



Received: 12 July 2018  
Accepted: 5 February 2019  
First Published: 7 March 2019

\*Corresponding author: Abdulwali H. Aldahmash, King Saud University, Saudi Arabia  
E-mail: [aaldahmash@ksu.edu.sa](mailto:aaldahmash@ksu.edu.sa)

Reviewing editor:  
Stuart Bevens, Sheffield Institute of Education, Sheffield Hallam University, UK

Additional information is available at the end of the article

## TEACHER EDUCATION & DEVELOPMENT | RESEARCH ARTICLE

# Saudi Arabian science and mathematics teachers' attitudes toward integrating STEM in teaching before and after participating in a professional development program

Abdulwali H. Aldahmash<sup>1\*</sup>, Naem, M. Alamri<sup>2</sup> and Mohammed A. Aljallal<sup>3</sup>

**Abstract:** For the advancement of current and future economic and overall well-being to occur, STEM professionals are highly needed. STEM education is an approach that integrates science, technology, engineering and mathematics curricula into one interdisciplinary curriculum. In the context of STEM education, learners acquire deep and critical thinking abilities, which help them become creative and analytic thinkers, and hence innovators in their careers. For this to happen, the teacher must be trained to successfully design and effectively teach an integrated STEM curriculum. The purpose of this study was to analyze Saudi Arabian science and mathematics teachers' attitudes toward integrating Science, Technology, Engineering and Mathematics (STEM) in teaching before and after they participated in a short professional development program focused on STEM integration in a specific middle school science and mathematics content. The participants were 48 Saudi Arabian science



Abdulwali H. Aldahmash

### ABOUT THE AUTHORS

Abdulwali H. Aldahmash, Professor of Chemical Education, at the Excellent Center for Science and Mathematics Education, King Saud University, Riyadh. His research focuses on science teacher's continuing professional development, STEM education. He has published many studies in the area of interest in well-known journals (e.g., An Analysis of Activities in Saudi Arabian Middle School Science Textbooks and Workbooks for the Inclusion of Essential Features of Inquiry, Kinetic vs. static computer-generated visuals for facilitating college students' understanding of reaction mechanisms in organic chemistry, secondary School Science Teachers' Views about Their Reflective Practices, Emerging Trends in Research on Math Teacher Professional Development, etc.).

Naem, M. Alamri, Associate professor of Math Education, King Saud University, curriculum and instruction dept. College of education, and Excellent Center for Science and Mathematics Education, King Saud University, Riyadh, Saudi Arabia. He has published a study in the area of interest in a well-known journal titled "Emerging Trends in Research on Math Teacher Professional Development". He also published studies in local journals.

### PUBLIC INTEREST STATEMENT

This study presents the attitudes of science and mathematics teachers about integrating STEM in teaching as a result of their participation in a professional program focused on teaching integrated STEM. The study was designed to investigate the impact of a short PD program on teacher's attitudes towards STEM education. Findings indicated that the short PD program had a slight positive impact on teacher's self-efficacy, and their perceived difficulty of teaching integrated STEM. However, it was shown that the short training program had no effect on perceived relevance, anxiety, and enjoyment of teaching integrated STEM among science and mathematics due to their participation in the PD program. This implicates that well planned long and continuous PD programs would be more effective than short PD programs in enhancing teachers' experience and affective factors about integrating STEM in teaching science and mathematics.

and mathematics teachers, who participated in a 6-day program held in Riyadh, Saudi Arabia. The research methodology was a pretest–posttest one group (pre-experimental) design. The primary data source was the Instrument for Teachers' Attitudes Toward Teaching Integrated STEM. The results indicate that Saudi Arabian science and mathematics teachers' perceptions of difficulties decreased due to their participation in the professional development program on integrated STEM. Meanwhile, the teachers' self-efficacy improved following their participation in the STEM professional development (PD) program. However, no perceived effect was found for the teachers' perceptions of the relevance of or their anxiety about or enjoyment of Integrated STEM teaching due to their participation in the 6-day PD program. We argue that Engaging teachers in integrated STEM professional development may improve their attitudes toward and increase their interest in teaching this approach. To improve teachers' attitudes toward, it is suggested that future PD programs should be long and continuous, and focus on training science and mathematics teachers to teach integrated STEM subjects.

**Subjects:** Educational Research; Education Studies; Sustainability Education, Training & Leadership; Teachers & Teacher Education; Classroom Practice

**Keywords:** STEM integration; attitude toward STEM; STEM program; science and mathematics teachers

## 1. Introduction

Challenges and issues such as the spread of poverty, global warming, environmental pollution, overpopulation, agricultural production, health, biodiversity, declining energy, water sources, and the social impacts of the twenty-first century must remain at the forefront of education reform efforts (Thomas & Watters, 2015, p. 42). To cope with such challenges and issues, modern societies need to devise multidisciplinary solutions that enable individuals to become creative and skilled problem solvers. This can be accomplished by changing the focus of education to align with twenty-first-century skills (Voogt & Roblin, 2010), which involves transitioning from expecting learners to merely have disconnection parts of knowledge to help them apply their knowledge into in their real life.

STEM is a multidisciplinary approach to teaching that integrates science, technology, engineering, and mathematics disciplines in one curriculum as cross-cutting or cross-disciplinary—overlap topics (Morrison, 2006; Morrison & Bartlett, 2009). This combination supplies societies with individuals who are capable of turning knowledge into action, and individuals who can solve the major problems facing their societies. In other words, integrated STEM can enable students to be critical of the world and find answers to solve issues present in society (Robinson, 2016; Hu & Garimella, 2015; Kennedy & Odell, 2014). For example, integrating biology and engineering allowed biomaterials engineers to help people suffering from pain and debilitating diseases feel healthier and safer (Vernengo, Farrell, Kadlowec, & Strobel, 2014).

In the context of STEM education, learners acquire deep and critical thinking abilities, which help them become creative and analytic thinkers, and hence innovators in their careers. Being an innovative thinker means being able to solve the most pressing problems facing society as well as the entire world. Furthermore, Furner & Kumar (2007) indicated that using an integrated education strengthens learner's opportunities for more stimulating experiences. It also guarantees student-centered learning and may improve higher-level thinking skills and problem-solving (Bell, 2016; Stohlmann, Moore, & Roehrig, 2012; Ellis & Fouts, 2001; King, & Wiseman, 2001). Similarly, Morrison (2006) asserted that integrated STEM education can

improve students' problem-solving, innovation, invention, and logical thinking skills. Integrated STEM curriculum can increase students' learning, but teachers appear to have greater difficulty shifting to this type of integrated curriculum due to their experiences with traditional preparation programs.

