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EXPLORING CHANGES IN PRIMARY STUDENTS' ATTITUDES TOWARDS SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) ACROSS GENDERS AND GRADE LEVELS

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Abstract. *Primary education is an essential stage and has an important impact on students' learning attitudes throughout the coming school years. The research explored the attitudes towards science, technology, engineering and mathematics among students through all grade levels in primary school. The Project-based Integrated STEM Program was proposed to study the changes of primary students' attitudes towards STEM. An assessment of S-STEM which consists of the STEM subscale and the 21st century skills subscale was utilized for both pre-test and post-test. The results showed that primary students exhibited little different attitudes on the S-STEM in the pre-test, regardless of gender and grade level. As evident from the comparison between the pre-test and post-test, the Project-based Integrated STEM Program had a positive effect on student attitudes towards STEM. It is encouraging if there are more STEM-related programs implemented at all educational stages covering the primary level.*
Keywords: *gender differences, grade levels, project-based integrated STEM program, school students, STEM education.*

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Introduction

Nowadays, the development of science and technology greatly boost the economy of many industrialized nations and developing countries. In the 21st century, there are increasing demands of jobs including positions such as electrical and electronics engineer, computer programmer, and construction manager, especially with the development of artificial intelligence. The labor market asks for the 21st century skills of knowledge, critical thinking and collaboration in science, technology, engineering and mathematics (STEM) (Partnership for 21st Century Skills, 2004). The demand reflects the importance of STEM education and motivates K-12 schools (K-12 education refers to education for children from kindergarten through twelfth grade) and universities to pay more attention to the teaching and training of 21st century skills. Attitudes towards STEM-related subjects from kindergarten kids through K-12 school students could have an impact on the possibility of the participation in the future STEM careers (Business-Higher Education Forum, 2010; President's Committee of Advisors on Science and Technology [PCAST], 2010). Therefore, the improvement of students' attitudes towards STEM requires increasing efforts in K-12 school systems.

However, many countries including United States and Countries in Europe were currently facing the challenge of decreasing numbers of students who were interested in the STEM-related subjects (National Science Board [NSB], 2012; Osborne & Dillon, 2008). Many companies were experiencing the shortage of qualified candidates with STEM-related skills and many job opportunities were unfilled (Pathways to Prosperity Project, 2011). It was reported by University of California at Los Angeles (UCLA) that K-12 and post-secondary students lost their interest in STEM and 40-60% of students in the university majoring in engineering and science

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switched to other majors or failed to obtain a degree (Drew, 2011). Many students in secondary school and post-secondary were switching from STEM majors to other fields. As well, most secondary school students come out on top in math, but did not choose STEM majors in college. In addition, only half of those students who originally studied STEM majors actually completed STEM degrees. (Carnevale, Smith, & Melton, 2011). A number of reports have warned that the current education system did not provide students with the appropriate science and technology training to prepare them for the skills and employment needs of the 21st century (EC, 2016; UNESCO, 2015). Holdren and Lander (2012) explained that the reasons for explaining the phenomenon included boring introductory courses and the lack of teaching support after school in mathematics courses. In 2011, educators were called on by the National Research Council (NRC) to increase the number of students who pursued STEM-related careers after secondary school (National Research Council, 2011). Experts on the President's Committee of Advisors on Science and Technology stated that improving K-12 students' interest and attitudes towards STEM was as significant as augmenting the overall STEM skills (President's Committee of Advisors on Science and Technology [PCAST], 2010).

Literature Review

Student attitudes towards STEM across genders

In the science literature, researchers found some contradictory evidences regarding the difference of student attitudes towards STEM across genders. On the one hand, some studies indicated that males had more positive attitudes than females (Jarvis & Pell, 2005). Another study revealed that the likelihood of career interest in a STEM-related field was 2.9 times higher for males than that for females by the end of secondary school (Sadler, Sonnert, Hazari, & Tai, 2012). Some researchers reported that male students in the middle school presented a more favorable attitude towards STEM than females (Catsambis, 1995; Jones, Howe, & Rua, 2000; Piburn & Baker, 1993; Greenfield, 1996). A study, conducted by Catsambis (1995), indicated that male students took more positive attitudes towards STEM than females. Simpson and Oliver (1985), and Hykle (1993) suggested that males were more inspired to succeed in science than females. Many females lacked of positive attitudes towards science to continue with scientific inquiries (Hacieminoglu, 2016). Sadler et al. (2012) revealed that females had fewer desires to pursue STEM careers. In most cases, females removed the STEM-related opportunities out of their career goals (Lent et al., 2005). It seemed that females prefered to connect school assignments from a more social context with the real world. Also, formal role models were also a significant factor that was often missing for girls in STEM areas (McCrea, 2010). In some researches of primary school students' attitudes towards science, girls showed less liking for STEM subjects than boys. More specifically, girls preferred fewer STEM lessons (Denessen, Vos, Hasselman, & Louws, 2015) and boys were eager to study in STEM areas (DeWitt & Archer, 2015).

