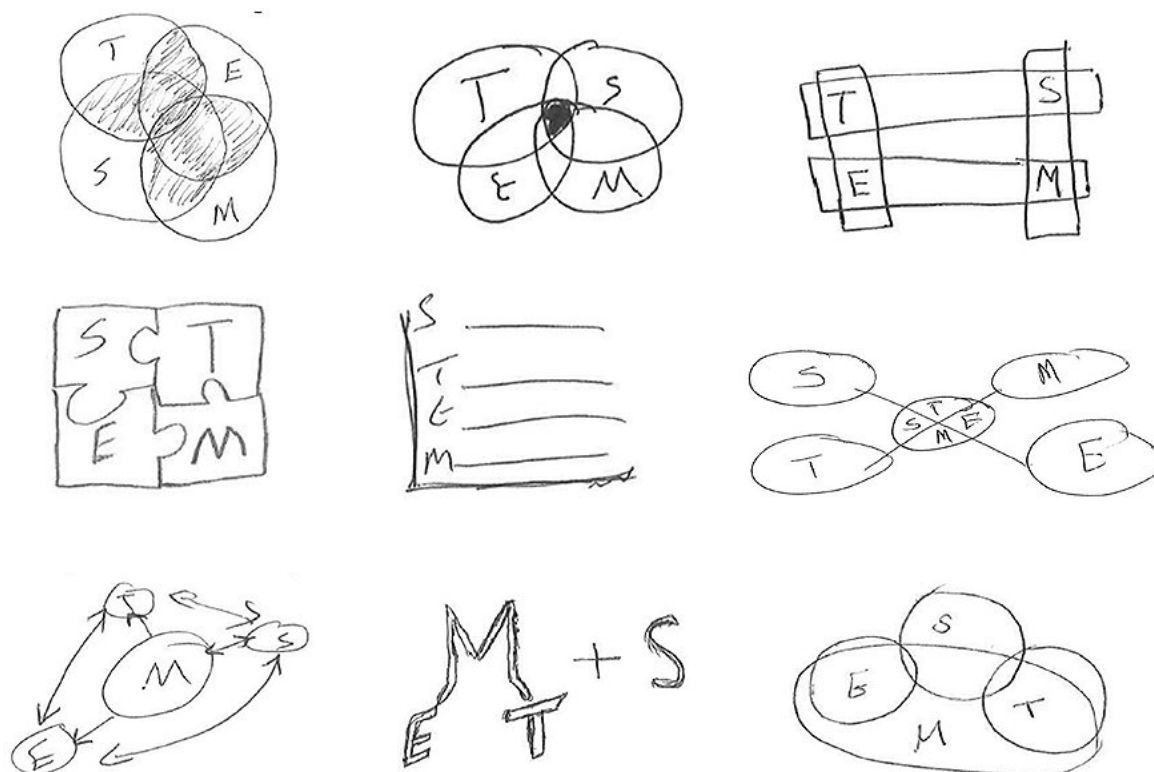


Figure 1: Teacher visual representations of STEM Education.

Finally an overall analysis of the initial survey (S1) data suggests that while most Saudi teachers were aware of the term, ‘STEM Education’ understandably most had very limited or naive understandings of what a STEM Education lesson might look like or how such a program might be integrated into the KSA curriculum or school lessons. All participants acknowledged never having taught STEM classes in their KSA schools or to having seen classes taught in other settings. An early common belief among the participants, although not universally held, was that STEM Education required a large school wide program that was project based, dependant on expensive digital technology, with classes of students working on coding robots with support

from expert digital technology teachers. Typically this was expressed as, *“I thought that STEM had to be at a grand scale, like a bigger project, you can’t tackle it in the class and has to be in collaboration with a lot of teachers. That’s the idea that I had back in my country.But now I can see that student STEM can happen everywhere, anywhere you want it to be can happen in a small scale, or even on a larger scale”* (FG2).