STEM education is an approach that includes four pillars, which are: Science, technology, engineering and mathematics. It was defined as "the creation of a discipline based on the integration of other disciplinary knowledge into a new 'whole' (Morrison, 2006; Sanders, 2009). As STEM education removed the borders between the four disciplines, and integrate them into one discipline, it equipped students with the ability to integrate the world, and deal with it as one entity. In this regard, Tsupros, Kohler, & Hallinen (2009) described STEM education as:

*"interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy".*

Many countries (Lucas, Claxton & Hanson, 2014; National Research Council, NRC, 2014; Office of the Chief Scientist, 2014; Office of the US President, 2013) turned their focus towards Promoting STEM education in their institutions. Among those efforts, some direction and pillars had been put forward. For example, the following four pillars for STEM education had been specified by the Irish Minister for Education and Skills (2017):

- Pillar 1. Nurture learner engagement and participation
- Pillar 2. Enhance early year's practitioner and teacher capacity
- Pillar 3. Support STEM education practice
- Pillar 4. Use evidence to support STEM education

Each of those pillars is associated with Objectives and High-Level Actions (Richard Bruton T.D. Minister for Education and Skills (2017)). Three of these pillars (2, 3, & 4) concentrated on teacher abilities to teach multi-disciplinary curricula.

The integration of science, technology engineering and mathematics (STEM) attracted the interest of educator and policymakers from the early 1990s. It was first introduced in the United States as a solution to the educational reforms at that time to provide the society with highly qualified labors with complex technology and engineering skills to perform in the high-tech knowledge-based economy (Quang1 et al., 2015; Wang, Moore, Roehrig, & Park, 2011). In addition, integrating STEM into curricula has been an element of many recent curriculum reforms, such as the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), the Common Core State Standards for Mathematics (CCSSM) (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), and the NAE and NRC (2014).

The advancement of current and future economic and overall well-being, not only for advanced economies such as the United States (Rockland et al., 2010) but also for growing economies worldwide, was the driver behind the initiation of interdisciplinary STEM curriculum. For this advancement to occur, STEM professionals are highly needed. The United States, for example, aimed to increase the number of STEM professionals and highly trained workers by 17% between 2008 and 2018 (Langdon, McKittrick, Beede, Khan, & Doms, 2011). An increase in STEM professionals and highly trained workers may increase the percentage of students who are interested in pursuing studies in STEM (Rockland et al., 2010), which is decreasing in the United States, Western countries and more prosperous Asian nations (Thomas & Watters, 2015, p. 42). To increase students' interest in STEM by integrating engineering and technology concepts into science and mathematics curricula, many approaches, which incorporate engineering

design-based units into the STEM curriculum have been introduced. An example of project-based learning that was found to increase students' interest in STEM learning (Hernandez et al., 2013), and using engineering design curricula to engage students in solving authentic problems while collaborating with others to build, design, or conceptualize real solutions (Laboy-Rush, 2011), which has been adopted in the reform of K-12 curricula (Brown, Brown, Reardon, & Merrill, 2011). Integrated STEM curriculum and teaching will provide society with highly qualified scientists, technologists, engineers and mathematicians and hence may drive these societies to achieve economic prosperity. Therefore, it is important to train teachers to successfully design and effectively teach an integrated STEM curriculum (Harris & Felix, 2010; Rogers & Portsmore, 2004).

Saudi Arabia also launched an ambitious program focusing on STEM education. However, this program was introduced “without a clear description of its meaning, purpose and framework of application” (Madani, 2017). Despite the fact that STEM is believed to have a great impact on mathematics and science learning, it was not fully adopted in the development of science, mathematics, engineering and technology subjects, and hence, those reforms could not be considered as STEM integration or implementation. It should be noted that curricular reform in Saudi Arabia has been launched to enable the Kingdom of Saudi Arabian Educational system to cope with the most advanced educational reforms projects in the world. The Ministry of Education in Saudi Arabia launched new science and mathematics curricula which were distributed to school in the beginning of the academic year 2009. These the science and mathematics curricula were adapted from textbooks' series, produced by the American publishing company McGraw Hill (Al ghamdi & Al-salouli, 2013; Almazroa & Al-Shamrani, 2015). To cope with the most advance reforms around the globe, Saudi Arabia needs to launch an ambitious project to integrate science, technology, engineering, and mathematics in a unified multi-disciplinary curriculum that could enhance students learning and skills, which may, in turn, ensure sustainable development in the country.

Implementing integrated STEM into actual classrooms can be successful if science and mathematics educators place an emphasis on promoting positive attitudes toward STEM, which in turn increases the number of students who are interested in STEM courses and careers (Bettinger, 2010; Krapp & Prenzel, 2011; OECD, 2006). In this regard, Laboy-Rush (2011) asserted that the improvement of teachers' attitudes toward STEM integration will lead to success in the implementation of this type of integrated curricula into the classroom. The new integrated STEM curriculum should address the demands of twenty-first-century skills, which is necessary to keep students motivated as well as to increase students' motivation to engage in STEM (Angell et al., 2003; Atkinson and Mayo, 2010).

The major challenge facing educators in implementing this reform is developing the ability to teach an interdisciplinary curriculum. To address this challenge, studies have suggested that teachers' professional development (PD) should focus on both the skills involved in and attitudes toward interdisciplinary teaching (English, 2016; Marginson, Tytler, Freeman, & Roberts, 2013; NAE and NRC, 2014). This type of PD should not be provided as a short and fast training session; rather, it should be an extended and continuous program focusing on interdisciplinary STEM teaching (Lauer et al., 2014). However, Al Salami, Makela, and De-Miranda (2017) showed that short PD sessions may help in changing teachers' attitudes toward teaching Integrated STEM curriculum. The authors found a positive change in teachers' attitudes toward Integrated STEM teaching in their quasi-experimental and single group pretest-posttest design study, which was conducted with 29 self-selected middle and high school teachers participating in a 12- to 15-week PD opportunity focused on an interdisciplinary teaching and design problem unit that spanned multiple STEM subjects.

Additionally, integrated STEM curricula that use project-based design have been found to increase K-12 students' interest in STEM. To achieve this result, we must increase teacher's positive

perceptions and interest in teaching STEM curricula. Shifting teachers from teaching a specific domain to teaching interdisciplinary curricula represents a significant challenge. To improve teacher's interest in teaching STEM education, we must develop their skills for teaching this type of approach. We should also focus on the improvement of their attitudes toward such an interdisciplinary approach. This can be done through professional development (PD) that focuses on an interdisciplinary STEM curriculum that focuses on both skills and affective domains.

Attitude is one factor which may influence teachers' interest in teaching a specific subject in addition to students' academic achievement. The origin of the word 'attitude' came from French and then from the Latin word "aptitude"- "aptus" means (Fishbein & Ajzen, 1975) fit. Attitude may also be defined as a positive or negative evaluation of anything of one's surroundings or environments. Attitude comes from our beliefs, intention and action (Fishbein and Ajzen, 1975) and it is a psychological tendency which is expressed by appraising a particular entity with some degree of favor or disfavor (Eagly and Chaiken, 1993). Mensah et al. (2013) defined attitudes as: "Psychological orientations developed as a result of one's experiences which influences a person's view of situations, objects people and how to respond to them either positively or negatively or favorably or unfavorably" (p. 1). Koballa (1988) also defined attitude as "a feeling toward an object". Meanwhile, Eagly & Chaiken (1993), defined it as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (p. 1).