On the other hand, some researchers emphasized similar attitudes towards STEM among male and female students (Dhindsa & Chung, 2003; Miller, Lietz, & Kotte, 2002; Smist, Archambault, & Owen, 1994; Akpinar, Yildiz, Tatar, & Ergin, 2009). It was also pointed out that students' attitudes towards STEM depended on the type of science that they prefered. For example, some research results revealed that males had a more favorable attitude towards physical sciences while females showed a more favorable attitude towards biological sciences (Schibeci & Riley, 1986; Weinburgh, 1995). Another similar research by Jones, Howe and Ria (2000) reported that males were interested in physics sciences, while females preferred life sciences. Furthermore, as stated from a previous study, girls were less positive than boys in their semantic perceptions of STEM, but girls were notably more positive than boys in semantic perceptions of STEM as a career (Christensen, Knezek, & Tyler-Wood, 2014).

Student attitudes towards STEM across grade levels

Primary science is an essential part of the K-12 science education system. It is recommended that students are taught to develop scientific attitudes towards STEM at an early age, starting with basic knowledge and skills from infant school through the primary years. Disappointingly, the scientific lessons have been diminished by the enactment of No Child Left Behind (NCLB) in many primary schools in the United States (Chonkaew, Sukhummek, & Faikhamta, 2016). It was reported that students' attitude towards STEM, such as enjoyment of STEM lessons and career interest in engineering and science, could be influenced significantly by grade levels

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(Toma & Greca, 2018). It seemed that as grade level increased, scientific attitudes towards STEM dropped consistently (Ali et al., 2013; Said, Summers, Abd-El-Khalick, & Wang, 2016).

As reported, the interest from ten-year-old students in STEM-related subjects was high, regardless of gender (Haworth, Dale, & Plomin, 2008), but their interest fell down considerably by the age of fourteen (Osborne, Simon, & Collins, 2003). An updated research revealed that student attitudes towards STEM were gradually improved from the age of ten and they were formed by the age of fourteen (Osborne, Simon, & Tytler, 2009). This period mainly might influence students' career interest and career choices. Lindahl (2007), after a longitudinal research with 12-to-16 years old students, concluded that attitudes towards STEM and career interest became evident at the age of thirteen and it became more difficult to engage students in STEM-related activities at later ages. In Denessen, Vos, Hasselman, and Louws' research (2015), first-year students in grade one in a secondary school generally had more positive STEM attitudes than second-year students in grade two in secondary school.

Research Focus

Students' choices of majors in college and their career interest after graduation are affected by their attitudes towards STEM at the primary school, middle school, or secondary school levels (Astin & Astin, 1993; Maltese & Tai, 2011). However, in the literature reviews, most researches were inclined to explore student attitudes towards STEM among students groups from grade four in upper primary school to postsecondary school (Denessen, Vos, Hasselman, & Louws, 2015; Haworth, Dale, & Plomin, 2008; Lindahl, 2007; Osborne, Simon, & Collins, 2003). There is an absence of related research about STEM attitudes involving primary students from grade one to grade three. Undoubtedly, primary education including grade one to grade three is an essential stage and has an important impact on student attitudes and scientific views throughout the coming school years. It suggests there is a need to study the attitudes towards STEM among students through all grade levels in primary school, involving the differences of attitudes across genders and grade levels. Furthermore, it is a crucial issue about how to improve student attitudes towards STEM at primary level (Kahveci, 2015). Therefore, a proposal for Project-based Integrated STEM Program was presented to gain a more particular knowledge about its impact on primary students' attitudes towards STEM.

The present research proposed the following questions:

1. Do primary students exhibit different attitudes towards STEM according to gender?
2. Do primary students exhibit different attitudes towards STEM according to grade level?
3. What change could the proposed Project-based Integrated STEM Program bring about on primary students' attitudes towards STEM?

Research Methodology

The Project-based Integrated STEM Program

In order to improve student attitudes towards Science, Technology, Engineering, & Mathematics (STEM), different proposals have been put forward in the previous researches or national reports. On one hand, some researches concentrated on the renovation of each subject related to STEM (Bybee, 2013). On the other hand, some educators and researchers focused on the integrative STEM education. For instance, SEEA group in Scotland published national reports which recommend the implementation of STEM education (Science and Engineering Education Advisory group, 2012). Australian Government and American Society for Engineering Education put forward an integrated STEM curriculum in Secondary Education (Australian Government, 2013; ASEE, 2011; Ritz & Fan, 2014; Pitt, 2009). These governments and organizations mainly highlight the significance of developing specialized STEM programs with inquiry teaching method at all educational stages. In the research conducted by Ritz and Fan (2014), the researcher suggested a multidisciplinary STEM education with the treatment of integrative STEM disciplines in real life. Also, Heil, Pearson, and Burger (2013) emphasized that there was a need to develop STEM programs under sufficient theoretical frameworks and empirical studies. However, the researcher pointed out that STEM programs were generally implemented in secondary school and there were limited related programs conducted at the primary level (Heil, Pearson, & Burger, 2013). In this research, the aim was to attempt at proposing a Project-based Integrated STEM Program to improve student attitudes towards STEM in primary school.