Focus group findings

The data collected from the focus group meetings provided valuable insights about how the Saudi teachers’ understandings of STEM Education were beginning to change. In general, focus group comments reflected that teachers were demonstrating broader thinking about what mattered in effective STEM education classes. While the initial survey (S1) data indicated that teachers were initially concerned about what discipline content knowledge to teach in STEM, the focus group data revealed many teachers were now considering that STEM Education needed to comprise more than just teaching blended discipline content knowledge. The data showed an emerging shift towards considerations about teaching in ways to enhance student learning, skills and capabilities. As one participant states, *“It’s about the journey. Not about the destination. So if the student is giving, is doing well, and is practising well, he’s getting more skills like communication, collaboration and ... critical thinking and also the creativity and a lot of the 21 century skills”* (FG2M). Teachers were also discussing the importance of developing learning opportunities in contexts which would enable their students to engage with relevant and personally meaningful learning experiences while building key thinking skills. In the focus group discussions, teachers talked about the importance of student engagement and making learning relevant to the everyday lives of students. A typical comment was, *“How the environment can help us. Connect the students with the environment using STEM disciplines like ... to teach the student the importance of farming, the importance of composting and e-waste. CERES is a good community. It’s a pretty rich community for STEM experience but also it’s kind of presented like a Saudi Arabia for small community or even just small aspect of life, like garden in the school or composting”* (FG2M). Teachers also appeared to be considering how these learning experiences could be developed to support particular cognitive and affective intentions for student learning.

What matters in STEM education?

In the initial survey data, teachers described the importance of teaching content knowledge in each of the STEM disciplines and indicated an awareness of the importance of establishing links between these areas of learning, although as previously discussed, a range of understandings was clearly evident. The focus group data however, revealed that for some teachers the importance of skill development was also being considered as a critical part of STEM education. In focus group discussions, some teachers were able to identify the particular skills they considered as essential for students in a changing world.

Many teacher comments conveyed this change of emphasis; discussions also revealed that teachers were aware of this shift in their personal thinking. One participant described how her initial thinking about STEM education had focused on, *“how to solve a problem using science, technology and math and also engineering”* (FG1F).

However, after participating in the early stages of this professional learning program she described how her thinking had moved beyond an intention to build student content knowledge in each STEM discipline. She states, *“Now, I understand it's more than just science, technology and math. It's more about building skills for the students or for the learner, like, how to communicate better, how to use technology better and how to prepare the students for college, for future jobs to be not only dependent on one field”* (FG1F). The potential to link these areas through skill development seemed to present for this teacher, a way to enable students to access and develop thinking across areas rather than be limited or dependent upon only discipline. Another teacher's comments reveal a similar perspective. *“I was thinking (about) how to make the four aspects of STEM math, technology, engineering and science related, related and teaching to each other,....(now) I have a clearer understanding. After the workshops we attend, after the places we visit, that stem it's all about building skills, problem solving, creativity, critical thinking, and all about making students get skills, besides the curriculum as explicit teaching”* (FG1M). These types of comments demonstrate how teachers were beginning to consider the importance of skill development in STEM Education. *“Firstly, I have the idea about STEM. If you want to apply STEM in your class, you must join each subject in the same lesson but now my ideas have changed. It has to do with a focus on the skills, not the subject information but skills, how can I build the skills into the student?”* (FG2M).

The ability of the teachers to clearly identify a range of skills aligned with STEM Education is evident. For some teachers this awareness is accompanied by the realisation that such teaching intentions extend beyond explicitly delivering curriculum content. *“(It is important that) ... he knows how to apply all the knowledge. If it's just teaching without knowing - you will lose this knowledge. I will forget it after one hour on but if I connect it to my life, for example, to make some plants the garden or take something in the house or make ... a maker space Then the students will see something in front of him so he will grow and share the knowledge”* (FG1M).

The data also revealed a shift away from the idea that STEM learning experiences need to be based around expensive equipment and large scale projects. *“(Before) I was thinking to apply STEM, you need special places or special apps, but now I can understand that I can do it anywhere. Yeah, and any place”* (FG1F) and, *“The teachers need to start in any class with a problem, big problem, to ask the students a question, to help them to think and to find a solution for this problem”* (FG1M). There appeared to be an increased awareness of the ‘everydayness’ of STEM of how it surrounds us all but needs to be made explicit for students. By noticing STEM in the world around them, the teachers began considering the opportunities this afforded to STEM teaching. *“Because when you use STEM, a part of STEM is technology to digitalise because we are in the modern world right now, we work using technology* (FG1F).