Silverman and Subramaniam (1999) indicated that there is a positive relationship between attitudes and beliefs. Jung (1921/71, p. 687) suggested that "attitude can be explicit and implicit that is consciousness and unconsciousness of our belief and behavior". Studies pointed out several components for the formation of attitude among students. Some of these components are; Emotional, Cognitive and Behavioral. In this study, the attitude scale has three major components, which are; Cognition, Affect, and Perceived Control. The first component "cognition" includes two themes; perceived relevance, and perceived difficulty, the second component "affect" includes also two themes, which are; anxiety, and enjoyment, while the third component "Perceived control" includes only one theme, which is "self-efficacy".

Several tools are used to measure teachers' and students' attitudes toward STEM-integrated curricula or courses. Among these tools is the STEM Semantics Survey (Tyler-Wood, Knezek, & Christensen, 2010), which is used to measure interest in each STEM subject as well as interest in STEM careers; this survey was developed by Knezek and Christensen (1998). Other examples of tool include the "Instrument for Teachers' Attitudes toward Teaching Integrated STEM", which was developed by the Research Institute for Work and Society (Thibaut, Knipprath, Dehaene, & Depaepe, 2018), under the title of "Development and Validation of An Instrument for Measuring Teachers' Attitudes toward Teaching Integrated STEM".

Although the formation of attitudes requires relatively long programs, however, long professional development programs for teachers are not currently available in the Kingdom of Saudi Arabia (KSA). The majority of the training and development programs that are carried out for science and mathematics teachers in KSA are too short and do not take more than one week. Our study is trying to fill this gap by investigating the effect of one of those short training programs, which was organized by and conducted by the educational district in Riyadh and focused on STEM education on science and math teacher's attitudes toward integrating STEM in teaching.

## 2. Purpose and research questions

The purpose of this study was to investigate the effectiveness of a 6-day PD program on science and mathematics teachers' attitudes toward teaching integrated STEM. To achieve this aim, the following research question was investigated:

Does the PD program improve science and mathematics teachers' attitudes toward teaching Integrated STEM?

### 3. Method

To achieve the goal of this study, the researchers used pre-post methodology (Fraenkel, Wallen, & Hyun, 2012) by employing an attitude scale designed by Thibaut et al. (2018). Although the formation of attitudes requires relatively long programs, however, long professional development programs for teachers are not currently available in the Kingdom of Saudi Arabia (KSA). The majority of the training and development programs for science and mathematics teachers in KSA are too short and do not take more than one week. As a result, the reason for conducting this study was to try to identify the impact of such short programs in some factors, which can impact science and mathematics teachers' professional development. Among those factors are teachers' attitudes in general and views about topics covered by professional development programs. No doubt that such trends and attitudes have an impact on teacher development, thus, they may improve science and mathematics teachers' teaching practices.

### 4. Participants

The participants include science and mathematics teachers from Riyadh City, SA (48 science and mathematics teachers, 21 males and 27 females), who were selected by the department of education in Riyadh district. The participants were attending a 6-day PD program on integrating STEM in the curriculum, entitled "Applying STEM in our classrooms". All 48 participating teachers were pretested prior to the start of the program, and 45 of the participants (21 males and 24 females) were post-tested immediately following the end of the program. Most of the participants had 6–10 years or more than 10 years of teaching experience. All the participants with fewer than 6 years of teaching experience were female.

### 5. Program specification

A 6-day professional development program was held from 12 to 17 January 2018 at King Saud University, KSA, in Riyadh. The program organizer focused the dialogue, content, and practical activities on a number of areas related to the theoretical and practical aspects of the integration and implementation of STEM lessons in the classroom. The program had three parts, each took 12 h within 2 days. This indicates that the whole period of the program added up to 6 days. It should be clear that we neither did nor design this program, but it was designed and organized by a specialist from the ministry of education, as part of the development programs. From our side, we design this study and selected the proper tool to examine the effect of such short (one shot) programs on teacher's attitudes on STEM education. Table 1 provides a detailed description of the development program.

### 6. Instrumentation

The primary data source was the "Instrument for Teachers' Attitudes Toward Teaching Integrated STEM", which was developed by Research Institute for Work and Society, HIVA (2017), under the title "Development and Validation of An Instrument for measuring Teachers' Attitudes toward Teaching Integrated STEM". This instrument includes 25 items that use a 5-point Likert scale to measure participants' attitudes toward teaching integrated STEM subjects. It covers three major domains: cognition, 10 items; affect, 10 items; and perceived control, 5 items. The first domain includes two subscales (perceived relevance, 5 items, and perceived difficulty, 5 items), the second domain includes two subscales (anxiety, 5 items, and enjoyment, 5 items), and the third domain includes one subscale (self-efficacy, 5 items).

Each of the developed instruments' subscales is also associated with one of five different subcomponents according to the order listed above: Integration of STEM content (int), Problem-centered learning (pcl), Inquiry-based learning (inq), Design-based learning (des) and Cooperative learning (co). The instrument, which was originally prepared in English, was translated into Arabic

**Table 1. Professional development program on integrating STEM for science and mathematics teachers (Riyadh Educational District, 2018)**

<b>Program title (topic)</b>	Implementation of STEM in our classrooms
<b>Duration of the program</b>	6 days
<b>Program goals</b>	<p><b>General goal</b> Informing practitioners of the theoretical and practical aspects of the implementation of STEM lessons in the classroom</p> <p><b>Specific goals</b></p> <ul style="list-style-type: none"> <li>• Strengthening teachers' knowledge of the following concepts: STEM education, teaching for conceptual understanding of scientific discourse, scientific inquiry, and discrepant phenomena in science and mathematics education.</li> <li>• Strengthening science and mathematics teachers' practices for teaching the subject "heat transfer" through engineering design.</li> <li>• Building an understanding that could contribute to other science and mathematics subjects taught according to the STEM approach.</li> </ul>
<b>The targeted groups</b>	<ul style="list-style-type: none"> <li>• Science and mathematics education practitioners and associates (teachers and supervisors, superintendents and teachers).</li> <li>• Researchers in the field of science and mathematics curriculum and teaching methods.</li> </ul>
<b>Program details</b>	<p><b>First part: dialogue (2 days, 12 hours)</b></p> <ul style="list-style-type: none"> <li>• Presentation of common experiences in teaching science and mathematics where scientific concepts do not necessarily appear.</li> <li>• The concept of STEM education.</li> <li>• The general framework for the implementation of STEM in our classrooms.</li> <li>• Engineering design in science and mathematics classrooms: teaching the science and mathematics of heat transfer through engineering design.</li> <li>• First day ends with describing the following concepts: scientific inquiry, discrepant phenomena in teaching science and mathematics, teaching for conceptual understanding and scientific discourse.</li> </ul> <p><b>Second part: content (2 days, 12 hours)</b></p> <ul style="list-style-type: none"> <li>• Discussion of the concepts related to scientific inquiry, teaching for conceptual understanding, scientific discourse, contradictory phenomena in science and mathematics teaching, and how they would observe science and mathematics classes.</li> <li>• Presentation of the concepts of convection and radiation.</li> <li>• Demonstration of the reverse radiation of light.</li> <li>• Provide a challenge for participants in building a dwelling that keeps penguins from melting.</li> <li>• Testing of different materials.</li> <li>• Building dwellings.</li> <li>• Testing the design.</li> </ul> <p><b>Third part: practices (2 days, 12 hours)</b></p> <ul style="list-style-type: none"> <li>• Redesign.</li> <li>• Reframing the points learned from the demos and engineering activities to reach the bottom line about the following: what STEM lessons need, what framework I will use to support learning science and mathematics.</li> <li>• Presentation of supportive sources for researchers and teachers dealing with the derivation of an engineering problem associated with the targeted unit and the teaching of STEM.</li> </ul>

because the participating teachers' mother language is the Arabic language. To ensure the validity of this instrument, the translated version was then translated back into English by a translator who did not read or look at the original copy. Then, some experts in science and math education reviewed the instrument to ensure that it was understandable.