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The Project-based Integrated STEM Program has been served as a support for STEM teaching activities with twelve projects through grade one to grade six at the primary level. Within the Project-based Integrated STEM Program, students' learning process contains three phases for each project lasting for about 1 hour.

The first phase: It is a 5 minutes' teacher-oriented activity with problem-based learning method. In this phase, the teacher provides several questions on a special STEM theme with a real-life context. Students are encouraged to ponder over the strategies of the experimental design and alternative solution of the problems that they may encounter when they focus on a special STEM theme.

The second phase: It is a student-oriented section, in which students have their own creative ideas and design their personal projects. In this phase, students are randomly divided into small teams with two students in one team. In each team, students share their ideas with each other and make a decision to choose a better experimental design. Students are encouraged to connect experimental design with scientific and mathematics knowledge. They construct their designs and explore new ideas. Sometimes they need to redesign their experiments when the previous one is invalid or without any convincing results. Students are asked to draw a conclusion from experimental results and explain the experimental phenomenon with the integrative knowledge of science and mathematics. It lasts for about 40 minutes in this phase.

The third phase: In the final phase of about 15 minutes, presentations are carried out by each team. Students present the experimental phenomena and results of their projects, and try to address the key concepts and principles of the scientific and mathematics knowledge related to the STEM theme. In this phase, the role of the teacher is to evaluate students' statements and give supplementary explanations.

In the Project-based Integrated STEM Program, the same set of 12 STEM projects, which are described in Table 1, were provided for students in grade one, grade two, and grade three. In China, the science course started in the third year in the primary school according to the curriculum provision before the year of 2017. At the end of 2017, the Chinese Ministry of Education published the latest science curriculum standards determining that students should learn science from the first year of primary education. Teaching lower primary students content knowledge related to science is a greenfield and tough work in the current educational background in China. Therefore, the same STEM projects were designed for students from grade one to grade three. Table 2, table 3, and table 4 illustrate twelve STEM projects for students in grade four, grade five, and grade six, respectively. This program is one of various school-based courses, which students are free to choose as an optional course. The course is carried out once per week, and it does not occupy the normal school time.

Table 1. Twelve STEM projects for students in grade one, grade two, and grade three.

Week	STEM Projects	The descriptions of each project
1	Purple flour	Color change by reaction with the iodine
2	Egg-beater	The operation and function of the gear
3	Tumbler	The knowledge of the gravity
4	Gyroscope	How does a gyroscope spin on a plane
5	Yo-yo	How does a yo-yo rotate in a vertical direction
6	Trailer	The mechanical structure of the automobile
7	Needle emitting pellets	The air pressure
8	Sandball	How to produce sound by the vibration
9	Pirate ship	The curvilinear motion
10	Beads floating on the water	The buoyancy
11	Crane	The lever rule
12	Robot arm	The elasticity

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Table 2. Twelve STEM projects for students in grade four.

Week	STEM Projects	The descriptions of each project
1	Magic Balloon	The citric acid reacts with the soda
2	Triangle stability and graphic reinforcement	The application of triangle and quadrilateral in daily life
3	Electric Fan	How does the circuit work
4	Equal-armed lever	The equal-armed lever
5	Colorful table lamp	How does the LED light work
6	Labor-saving lever	Learn the labor-saving lever
7	Caged Birds	The application of the parallax
8	Laborious lever	Learn the laborious lever
9	Making a steelyard	The application of the lever in daily life
10	Compound lever	Learn the compound lever
11	Runaway spider	The application of the eccentric wheel
12	Lever comprehensive application	Learn the application of leverage principle

Table 3. Twelve STEM projects for students in grade five.

Week	STEM Projects	The descriptions of each project
1	Rainbow windmill	The integration of circuit and parallax
2	Fixed pulley and movable pulley 1	Learn simple fixed pulley and movable pulley
3	Rain alarm	The application of the humidity sensor
4	Fixed pulley and movable pulley 2	How do fixed pulley and movable pulley work
5	Storm frog	How does the motor drive gears
6	Wireless power supply	How is the energy transmitted wirelessly
7	Rotation of the pulley	Learn the rotation of the pulley
8	Dryers	The application of the centrifugal force
9	Pulley acceleration and deceleration	Learn acceleration and deceleration of the pulley
10	Four-wheel drive (4WD)	How to make an electric trolley
11	Composite pulley drive 1	Learn the pulley drive
12	Composite pulley drive 2	The application of the pulley drive

Table 4. Twelve STEM projects for students in grade six.