These considerations indicated a shift in teacher thinking from a focus on STEM teaching to STEM learning. Some teachers appeared to be thinking about the conditions they need to create to enhance student engagement, highlight relevance and encourage students to better invest in their own learning. The implications of such considerations for teaching approaches were also being considered. *“STEM is more active than a traditional class and enjoyable. That's what I notice about a lesson in the STEM. It has been interesting, exciting”* (FG2M). Shifting to more active ways of

learning held obvious challenges for teaching but some teachers articulated how important it was that students develop ‘understanding’ as a key outcome. *“And it's very important for the student to understand how tonot only be users. How to work this technology (in ways that) can benefit their field or their world or something”* (FG1F). The focus group data also indicated that some teachers were placing a value on independent thinking as a learning outcome, yet achieving this required teachers to think and work differently. *“Sometimes we just give the students the instructions, and the students will do that and the result will be we will give them the result will be like that. But now ... just give the students the problem and they will think in different ways”* (FG2M).

Discussion

These new ways of thinking about STEM learning and teaching held a number of implications for the Saudi teachers and these implications began to emerge from the data analysis as a series of tensions between traditional practice and new preferred ways of working.

Challenges and opportunities associated with implementing STEM Education in a KSA context

Teachers discussed a need to develop effective STEM learning and teaching by being more flexible in their teaching so as to provide more effective conditions to enhance student interest and engagement. Yet it became clear that a growing tension exists between this aspirational teaching approach and the reality of delivering their existing more prescriptive curriculum. While watching teachers in Australia work in ways which were responsive to student learning needs, some Saudi teachers were reminded that they did not always have the same opportunities to work in similar ways. *“I think back home we are stuck in our curriculum but here you have the flexibility to change your curriculum in the ... the lesson that you want to give the students. So it's a bit hard to apply STEM there (in KSA), but also you have to be creative to manage your class ... to also manage your lesson”* (FG1F). The data indicated that teachers recognised this as a concern and were considering how they may be able to address this issue. *“So I think this is the thing that is not clear for us at the moment. Because we have also curriculum, specific curriculum in KSA so that we don't have flexible curriculum. Yeah. How to do that? How we can do that without problem”?* (FG2M).

There was another tension that became clear in the data analysis related to assessment and planning. Teachers described how present Saudi student assessment requirements dominated their teaching. *“But for my countryit's all about the assessment, the result”* (FG2M). Yet some teachers were beginning to see that this focus needed to be broadened to include skills development and this required them to rethink their planning and invest time to develop new learning experiences. Determining how both content knowledge and skill development could be successfully achieved required a different approach to planning and this was challenging for many of the teachers. The data revealed they were grappling with what aspects of learning should take precedence and how time should be allocated in their teaching. *“I think is not all the time, you can (only do) some parts of a STEM project in it (class time) but some you can't. That's what I think and maybe it's wrong? So, I think sometimes you need to use your traditional way to teach. Yeah. I don't know”* (FG2M). While many teachers had

identified that they needed to think and work differently, the opportunities to do so and the time they needed to rethink their planning was limited and this concern emerged in the data. *“It seems to me that a lot of time of preparation of planning”* (FG2M).

Class sizes of around 40 students, the number of classes teachers were required to teach and a desire to implement new projects and activities, also emerged as a tension in the focus group data. *“It’s a challenge with the big number of classes ... for the STEM project, how I make the project and with clear activities. The students (need to) know what must be learnt and what is the information ... the goals for this activity”* (FG2F). Time spent on learning experiences and the allocation of resources for STEM education appeared to be impacted by this concern. *“I think one of the most challenges in (the) KSA is it’s too expensive to use ... to buy the materials or to build the sensors or resources”* (FG2M).

Tensions continue to emerge as teachers described; the need to attend to existing prescriptive curriculum when seeing a need to be more flexible in their teaching; when the assessment outcomes, which are highly prescriptive and valued, do not include skill development; the demands of large class sizes; and, the need for expensive resources.