**Table 2. Means, standard deviations, and t-tests of the differences in perceived difficulties of Integrated STEM teaching between the pre- and posttest administrations with science and mathematics teachers**

Learning environments for integrated STEM	Item	test	N	Mean	Std. deviation	t	df	Sig
Integration of STEM content	I think math teachers find it difficult to align contents of science & math.	Pre	35	4.17	.664	1.779	73	.079
		Post	40	3.75	1.256			
Problem-centered learning	I think teachers find it difficult to use complex tasks with multiple solutions.	Pre	35	4.29	.572	2.582	73	.012
		Post	40	3.75	1.104			
Inquiry-based learning	I think teachers find it hard to teach a class in which students execute experiments.	Pre	36	3.81	.786	2.484	74	.015
		Post	40	3.23	1.187			
Design-based learning	I think teachers find it hard to teach a class in which students are involved in design.	Pre	36	4.17	.737	2.991	74	.004
		Post	40	3.48	1.198			
Cooperative learning	I think teachers find it hard to ensure that all students are actively involved in group work.	Pre	37	3.78	1.004	.809	75	.421
		Post	40	3.58	1.238			

**Table 3. Means, standard deviations, and t-tests of the differences in the perceived relevance of Integrated STEM teaching between the pre- and posttest administrations with science and mathematics teachers**

Learning environments for integrated STEM	Item	test	N	Mean	Std. dev.	t	df	Sig
Integration of STEM content	Linking technological, mathematical & scientific concepts increases students' understanding.	Pre	36	4.72	.513	-.419-	74	.676
		Post	40	4.78	.577			
Problem-centered learning	Involving students in real-life challenges gives them a better understanding of the relevance of STEM.	Pre	37	4.70	.520	.404	74	.687
		Post	39	4.64	.778			
Inquiry-based learning	Students gain insight by doing experiments.	Pre	37	4.73	.450	-.149-	75	.882
		Post	40	4.75	.707			
Design-based learning	Designing helps students to develop their reasoning skills.	Pre	37	4.59	.498	-.560-	75	.577
		Post	40	4.68	.730			
Cooperative learning	Students acquire social skills by working in groups.	Pre	37	4.76	.435	1.001	74	.320
		Post	39	4.62	.747			

## 7. Results

This section includes the presentation, discussion and interpretation of the results for the five themes in the attitude scale. Each theme is presented in a separate table; hence, the results for each theme are presented, interpreted, and discussed separately. The following sections present the results for each theme relating to teachers' attitudes toward teaching integrated STEM curriculum. It should be noted that some of the participants did not respond to some of the items, which interprets the difference in sample numbers in the results' tables.

### 7.1. Theme 1: Perceived difficulty

This theme includes five items, each of which belongs to one component of Learning Environments for Integrated STEM. Table 2 includes the means, standard deviations, and t-tests of the differences between the pre- and posttest responses from the science and mathematics teachers. Significant differences between the pre- and posttest administrations were observed for three items: the item associated with the problem-solving component, the item related to inquiry-based learning, and the item associated with design-based learning. All the differences were in favor of the pretest, indicating that the teachers' perceptions of difficulties regarding these elements decreased due to their participation in the 6-day professional development program.

### 7.2. Theme 2: Perceived relevance

As was the case with the first theme, the theme of perceived relevance includes also five items. However, no significant differences were found between the pretest that was administered before the PD program and the posttest that was administered after the PD program for any of the items in this theme. This result (Table 3) indicates that the participants' views on the perceived relevance of Integrated STEM teaching did not change due to their participation in the PD training program.

### 7.3. Theme 3: Anxiety

The data in Table 4, which are related to theme 3, show that the scores for the pretest administration are higher than the scores for the posttest, but these differences are not significant. This result means that no differences were found between the pre- and posttest administration of the questionnaire for the theme of teachers' anxiety about Integrated STEM teaching. We can deduce that the 6-day program had no impact on teachers' anxiety about Integrated STEM teaching.

### 7.4. Theme 4: Enjoyment

Theme 4, which focuses on teachers' enjoyment of Integrated STEM teaching, also includes five items. The data in Table 5 indicate that there were no significant differences between the pre- and posttest for any of the items associated with the enjoyment of teaching Integrated STEM subjects or curricula. This result indicates that the participants' views regarding their enjoyment of teaching Integrated STEM curriculum did not change due to their participation in the PD training program.

### 7.5. Theme 5: Self-efficacy

Theme 5 includes five items that are associated with self-efficacy in Integrated STEM teaching. Table 6 includes the means, standard deviations, and t-tests of the differences between the pre- and posttest administrations with science and mathematics teachers. Significant differences between the pre- and posttest were observed for three items: the item associated with inquiry-based learning, the item related to design-based learning, and the item associated with cooperative learning. All the differences were in favor of the posttest, indicating that **self-efficacy** in integrated STEM teaching increased slightly following participation in the 6-day professional development program.

## 8. Discussion

The result of the first part indicating that the teachers' felt that the perceived difficulties decreased due to their participation in the 6-day professional development program. The reason behind this result may be due to teacher's lack of a clear conception of STEM before the training program.