Week	STEM Projects	The descriptions of each project
1	Laser alarm	The principle of laser alarm
2	Idler	The application of the idler in daily life
3	Track tank	How to make a track tank

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Week	STEM Projects	The descriptions of each project
4	Gear drive	How does the gear drive work
5	Electric carbon swing	The electromagnetic induction
6	Gear ratio	Learn the transmission ratio of the gear
7	Energy conversion demonstrator	Learn the energy conversion
8	Crown gears	How do crown gears work
9	Speed regulator	Learn to make a speed regulator
10	Helical gears	How do helical gears work
11	Gravity trolley	The application of the gravity
12	Crown gears and helical gears	Learn the application of crown and helical gears

Participants

The research was conducted in a comprehensive school in Guangdong, a central province in southern China. The school provides not only primary education, but also kindergarten education and middle school education. The school is equipped with various laboratories, such as physics laboratory, biology laboratory, chemical experiment and integrated science laboratory, which can provide with experimental sites for the present research. The researcher only needs to supplement some necessary experimental materials when carrying out the program.

The school consisted of 877 students at the primary level from grade one to grade six. The size of the each of the classes varied from 38 to 48. Students who chose the Project-based Integrated STEM Program as an optional course constituted the sample of our research. The sample of participants included 242 students from grade one to grade six (173 boys, 67 girls, and 2 students without gender markers), with 20 students in grade one (15 boys and 5 girls), 55 students in grade two (47 boys, 6 girls, and 2 students without gender markers), 48 students in grade three (34 boys and 14 girls), 51 students in grade four (36 boys and 15 girls), 33 students in grade five (19 boys and 14 girls), and 35 students in grade six (22 boys and 13 girls). All of the students volunteered to join the research program. Most of these students did not receive extra tutoring on STEM-related skills except of the traditional instruction at school, because their parents who are general workers, farmers or self-employed labourers have limited time and financial support for additional STEM-related education outside school.

Procedures

In this research, the Project-based Integrated STEM Program was carried out in the spring semester of 2018. Each STEM project was conducted by a science teacher for each week, and the entire program with twelve STEM projects for each grade lasted for twelve weeks.

In order to explore how primary students exhibit different attitudes towards STEM according to gender and grade level, and what change the proposed Project-based Integrated STEM Program could bring about on primary student attitudes towards STEM, the 15-minute pre-test and post-test on student attitudes towards STEM were administered. The pre-test was carried out among students in the first week before the implementation of the first STEM project, and the post-test was carried out after the completion of the last STEM project in the 12th week. It is necessary to note that, when the pre-test was carried out, it happened to conflict with the schedule of physical examination arranged by the school. There was a small amount of participants who were unable to take the pre-test, while they took part in both the entire Project-based Integrated STEM Program and the post-test. Therefore, the participants in the pre-test were 181 students in total (127 boys and 54 girls), including 12 students in grade one (7 boys and 5 girls), 21 students in grade two (17 boys and 4 girls), 48 students in grade three (34 boys and 14 girls), 51 students in grade four (36 boys and 15 girls), 21 students in grade five (11 boys and 10 girls), and 28 students in grade six (22 boys and 6 girls).

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Assessment

A questionnaire on student attitudes towards science, technology, engineering, and math named S-STEM developed by a research team at North Carolina State University (Unfried, Faber, Stanhope, & Wiebe, 2015) was utilized for both pre-test and post-test. The S-STEM questionnaire was constructed based on the items of Erkut and Marx's (2005) STEM attitudes questionnaire and the items on the attitudes towards 21st century skills from the Student Learning Conditions questionnaire (Friday Institute, 2010). The S-STEM questionnaire which was produced for upper primary school students was translated into Chinese as simple and suitable as possible for lower graders by two of researchers. In particular, for the students in grade one and grade two, teachers would read the sentences if necessary to ensure that students understand the meaning of all items. The S-STEM questionnaire consisted of 37 5-point (Strongly agree to strongly disagree) Likert-type items (see Aappendix). Within the entire questionnaire, there are 26 items assessing students' STEM attitudes, with 8 items (Q1-Q8) towards Mathematics, 9 items (Q9-Q17) towards Science, and 9 items (Q18-Q26) towards Engineering/Technology. The remaining 11 items (Q27-37) in the questionnaire are set as the 21st century skills subscale.