Summary and conclusion

This study aims to explore the impact of intensive professional learning in changing Saudi Arabian teachers’ attitudes towards, and understandings of, STEM education. The initial survey (S1) data attempted to gain insight about the ideas the participants held about STEM education at the beginning of the program. The data analysis revealed Saudi teachers shared some common ways of thinking about STEM Education with most able to identify the four discipline based STEM areas of science, technology, engineering and mathematics. Most participants also expressed an idea that these areas would in some way be integrated, although a diversity of thinking about the types of links and how they could be enacted between these areas was evident.

The focus group data, collected after the initial survey but still within the early stages of the program, revealed that some shifts in thinking were beginning to emerge. Teachers were now considering the role of skill development in STEM Education and the importance of ensuring the nature of the learning experiences were relevant and meaningful for students. These ideas indicated a shift in teacher thinking from considerations about teaching content to considerations about teaching to enhance learning. The focus group data also revealed the teachers were considering how STEM Education could be implemented within the constraints of the KSA curriculum and this was raising a number of tensions for them in terms of the need for flexible and responsive teaching and a need for broader considerations around assessment and planning. While the results in this paper only represent teacher feedback in the early stages of the program, the data does provide evidence that teachers are beginning to broaden their thinking about what matters in STEM Education. The final stages of the research will involve further survey data and the analysis will continue to explore changes in the KSA teacher thinking about STEM Education.

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References

Chubb, I. (2013). Science Technology, Engineering and Mathematics in the National Interest: A Strategic Approach. *Canberra: Office of the Chief Scientist, Australian Government.*

CEIC (2016). Saudi Arabia macroeconomic and sector data, *ISI Emerging Markets Group*. <https://www.ceicdata.com/en/indicator/saudi-arabia/current-account-balance>, Accessed 15/10/2019.

Dudley, B. (2018). BP statistical review of world energy. *BP Statistical Review, London, UK.*

El-Deghaidy, H., & Mansour, N. (2015). Science teachers' perceptions of STEM education: Possibilities and challenges. *International Journal of Learning and Teaching, 1*(1), 51-54.

El-Deghaidy, H., Mansour, N., Alzaghbi, M., & Alhammad, K. (2017). Context of STEM integration in schools: Views from in-service science teachers. *EURASIA Journal of Mathematics, Science and Technology Education, 13*, 1-26.

Ewers, M. C., & Malecki, E. J. (2010). Leapfrogging into the knowledge economy: Assessing the economic development strategies of the Arab Gulf states. *Tijdschrift voor economische en sociale geografie, 101*(5), 494-508.

Freeman, B., Marginson, S., & Tytler, R. (Eds.). (2014). *The age of STEM: educational policy and practice across the world in science, technology, engineering and mathematics*. Routledge.

Head, B. (2014). 'STEM education and innovation are essential for national success': A profile of Australia's Chief Scientist, Ian Chubb. *Australian Journal of Telecommunications and the Digital Economy, 2*(1), 30.

Khan, M. (2016). Saudi Arabia's Vision 2030. *Defence Journal, 119*(11), 36-42.
Kingdom of Saudi Arabia (2016) Vision 2030, <https://vision2030.gov.sa/en>, Accessed 15/10/2019

Moshashai, D., Leber, A. M., & Savage, J. D. (2018). Saudi Arabia plans for its economic future: Vision 2030, the National Transformation Plan and Saudi fiscal reform. *British Journal of Middle Eastern Studies, 1-21.*

Nurunnabi, M. (2017). Transformation from an oil-based economy to a knowledge-based economy in Saudi Arabia: the direction of Saudi vision 2030. *Journal of the Knowledge Economy, 8*(2), 536-564.

Observatory of Economic Complexity (2017) Saudi Arabia Macroeconomic data. <https://oec.world/en/profile/country/sau/>, Accessed 15/10/2019

Ramirez, F. O., Luo, X., Schofer, E., & Meyer, J. W. (2006). Student achievement and national economic growth. *American Journal of Education, 113*(1), 1-29.

Wiseman, A., Abdelfattah, F., & Almassaad, A. (2016). The Intersection of Citizenship Status, STEM Education, and Expected Labor Market Participation in Gulf Cooperation Council Countries, *Digest of Middle Eastern Studies*, 1-30, Wiley Periodicals, Inc.

West, M. (2012). STEM education and the workplace (Vol. 4). *Office of the Chief Scientist, Australian Government*.

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