**Table 4. Means, standard deviations, and t-tests of the differences in anxiety about Integrated STEM teaching between the pre- and posttest administrations with science and mathematics teachers**

Learning environments for integrated STEM	Item	Test	N	Mean	Std. dev.	T	df	Sig																																															
Integration of STEM content	I find it stressful to align the content of my course with that of other STEM courses.	Pre	37	3.35	1.111	.856	75	.395																																															
		Post	40	3.13	1.202				Problem-centered learning	I find it stressful to use complex tasks with multiple solutions.	Pre	37	3.57	1.168	1.386	75	.170	Post	40	3.23	1.000	Inquiry-based learning	I find it stressful to teach a class in which students execute experiments.	Pre	37	3.11	1.265	1.533	75	.129	Post	40	2.65	1.350	Design-based learning	I find it stressful to teach a class in which students are involved in design.	Pre	37	3.24	1.164	1.767	75	.081	Post	40	2.75	1.276	Cooperative learning	I find it stressful to ensure that all students are actively involved in group work.	Pre	36	3.47	1.320	1.075	74
Problem-centered learning	I find it stressful to use complex tasks with multiple solutions.	Pre	37	3.57	1.168	1.386	75	.170																																															
		Post	40	3.23	1.000				Inquiry-based learning	I find it stressful to teach a class in which students execute experiments.	Pre	37	3.11	1.265	1.533	75	.129	Post	40	2.65	1.350	Design-based learning	I find it stressful to teach a class in which students are involved in design.	Pre	37	3.24	1.164	1.767	75	.081	Post	40	2.75	1.276	Cooperative learning	I find it stressful to ensure that all students are actively involved in group work.	Pre	36	3.47	1.320	1.075	74	.286	Post	40	3.15	1.292								
Inquiry-based learning	I find it stressful to teach a class in which students execute experiments.	Pre	37	3.11	1.265	1.533	75	.129																																															
		Post	40	2.65	1.350				Design-based learning	I find it stressful to teach a class in which students are involved in design.	Pre	37	3.24	1.164	1.767	75	.081	Post	40	2.75	1.276	Cooperative learning	I find it stressful to ensure that all students are actively involved in group work.	Pre	36	3.47	1.320	1.075	74	.286	Post	40	3.15	1.292																					
Design-based learning	I find it stressful to teach a class in which students are involved in design.	Pre	37	3.24	1.164	1.767	75	.081																																															
		Post	40	2.75	1.276				Cooperative learning	I find it stressful to ensure that all students are actively involved in group work.	Pre	36	3.47	1.320	1.075	74	.286	Post	40	3.15	1.292																																		
Cooperative learning	I find it stressful to ensure that all students are actively involved in group work.	Pre	36	3.47	1.320	1.075	74	.286																																															
		Post	40	3.15	1.292																																																		

**Table 5. Means, standard deviations, and t-tests of the differences in the enjoyment of integrated STEM teaching between the pre- and posttest administrations with science and mathematics teachers**

Learning environments for integrated STEM	Item	test	N	Mean	Std. dev.	T	Df	Sig																																															
Integration of STEM content	I like aligning the content of my course with that of other STEM courses.	Pre	36	4.47	.654	.494	74	.623																																															
		Post	40	4.38	1.005				Problem-centered learning	I like using complex tasks with multiple solutions	Pre	37	3.92	1.064	.068	75	.946	Post	40	3.90	1.355	Inquiry-based learning	I like teaching a class in which students execute experiments.	Pre	37	4.59	.551	-.429-	75	.669	Post	40	4.65	.580	Design-based learning	I like teaching a class in which students are involved in design.	Pre	37	4.59	.644	-.766-	75	.446	Post	40	4.70	.564	Cooperative learning	I like ensuring that all students are actively involved in group work.	Pre	35	4.54	.701	-.750-	73
Problem-centered learning	I like using complex tasks with multiple solutions	Pre	37	3.92	1.064	.068	75	.946																																															
		Post	40	3.90	1.355				Inquiry-based learning	I like teaching a class in which students execute experiments.	Pre	37	4.59	.551	-.429-	75	.669	Post	40	4.65	.580	Design-based learning	I like teaching a class in which students are involved in design.	Pre	37	4.59	.644	-.766-	75	.446	Post	40	4.70	.564	Cooperative learning	I like ensuring that all students are actively involved in group work.	Pre	35	4.54	.701	-.750-	73	.455	Post	40	4.65	.533								
Inquiry-based learning	I like teaching a class in which students execute experiments.	Pre	37	4.59	.551	-.429-	75	.669																																															
		Post	40	4.65	.580				Design-based learning	I like teaching a class in which students are involved in design.	Pre	37	4.59	.644	-.766-	75	.446	Post	40	4.70	.564	Cooperative learning	I like ensuring that all students are actively involved in group work.	Pre	35	4.54	.701	-.750-	73	.455	Post	40	4.65	.533																					
Design-based learning	I like teaching a class in which students are involved in design.	Pre	37	4.59	.644	-.766-	75	.446																																															
		Post	40	4.70	.564				Cooperative learning	I like ensuring that all students are actively involved in group work.	Pre	35	4.54	.701	-.750-	73	.455	Post	40	4.65	.533																																		
Cooperative learning	I like ensuring that all students are actively involved in group work.	Pre	35	4.54	.701	-.750-	73	.455																																															
		Post	40	4.65	.533																																																		

**Table 6. Means, standard deviations, and t-tests of the differences in self-efficacy in Integrated STEM teaching between the pre- and posttest administrations with science and mathematics teachers**

Learning environments for integrated STEM	Item	test	N	Mean	Std. dev.	T	df	Sig
Integration of STEM content	I feel capable of aligning the content of my course with that of other STEM courses.	Pre	36	3.92	.806	1.436-	73	.155
		Post	39	4.21	.923			
Problem-centered learning	I feel capable of using complex tasks with multiple solutions.	Pre	37	3.84	.866	1.296-	74	.199
		Post	39	4.10	.912			
Inquiry-based learning	I feel capable of teaching a lesson in which students execute experiments.	Pre	37	4.30	.661	2.103-	74	.039
		Post	39	4.59	.549			
Design-based learning	I feel capable of teaching a class in which students are involved in design.	Pre	37	3.97	.897	2.270-	74	.026
		Post	39	4.38	.673			
Cooperative learning	I feel capable of ensuring that all students are actively involved in group work.	Pre	37	3.92	.759	2.101-	73	.039
		Post	38	4.29	.768			

Therefore, their choices in pre-testing were inaccurate, but after having a clear conception of STEM education, particularly, the strategies (problem-solving and inquiry). As a result, teachers find it difficult to implement this approach in teaching, especially in light of their knowledge of the schools' situation and the lack of the necessary means to implement STEM, in addition to the increased number of students in the lab.

The results indicated that there were no statistically significant differences related to perceived difficulty among participating teachers due to the development program. This could be happened due to the short period for the implementation of the PD program. This may also indicate that the teachers had a clear picture of STEM, but they found it as difficult to apply. This interpretation is clarified by Scott and Martin (2013) study, which have pointed out that teachers hold beliefs that using the Steam input is not easy. Scott and Martin (2013) added that teachers perceive STEM subjects as being more difficult than separate, non-STEM subjects and think that students may achieve better results in non-STEM subjects. This perception regarding the difficulties of STEM subjects causes teachers to believe that students may have more success in non-STEM subjects. However, these challenges or difficulties could be eased by having teachers engage in intentional CPD programs that concentrate on teaching Integrated STEM fields. Even though this training program was short, the teachers appeared to perceive fewer difficulties after participating in the program.

Result related to the second part "Perceived relevance" proved that the participants' views on the perceived relevance of Integrated STEM teaching did not change due to their participation in the PD training program. Scott and Martin (2013, P. 14) argued that "the perceptions of challenges in pursuing STEM studies can lead to disengagement and lowered expectations, despite actual aptitude and potential". In this study, the teachers' perceptions of STEM relevance were not low for the pretest or the posttest: the mean ranges were between 4.59 and 4.76 for the pretest administration of the attitude scale and between 4.62 and 4.78 for the posttest administration; these values are considered high according to our ratings.