Data Analysis

The obtained data of student performances on S-STEM were described with regard to mean scores and standard deviations. The reliabilities of S-STEM for both pre-test and post-test were estimated using Cronbach's alpha coefficients. The Cronbach's alpha coefficients were 0.896 and 0.907 for the pre-test and post-test, indicating sufficient consistencies in the outcomes of two tests in this research. The data supported the use of the S-STEM questionnaire for the research. A t-test statistic was applied to test whether there were significant differences between boy students and girl students, or among lower primary students and upper primary students. Also, a t-test statistic was used to test the significant differences between pre-test and post-test.

Research Results

Primary Students' Performances on S-STEM in the Pre-test

The overall mean score of students on the whole S-STEM in the pre-test was higher than 3 (M=3.63, SD=.61), that indicates a positive attitude on the whole S-STEM test for all participants. Students achieved a little higher mean score in the 21st century skills subscale (M=3.70, SD=.83) than that in the STEM subscale (M=3.61, SD=.60).

One of the research aims was to explore whether primary students exhibited different attitudes towards science, technology, engineering and mathematics. Student performances were compared on the whole S-STEM in the pre-test according to gender and grade level. In terms of grade levels, all of the primary students were divided into two groups: lower primary group and upper primary group. The lower primary group included students from grade one to grade three. And students from grade four to grade six constituted the upper primary group. Table 5 presents the mean score for each group of students and the results of t-test statistic. For the whole S-STEM, the data showed that there was no significant difference either between boy students and girl students (t=.25, p=.804; boys: M=3.64, SD=.64; girls: M=3.62, SD=.55) or between lower primary students and upper primary students (t=1.58, p=.117; lower: M=3.71, SD=.58; upper: M=3.57, SD=.63).

Table 5. Primary Students' Performances on S-STEM in the pre-test and the t-test results on the differences between boy students and girl students, and between lower primary students and upper primary students.

Subscales	Groups	*M (SD)*	*t*	*p*	*Effect Size*
The whole S-STEM	Boys	3.64(.64)	.25	.804	.040
	Girls	3.62(.55)			
	Lower primary students	3.71 (.58)	1.58	.117	.235
	Upper primary students	3.57(.63)			

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Subscales	Groups	*M (SD)*	*t*	*p*	*Effect Size*
STEM subscale	Boys	3.64(.63)	1. 25	.211	.204
	Girls	3.52(.53)			
	Lower primary students	3.71(.59)	2.07	.040	.310
	Upper primary students	3.52(.60)			
21st century skills subscale	Boys	3.64(.85)	-1.51	.134	-.245
	Girls	3.84(.77)			
	Lower primary students	3.73(.80)	.34	.732	.051
	Upper primary students	3.68(.86)			

To further study students' different performances on both the STEM subscale and the 21st century skills subscale of S-STEM, the data in each subscale were categorized into four groups in terms of the variables of gender and grade level.

For the STEM subscale, the statistical value (t=1.25, p=.211) indicated that there was no significant difference between boy students and girl students, with the mean score of 3.64 (SD=.63) for boy students and the mean score of 3.52 (SD=.53) for girl students. However, a significant difference (t=2.07, p=.040) was detected in terms of grade levels. From the data, the mean score of lower primary students (M=3.71, SD=.59) was statistically significantly higher than that of upper primary students (M=3.52, SD=.60).

For the 21st century skills subscale of S-STEM, no significant differences were detected either between boy students and girl students (t=-1.51, p=.134; boys: M=3.64, SD=.85; girls: mean score=3.84, SD=.77) or between lower primary students and upper primary students (t=.34, p=.732; lower: M=3.73, SD=.80; upper: M=3.68, SD=.86). It's worth noting that boy students pursued higher scores than girl students in the whole S-STEM and the STEM subscale, but girl students performed better on the 21st century skills subscale, even though all these differences were not significant.

Primary Students' Differences of Performances on S-STEM between the Pre-test and Post-test

Another aim of the study was to investigate what change the proposed Project-based Integrated STEM Program would bring about on primary students' attitudes towards STEM. The post-test for all students was carried out after the completion of twelve STEM projects of the Project-based Integrated STEM Program in the 12th week. The mean score with standard deviation of each group in the post-test is shown in table 6. Roughly comparing the data between the pre-test and post-test, it could be found that students performed better in the post-test than in the pre-test. Obviously, boy students had the same mean score of 3.64 in the whole S-STEM, the STEM subscale and the 21st century skills subscale in the pre-test, but the mean scores in the post-test were much higher, with 3.82, 3,76, 3.97 for the whole S-STEM, the STEM subscale and the 21st century skills subscale, respectively. With respect to the 21st century skills subscale, the mean score of each group was very close to 4, with 3.97, 3.93, 3.95, and 3.98 for boy students, girl students, lower primary students, and upper primary students, respectively. However, all mean scores of the four groups were less than 3.90 for the 21st century skills subscale in the pre-test.

Table 6. Primary Students' Performances on S-STEM in the post-test.

	M (SD)		
Groups	**The whole S-STEM**	**STEM subscale**	**21st century skills subscale**
All participants	3.82 (.57)	3.76 (.62)	3.97 (.69)
Boys	3.90 (.56)	3.86(.62)	3.97(.68)
Girls	3.62 (.54)	3.49(.56)	3.93(.70)

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Groups	*M (SD)* The whole S-STEM	STEM subscale	21st century skills subscale
Lower primary students	3.87 (.62)	3.83(.68)	3.95(.73)
Upper primary students	3.78 (.51)	3.69(.55)	3.98(.64)

A t-test statistic was used to test the significant differences between pre-test and post-test. The data are shown in table 7. Overall, there was a significant difference on the whole S-STEM between pre-test and post-test (t=-3.27, p=.001), indicating that primary students performed much better in the post-test than in the pre-test. For gender, the difference (t=-3.64, p=.000) was detected significantly between pre-test and post-test for boy students on the whole S-STEM, but the performance of girl students on the whole S-STEM in the post-test was equivalent to that in the pre-test (t=-.02, p=.982). For grade level, students in both lower primary group and upper primary group had better performances on the whole S-STEM in the post-test than that in the pre-test (lower: t=-1.78, p=.077; upper: t=-2.60, p=.010). The results indicate that except for girl students, students in other groups showed much better performances on the whole S-STEM in the post-test.

Table 7. The t-test results of the differences on S-STEM and its subscales between pre-test and post-test for four Groups of students: boy students and girl students, lower primary students, and upper primary students.

Subscales	Groups	t-test (pre-post)		
		t	*p*	Effect Size
The whole S-STEM	All participants	-3.27	.001	-.321
	Boys	-3.64	.000	-.424
	Girls	-.02	.982	-.004
	Lower primary students	-1.78	.077	-.254
	Upper primary students	-2.64	.009	-.358
STEM subscale	All participants	-2.60	.010	-.255
	Boys	-3.04	.003	-.354
	Girls	.33	.741	.061
	Lower primary students	-1.35	.179	-.193
	Upper primary students	-2.14	.034	-.290
21st century skills subscale	All participants	-3.47	.001	-.341
	Boys	-3.71	.000	-.432
	Girls	-.67	.507	-.122
	Lower primary students	-2.07	.039	-.297
	Upper primary students	-2.86	.005	-.388

When it comes to the STEM subscale, overall, students in the post-test demonstrated a higher level of attitudes towards STEM than that in the pre-test (t=-2.64, p=.009). Besides, boy students performed significantly better in the post-test than in the pre-test (t=-3.04, p=.003). Also, the difference between pre-test and post-test for upper primary students was significant at the .05 level (t=-2.14, p=.034). While, the statistical value (t=.33, p=.741) showed that girl students did not perform much differently on the attitude towards STEM between the pre-test and the post-test. And the difference between pre-test and post-test for lower primary students was not detected significantly (t=-1.35, p=.179).

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For the 21st century skills subscale, the significant differences resembled those of the whole S-STEM. Overall, the difference between pre-test and post-test was significant (t=-3.47, p=.001), indicating that students in the post-test achieved a noticeably higher performance on the attitude towards the 21st century skills than that in the pre-test. Among four groups of students, there were significant differences between the pre-test and the post-test among three groups of students: boy students (t=-3.71, p=.000), lower primary students (t=-2.07, p=.039), and upper primary students (t=-2.86, p=.005). However, no statistically significant difference was consistently detected between pre-test and post-test for girl students (t=-0.67, p=.507).

Discussion

Primary Students' Performances on S-STEM across Genders and Grade Levels

The above analysis in the pre-test provided us the interesting result that primary students exhibited little different attitudes towards science, technology, engineering and mathematics on the S-STEM, regardless of gender and grade level. No significant differences were detected either between boy students and girl students, or between lower primary students and upper primary students. As evident from the results of different subscales of the S-STEM, boy students showed a bit better attitude on the STEM subscale, but a little worse attitude on the 21st century skills subscale than girl students. However, both differences were not significant. In the literature, there were some findings regarding the difference of student attitudes towards STEM across genders. Most studies indicated that boy students had more positive attitudes towards STEM than girl students (Catsambis, 1995; Greenfield, 1996; Jarvis & Pell, 2005; Jones, Howe, & Rua 2000; Piburn & Baker, 1993) and girl students preferred fewer STEM lessons (Denessen, Vos, Hasselman, & Louws, 2015). However, this research into primary students' attitudes towards STEM suggests that boy students and girl students do not exhibit differently on either the attitudes towards STEM, or the attitudes towards the 21st century skills. There is the evidence supporting the previous researches which confirmed similar attitudes towards STEM between boy students and girl students (Akpinar, Yildiz, Tatar, & Ergin, 2009; Dhindsa & Chung, 2003; Miller, Lietz, & Kotte, 2002; Smist, Archambault, & Owen, 1994).