Other research studies (Osborne, Simon & Collins, 2003; Russell & Hollander, 1975; Shrigley, Koballa & Simpson, 1988) have shown also that there is a positive correlation between teachers' attitudes toward science and their personal effectiveness in the classroom as well as their choice of effective teaching strategies. Therefore, teachers may perform better when teaching STEM-related curricula if they perceive these curricula to be relevant to them and to society.

From the overview of the result of this theme; it is noted that the mean scores for pre and post-testing are relatively high. This result could be due to the generality of these terms (items), which are related to the integration of teaching courses in general. For example, by looking at the result for the first item (*Linking technological, mathematical & scientific concepts increases students' understanding*), we can find that the teachers may be convinced about it, either before or after the program, because it is not specific to science or math courses. However, the problem was found in linking the shapes with each other, and in the ability of teachers themselves to link the concepts together as it happened with the first theme, where teachers felt that there is difficulty in performing adjustments in their courses to fit with other STEM components.

Regarding the third part "anxiety" the result indicated that the 6-day program had no impact on teachers' anxiety about Integrated STEM teaching. The reason for this result could be that short PD sessions have little or no effect on teachers' attitudes toward teaching Integrated STEM curriculum, especially their anxiety regarding the approach to teaching STEM.

As indicated in theme 1, teachers perceive difficulties associated with teaching Integrated STEM curriculum because they are anxious that students may experience lower achievement in Integrated STEM subjects than in traditional or non-integrated subjects (Scott & Martin, 2013).

They think that the challenges that students face in achieving success in STEM subjects may arise from internal and external barriers to STEM education. Studies (CaSE, 2014; Dearing & King, 2006; Myers, 2006; Smith, 2011) have indicated that there is a perceived concern among teachers that students may prefer non-STEM fields or subjects because they view those subjects as being less difficult than Integrated STEM subjects. In terms of the teachers' perceived difficulties, the teachers' anxiety about teaching integrated STEM subjects appeared to be lower after the 6-day STEM program, which indicates that any type of intentional CPD program could be effective in mitigating teachers' anxiety about teaching integrated STEM subjects.

Regarding the fourth part "enjoyment", the result indicates that the participants' views regarding their enjoyment of teaching Integrated STEM curriculum did not change due to their participation in the PD training program. The reason for this result could be associated with the short period of the professional development training program; it is possible that a 6-day PD session may not be sufficient to make the desired change in teachers' enjoyment of Integrated STEM teaching. As indicated by this theme, teachers may perform better when teaching STEM-related curricula if they enjoy working in STEM subjects or curricula and in the STEM environment. In addition, Derri, Vasiliadou, and Kioumourtzoglou (2015) proved that short-term training programs have a noticeable effect on teacher behavior and student engagement in learning. Those results are contradicting our result for this theme, which indicated that short training programs have no impact on teachers' enjoyment in the subject of training. On the other hand, Benfield et al. (2001) indicated that long-term CPD was very effective in performance/behavior (impact on practice); learning (improved knowledge of participants); reaction (e.g., from an end of course evaluation); and participation (attendance).

Results for the fifth part "self-efficacy" showed that the short PD program had slightly improved science and math teacher's self-efficacy in their ability to deal with integrated STEM teaching. In line with the result of our study, Weißenrieder, Roesken-Winter, Schueler, Binner, and Blömeke (2015) study showed different developments within the two specific CPD courses, with one course featuring a significant development. They found that developments differ with respect to the duration of the CPD course.

## 9. Conclusion and implications

The result of this study indicated that no perceived impact was found on science and math teachers' perceptions of the relevance of or their anxiety about or enjoyment of Integrated STEM teaching due to their participation in the 6-day PD program. This means that the PD program did not contribute to improving science and mathematics teachers' attitudes toward teaching Integrated STEM curriculum. This could have resulted from the period of the PD program being too short. On the other hand, science and mathematics teachers' perceptions of difficulties decreased due to their participation in the professional development program on integrated STEM. In addition, the teachers' self-efficacy improved following their participation in the STEM professional development (PD) program. We could conclude that short PD programs may have an impact on teacher's perceived difficulty of STEM education and could improve their self-efficacy. Although the formation of attitudes requires relatively long programs, however, such long professional development programs for teachers are not currently available in KSA. The majority of the training and development programs for science and math teachers in KSA are too short and do not take more than one week. Our point from this study was to try to identify the impact of pre-designed and organized short or one-shot program in some factors, which can impact science and mathematics teacher's professional development. Among those factors are teachers' attitudes about topics covered by professional development programs. No doubt that attitude has an impact on teacher behavior and development, as they may improve science and mathematics teachers' teaching practice.

Following are some implications that can be drawn from the present study:

- Engaging teachers in integrated STEM professional development may improve their attitudes toward and increase their interest in teaching this approach.
- Students will be able to transfer the knowledge and skills they learn in the STEM context into action and hence will be able to solve the problems facing them.
- There is a greater demand to change teachers' skills and attitudes through preparation programs to encourage them to be more attentive and responsive to fast-changing education trends, including the current focus on teaching interdisciplinary subjects.

Based on the results of the study, we offer the following recommendations:

- Future PD programs should focus on training science and mathematics teachers who specialize in all fields of science and mathematics to teach integrated STEM subjects.
- These PD programs should be continuous throughout the year rather than brief sessions, as brief sessions proved to be less effective in changing teachers' attitudes toward teaching integrated STEM curriculum.
- These PD programs should be held in schools so that all science and mathematics teachers, rather than a limited number of teachers, can participate in the programs.

#### Acknowledgements

This research project was supported by the Excellent Research Center of Science and Mathematics Education, Deanship of Scientific Research at King Saud University.

#### Funding

This work was supported by the Excellent Research Center of Science and Mathematics Education, Deanship of Scientific Research at King Saud University.

#### Author details

Abdulwali H. Aldahmash<sup>1</sup>  
E-mail: [aaldahmash@ksu.edu.sa](mailto:aaldahmash@ksu.edu.sa)  
Naem, M. Alamri<sup>2</sup>  
E-mail: [naamry@ksu.edu.sa](mailto:naamry@ksu.edu.sa)  
Mohammed A. Aljallal<sup>3</sup>  
E-mail: [m.aljallal@hotmail.co](mailto:m.aljallal@hotmail.co)

<sup>1</sup> Chemical education, The Excellent Center for Science and Mathematics Education, King Saud University, P.O. Box 2458, Riyadh, Saudi Arabia.

<sup>2</sup> Math education, King Saud University, curriculum and instruction dept. College of education, and Excellent Center for Science and Mathematics Education, King Saud University, P. O. Box 2458, Riyadh 11451, Saudi Arabia.

<sup>3</sup> Educational Administration, The Ministry of Education, Riyadh, Saudi Arabia.

#### Citation information

Cite this article as: Saudi Arabian science and mathematics teachers' attitudes toward integrating STEM in teaching before and after participating in a professional development program, Abdulwali H. Aldahmash, Naem, M. Alamri & Mohammed A. Aljallal, *Cogent Education* (2019), 6: 1580852.