From the perspective of grade level, there was a disappointing result that upper primary students achieved worse performance than lower primary students on the whole S-STEM, the STEM subscale, and the 21st century skills subscale. A significant difference was detected in the STEM subscale between the two groups of students, indicating that lower primary students performed much better on the attitude towards science, technology, engineering and mathematics than upper primary students. Among the participants in this research, students from grade one and grade two in the lower primary group rarely receive science course, as the science course in China started from the third year in the primary school according to the curriculum provision before the year of 2017. All students in the upper primary group from grade four, grade five, and grade six have received different years of science course according to the curriculum plan. The result suggests that the current science curriculum and instruction fail to bring positive effect to students on their attitude towards science, technology, engineering and mathematics at the primary level. The results strongly support the opinion in the solid body of literature that students' attitudes towards STEM dropped consistently as grade level increased (Ali et al., 2013; Osborne, Simon, & Collins, 2003; Said, Summers, Abd-El-Khalick, & Wang, 2016). It reflects the failure in the traditional educational system to improve primary students' positive attitudes towards STEM. As reported, many countries were currently facing the challenge of decreasing numbers of students who were interested in the STEM-related subjects (National Science Board [NSB], 2012; Osborne & Dillon, 2008). Experts stated that improving K-12 students' interest and attitudes towards STEM was significant (President's Committee of Advisors on Science and Technology [PCAST], 2010). The result gives full expression to the importance of STEM education and the training of 21st century skills. It demands the educational system to provide students with the appropriate science and technology training to prepare them for the skills and employment needs of the 21st century (EC, 2016; UNESCO, 2015).

The Effect of Project-based Integrated STEM Program on Primary Students' Attitudes towards STEM

The Project-based Integrated STEM Program was a core strategy and implementation for supporting the STEM teaching activities through grade one to grade six at the primary level in the research. As evident from the comparison between pre-test and post-test, it could be found that the Project-based Integrated STEM Program had a positive effect on student attitudes towards STEM. Overall, students improved their performances not only

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on the whole S-STEM, but also on the STEM subscale and the 21st century skills subscale in the post-test, compared with the result in the pre-test. Although, some governments and organizations have addressed the significance of STEM education and put forward different proposals in the national reports or previous researches, such as the implementation of STEM education in Scotland (Science and Engineering Education Advisory group, 2012), and the integrated STEM curriculum in Australian and American (ASEE, 2011; Australian Government, 2013; Pitt, 2009; Ritz & Fan, 2014), most of these proposals were generally implemented in secondary school and there were limited related projects conducted at the primary level (Heil, Pearson, & Burger, 2013). In this study, the Project-based Integrated STEM Program was designed for students at the primary level and its instructional achievements were remarkable and encouraging. It reveals that the implementation of the Project-based Integrated STEM Program is effective for primary students. It is hopeful if there are more and more specialized STEM programs and integrated STEM curricula propounded and implemented at all educational stages covering the primary level.

In the further analysis on the differences of student attitudes towards STEM between pre-test and post-test, there were some special results from the aspects of gender and grade level. Regarding to gender, boy students effectively enhanced their performances on the attitudes towards STEM in the post-test in contrast to the pre-test. They showed significant differences on the whole S-STEM, the STEM subscale and the 21st century skills subscale between the pre-test and post-test. However, the performances of girl students on either the whole S-STEM or two subscales of the STEM and the 21st century skills in the post-test were equivalent to those in the pre-test. No significant difference was consistently detected between pre-test and post-test for girl students. From the data, even though there was not much difference between boy students and girl students in the pre-test, boy students achieved much higher scores in the post-test than those of girl students, especially in the whole S-STEM (t=3.57, p=.001), and the STEM subscale (t=4.45, p=.000). From the perspective of girl students who have participated in twelve STEM projects identical to those of boy students at the same grade, the Project-based Integrated STEM Program did not support the change of their attitudes towards STEM. It is in line with the previous research results that boy students were more inspired to succeed in science than girl students (Hykle, 1993; Simpson & Oliver, 1985). The reason for the lack of improvement of girl students may be consistent with previous studies in which girl students preferred fewer STEM lessons and tended to report more unfavorable attitudes on STEM (Catsambis, 1995; Denessen, Vos, Hasselman, & Louws, 2015; DeWitt & Archer, 2015; Greenfield, 1996; Jones, Howe, & Rua 2000; Piburn & Baker, 1993). In addition, the majority of the proposed projects in the Project-based Integrated STEM Program has been designed with the contexts of physical sciences, which failed to motivate girl students' learning interest. As revealed in previous researches, girl students might have had a more favorable attitude towards life sciences (Howe and Ria, 2000) and biological sciences (Schibeci & Riley, 1986; Weinburgh, 1995).