#### References

Al Ghamdi, A. H., & Al-Salouli, M. S. (2013). Saudi elementary school science teachers' beliefs: Teaching science in the new millennium. *International Journal of Science & Mathematics Education*, 11(2), 501-525.

Al Salami, M. K., Makela, C. J., & De-Miranda, M. A. (2017). Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching. *International Journal*

*of Technology and Design Education*, 27(1), 63-88.  
doi:10.1007/s10798-015-9341-0

Almazroa, H., & Alshamrani, S. (2015). Saudi science teacher professional development: Trends, practices, and future directions. In N. Mansour and S. Alshamrani (Eds.), *Science education in the Arab Gulf States: Visions, sociocultural contexts, and challenges*. Rotterdam: Sense Publishers.

Angell, K. L., Kreshka, M. A., McCoy, R., Donnelly, P., TurnerCobb, J. M., Graddy, K., Kraemer, H. C., & Koopman, C. (2003). Psychosocial intervention for rural women with breast cancer. *Journal of General Internal Medicine*, 18, 499-507.

Atkinson, R. D., & Mayo, M. (2010). "Refueling the U.S. innovation economy: Fresh approaches to science, technology, engineering and mathematics (STEM) education," The Information Technology & Innovation Foundation, December 2010.

Belfield, C. R., Morris, Z. S., Bullock, A. D., & Frame, J. W. (2001). The benefits and costs of continuing professional development (CPD) for general dental practice: A discussion. *European Journal of Dental Education*, 5, 47-52.

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education*, 26(1), 61-79.  
doi:10.1007/s10798-015-9300-9

Bettinger, E. (2010). To be or not to be: Major choices in budding scientists. In C. T. Clotfelter (Ed.), *American universities in a global market* (pp. 69-98). Chicago: University of Chicago Press.

Brown, R., Brown, J., Reardon, K., & Merrill, C. (2011). Understanding STEM: Current perceptions. *Technology and Engineering Teacher*, 70(6), 5-9.

CaSE. (2014). *Improving diversity in STEM*. London, UK: Campaign for Science and Engineering.

Dearing, R., & King, L. (2006). *Languages review*. Nottingham, UK: Department for Education and Skills. Retrieved from <http://dera.ioe.ac.uk/7613/1/LanguageReview.pdf>

Derri, V., Vasiliadou, O., & Kioumourtzoglou, E. (2015). The effects of a short-term professional development program on physical education teachers' behavior

- and students' engagement in learning. *European Journal of Teacher Education*, 38(2), 234–262. doi:10.1080/02619768.2014.947024
- Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX: Harcourt Brace Jovanovich.
- Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Orlando, FL, US: Harcourt Brace Jovanovich College Publishers.
- Ellis, A., & Fouts, J. (2001). Interdisciplinary curriculum: The research base. *Music Educators Journal*, 86(6), 22–26.
- English, L. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education*, 3(3), 1–8. doi:10.1186/s40594-016-0036-1
- Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). New York, NY: McGraw-Hill Higher Education.
- Furner, J. M., & Kumar, D. D. (2007). The mathematics and science integration argument: A stand for teacher education. *Eurasia Journal of Mathematics, Science and Technology Education*, 3(3), 185–189.
- Harris, J., & Felix, A. (2010). A project-based, STEM-integrated team challenge for elementary and middle school teachers in alternative energy. Retrieved from [saintfrancisuniversity.edu](http://saintfrancisuniversity.edu), October 9th, 2010.
- Hernandez, P. R., Bodin, R., Elliott, J. W., Ibrahim, B., Rambo-Hernandez, K. E., Chen, T. W., & de Miranda, M. A. (2013). Connecting the STEM dots: Measuring the effect of an integrated engineering design intervention. *International Journal of Technology and Design Education*, 24(1), 107–120. doi:10.1007/s10798-013-9241-0
- Hu, H., & Garimella, U. (2015). Beginner robotics for STEM: Positive effects on middle school teachers. In D. Rutledge & D. Slykhuus (Eds.), *Proceedings of SITE 2015–Society for Information Technology & Teacher Education International Conference* (pp. 3227–3234). Las Vegas, NV: Association for the Advancement of Computing in Education (AACE). Retrieved from <https://www.learntechlib.org/p/150537/>
- Jung, Carl G. (1921/71). *Collected Works*, Volume 6: *Psychological Types*. Princeton, NJ: Princeton University Press.
- Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, 25(3), 246–258.
- King, K. P., & Wiseman, D. L. (2001). Comparing science efficacy beliefs of elementary education majors in integrated and non-integrated teacher education coursework. *Journal of Science Teacher Education*, 12(2), 143–153.
- Knezek, G., & Christensen, R. (1998). Internal consistency reliability for the teachers' attitudes toward information technology (TAT) questionnaire. In S. McNeil, J. Price, S. Boger-Mehall, B. Robin, & J. Willis (Eds.), *Proceedings of the Society for Information Technology in Teacher Education Annual Conference* (pp. 831–836). Bethesda, MD: Society for Information Technology in Teacher Education.
- Koballa, T. R. (1988). Attitude and related concepts in science education. *Science Education*, 72(2), 115–126.
- Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, 33, 27–50. doi:10.1080/09500693.2010.518645
- Laboy-Rush, D. (2011). Whitepaper: integrated STEM education through project-based learning. Retrieved from <http://www.learning.com/stem/whitepaper/>
- Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future. ESA issue brief #03-11*. Washington, DC: Department of Commerce, Economics and Statistics Administration.
- Lauer, P. A., Christopher, D. E., Firpo-Triplett, R., & Buchting, F. (2014). The impact of short-term professional development on participant outcomes: A review of the literature. *Professional Development in Education*, 40(2), 207–227. doi:10.1080/19415257.2013.776619
- Lead States, N. G. S. S. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.
- Lucas, B., Claxton, G. & Hanson, J. (2014). *Thinking like an engineer: Implications for the education system*. A Report for the Royal Academy of Engineering Standing Committee for Education and Training. Royal Academy of Engineers, UK.
- Madani, F. R. (2017). *Teacher Perceptions of the New Mathematics and Science Curriculum: A Step Towards STEM Implementation in Saudi Arabia*. Dissertation, The British University in Dubai
- Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons*. Melbourne: Australian Council of Learned Academies.
- Mensah, J., Okyere, M., & Kuranchie, A. (2013). Student attitude towards mathematics and performance: Does the teacher attitude matter? *Journal of Education and Practice*, 4(3), 132–139.
- Morrison, J., & Bartlett, B. (2009). *STEM as a curriculum: An experimental approach*. Retrieved from <http://www.lab-aids.com/docs/stem/EdWeekArticleSTEM.pdf>
- Morrison, J. S. (2006). *Attributes of STEM education. TIES STEM education monograph series*. Baltimore, MD: Teaching Institute for Essential Science.
- Myers, H. (2006). *The “severe grading” of MFL grades at GCSE and A level*. London, UK: Association for Language Learning.
- National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for mathematics*. Washington, DC: Authors.
- National Research Council, NRC. (2014). *The growth of incarceration in the United States: Exploring causes and consequences*. Washington, DC: The National Academies Press. doi:10.17226/18613
- OECD. (2006). *Evolution of student interest in science and technology studies policy report*. Paris: Author.
- Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049–1079. doi: 10.1080/0950069032000032199
- Quang, D., Chen, Y., & Xie, X. (2015). Dann: A deep learning approach for annotating the pathogenicity of genetic variants. *Bioinformatics*, 31(5), 761–763.
- Riyadh Educational District. (2018). *Professional development program on integrating STEM for science and mathematics teachers*. Riyadh, Saudi Arabia: King Saud University.
- Robinson, N. (2016). *A Case Study Exploring the Effects of Using an Integrative STEM Curriculum on Eighth Grade Students' Performance and Engagement in the Mathematics Classroom*. Dissertation, Georgia State University
- Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the “E” in K-12 STEM education. *Journal of Technology Studies*, 36(1), 53–64.

- Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education*, 5(3), 17–28.
- Russell, J., & Hollander, S. (1975). A biology attitude scale. *The American Biology Teacher*, 37(5), 270-273.
- Sanders, M. (2009). STEM, STEM education, STEM mania. *The Technology Teacher*, 68(4), 20–26.
- Scott, A., & Martin, A., (2013). Perceived barriers to higher education in STEM among high-achieving underrepresented high school students of color. The American Educational Research Association annual conference in San Francisco, April 27-31, 2013.
- Shrigley, R. L., Koballa, T. R., & Simpson, R. D. (1988). Defining attitudes for science. *Journal of Research in Science Teaching*, 25(8), 659-678.
- Silverman, S., & Subramaniam, P. R. (1999). Student attitude toward physical education and physical activity: A review of measurement issues and outcomes. *Journal of Teaching in Physical Education*, 19, 97–125. doi:10.1123/jtpe.19.1.97
- Smith, E. (2011). Staying in the science stream: Patterns of participation in A-level science subjects in the UK. *Education Studies*, 37, 59–71. doi:10.1080/03055691003729161
- Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research*, 2(1), 28–34. doi:10.5703/1288284314653
- Thibaut, L., Knipprath, H., Dehaene, W., & Depaep, F. (2018). How school context and personal factors relate to teachers' attitudes toward teaching integrated STEM. *International Journal of Technology and Design Education*, 28, 631–651.
- Thomas, B., & Watters, J. (2015). Perspectives on Australian, Indian and Malaysian approaches to STEM education. *International Journal of Educational Development*, 45, 42–53. doi:10.1016/j.ijedudev.2015.08.002
- Tsupros, N., R. Kohler, and J. Hallinen, (2009). *STEM education: A project to identify the missing components*, Intermediate Unit 1 and Carnegie Mellon, Pennsylvania.
- Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for assessing interest in STEM content and careers. *Journal of Technology and Teacher Education*, 18(2), 345-368.
- Vernengo, J., Farrell, S., Kadlowec, J., & Strobel, J. (2014). Enhancing the STEM curriculum through a multidisciplinary approach that integrates biology and engineering. American Society of Engineering Education (ASEE) Annual Conference & Exposition, Indianapolis, IN, 14
- Voogt, J., & Roblin, N. P. (2010). Discussion paper: 21st century skills. [http://www.kennisnet.nl/uploads/tx\\_kncontentelements/21st-Century-Skills.pdf](http://www.kennisnet.nl/uploads/tx_kncontentelements/21st-Century-Skills.pdf). Accessed April 25, 2015.
- Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, 1(2), 1–13. doi:10.5703/1288284314636
- Weißrieder, J., Roesken-Winter, B., Schueler, S., Binner, E., & Blömeke, S. (2015). Scaling CPD through professional learning communities: Development of teachers' self-efficacy in relation to collaboration. *ZDM*, 1(47), 27–38. doi:10.1007/s11858-015-0673-8

## Appendices

*Appendix A: Instrument for Measuring Teachers' Attitudes toward Teaching Integrated STEM* (Thibaut et al., 2018)

This scale is designed to know the effect of Participation in a Professional Development Program on your attitude toward teaching integrating STEM before and after the program. We are confident that your careful completion of this scale will definitely contribute to obtaining more reliable data. We assure you that the information will be kept confidential and will be used just for research purposes.

Thank you very much in advance for your time and cooperation.

Learning environments for integrated STEM	Item	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Theme 1: Perceived difficulty						
Integration of STEM content	I think math teachers find it difficult to align contents of science & math.					
Problem-centered learning	I think teachers find it difficult to use complex tasks with multiple solutions.					
Inquiry-based learning	I think teachers find it hard to teach a class in which students execute experiments.					
Design-based learning	I think teachers find it hard to teach a class in which students are involved in design.					
Cooperative learning	I think teachers find it hard to ensure that all students are actively involved in group work.					
Theme 2: Perceived relevance						
Integration of STEM content	Linking technological, mathematical & scientific concepts increases students' understanding.					
Problem-centered learning	Involving students in real-life challenges gives them a better understanding of the relevance of STEM.					
Inquiry-based learning	Students gain insight by doing experiments.					
Design-based learning	Designing helps students to develop their reasoning skills.					
Cooperative learning	Students acquire social skills by working in groups.					
Theme 3: Anxiety						
Integration of STEM content	I find it stressful to align the content of my course with that of other STEM courses.					
Problem-centered learning	I find it stressful to use complex tasks with multiple solutions.					
Inquiry-based learning	I find it stressful to teach a class in which students execute experiments.					
Design-based learning	I find it stressful to teach a class in which students are involved in design.					
Cooperative learning	I find it stressful to ensure that all students are actively involved in group work.					

(Continued)

<b>(Continued)</b>						
<b>Learning environments for integrated STEM</b>	<b>Item</b>	<b>Strongly agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>Strongly disagree</b>
<b>Theme 4: Enjoyment</b>						
Integration of STEM content	I like aligning the content of my course with that of other STEM courses.					
Problem-centered learning	I like using complex tasks with multiple solutions.					
Inquiry-based learning	I like teaching a class in which students execute experiments.					
Design-based learning	I like teaching a class in which students are involved in design.					
Cooperative learning	I like ensuring that all students are actively involved in group work.					
<b>Theme 5: Self-efficacy</b>						
Integration of STEM content	I feel capable of aligning the content of my course with that of other STEM courses.					
Problem-centered learning	I feel capable of using complex tasks with multiple solutions.					
Inquiry-based learning	I feel capable of teaching a lesson in which students execute experiments.					
Design-based learning	I feel capable of teaching a class in which students are involved in design.					
Cooperative learning	I feel capable of ensuring that all students are actively involved in group work.					



© 2019 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format.

Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

***Cogent Education* (ISSN: 2331-186X) is published by Cogent OA, part of Taylor & Francis Group.**

**Publishing with Cogent OA ensures:**

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

**Submit your manuscript to a Cogent OA journal at [www.CogentOA.com](http://www.CogentOA.com)**