For the aspect of grade level, both lower primary students and upper primary students had a positive change on the whole S-STEM according to the data. It indicates that the proposed Project-based Integrated STEM Program has achieved significant results to improve the attitudes towards STEM for students in both groups. It is seen that the differences between pre-test and post-test on the whole S-STEM and the 21st century skills subscale for upper primary students were significant at the 0.01 level, but the differences between pre-test and post-test on these two aspects for lower primary students were significant at the .05 level. It is also observed that upper primary students performed significantly better in the STEM subscale in the post-test, but lower primary students did not perform much differently on the attitudes towards STEM between the pre-test and the post-test. Although, there was a disappointing result that upper primary students performed worse than lower primary students on the whole S-STEM, the STEM subscale, and the 21st century skills subscale in the pre-test, the Project-based Integrated STEM Program has promoted more positive changes for upper primary students than lower primary students in the post-test. The result is inspiring that although upper primary students currently may not show favorable attitudes or interest towards STEM, they are able to develop more positive attitudes and interest by studying STEM-related projects. From another perspective, there is a need to pay much attention to lower primary students who do not perform much better on the STEM subscale in the post-test. It is worth pondering the reason that lower primary students achieved significant improvement on the whole S-STEM and the 21st century skills subscale, while they had no positive change on the STEM subscale. All details of the procedure including content settings, project implementation approach and schedule arrangement of the Project-based Integrated STEM Program are needed to reflect on. For lower primary students, developing suitable programs to improve their attitudes towards STEM will be challenging and encouraging work in future research.

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Conclusions and Future Work

The present research explored the attitudes towards science, technology, engineering and mathematics among students through all grade levels in primary school using the S-STEM questionnaire for the pre-test. The results showed that primary students exhibited almost no difference of attitudes on the S-STEM, regardless of gender and grade level. After the completion of twelve STEM projects of the Project-based Integrated STEM Program, students had a positive change on their attitudes towards STEM in the post-test. However, boy students effectively enhanced their performances on the attitudes towards STEM, while girl students did not. Also, the program has promoted more positive changes for upper primary students than lower primary students.

Based on the current research results, future work maybe of the following aspects: (1)how to improve the attitudes towards STEM for girl students at the primary level? From the data of the research, girl students have participated in twelve STEM projects which were identical to those of boy students at the same grade, but the Project-based Integrated STEM Program did not support the change of their attitudes towards STEM. Therefore, designing suitable projects or curricula to develop the attitudes towards STEM for girl students at the primary level is one of the challenging work in the later research. (2)how to develop lower primary students' attitudes towards STEM? In the present results, the Project-based Integrated STEM Program has promoted many positive changes on the attitudes towards STEM for upper primary students, but lower primary students did not perform much better on the STEM subscale of the S-STEM. It may make sense to ponder the reason that there was no significant progress on the attitudes towards STEM for lower primary students. As well, it is worth designing suitable STEM-related projects to improve lower primary students' attitudes towards STEM in future work. (3)do primary students exhibit different attitudes on subscales of science, technology, engineering and mathematics? In the research, the assessment of S-STEM consists of 9 items, 8 items, and 9 items towards STEM respectively. It's worthwhile to explore primary students' various performances on the subscales of the STEM, and it may show great importance on the future research of the correlation of these subscales of STEM with each other.

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Appendix

Items
1. Math has been my worst subject.
2. When I am older, I might choose a job that uses math.
3. Math is hard for me.
4. I am the type of student to do well in math.
5. I can understand most subjects easily, but math is difficult for me.
6. In the future, I could do harder math problems.
7. I can get good grades in math.
8. I am good at math.
9. I feel good about myself when I do science.
10. I might choose a career in science.
11. After I finish high school, I will use science often.
12. When I am older, knowing science will help me earn money.
13. When I am older, I will need to understand science for my job.
14. I know I can do well in science.
15. Science will be important to me in my future career.
16. I can understand most subjects easily, but science is hard for me to understand.
17. In the future, I could do harder science work.
18. I like to imagine creating new products.
19. If I learn engineering, then I can improve things that people use every day.
20. I am good at building and fixing things.
21. I am interested in what makes machines work.
22. Designing products or structures will be important for my future work.
23. I am curious about how electronics work.
24. I want to be creative in my future jobs.

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Items
25. Knowing how to use math and science together will help me to invent useful things.
26. I believe I can be successful in engineering.
27. I can lead others to reach a goal.
28. I like to help others do their best.
29. In school and at home, I can do things well.
30. I respect all children my age even if they are different from me.
31. I try to help other children my age.
32. When I make decisions, I think about what is good for other people.
33. When things do not go how I want, I can change my actions for the better.
34. I can make my own goals for learning.
35. I can use time wisely when working on my own.
36. When I have a lot of homework, I can choose what needs to be done first.
37. I can work well with all students, even if they are different from me.

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