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PRIMARY STUDENTS' PERFORMANCE OF STEM DOMAIN-SPECIFIC SELF- EFFICACY BELIEF AND EXPECTANCY-VALUE BELIEF

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Introduction

Nowadays, the developments of information and communication technology occurring with globalization have affected the lives and economies of all nations. The common motivation for countries around the world today is to improve the educational system to make the new generation more innovative and creative (Lederman, 2008). Demand has also increased for countries which would develop new technologies and produce more valuable and innovative products (Ergun, 2019). For example, workers in the field of science, technology, engineering, and math (STEM) are favored in the United States (Carnevale et al., 2011; Rothwell, 2013), and it has been predicted that the demand of STEM workers will continue for years (National Academy of Engineering, 2008; Unfried et al., 2015). It is stated that STEM skills are necessary for everyone, not only those who want to pursue STEM careers, but also those who do not (Yerdelen et al., 2016). Students need to actively improve their STEM capabilities to cope with the challenges of globalization and the development of the knowledge-based economy (Kristen et al., 2012). Therefore, the economic globalization encourages individuals to make adequate efforts and preparations to improve STEM literacy and to pursue STEM related careers (Yerdelen et al., 2016).

In educational field, with countries recognizing the role of STEM education in the future's economy, improving students' STEM learning has become a top priority (McMahon & Showers, 2012). STEM education has been considered as a government policy in the United States, (National Research Council [NRC], 2010) and the interest in STEM disciplines has increased in many European countries (Corlu et al., 2014). STEM Education has also been regarded as one of the hot topics in the ministry of education of many countries, such as China (Zhou et al., 2019) and Turkey (Yerdelen et al., 2016). Generally, improving students' attitudes towards STEM could raise the possibilities of students to choose STEM careers in the future. Therefore, the importance of STEM education requires more attention to the attitudes towards STEM-related domains from kindergarten kids through



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Abstract. *Most studies have concentrated in assessing students' overall attitudes towards science, mathematics, and engineering/technology or the attitude towards individual STEM domain. The present research aims to explore primary students' gender and grade differences of their STEM domain-specific attitudes including self-efficacy and expectancy-value beliefs, as well as their correlations. The results showed no detected significant effects among these different STEM domains in the overall attitudes, the overall self-efficacy beliefs, and the overall expectancy-value beliefs for primary students. The correlations between self-efficacy and expectancy-value were much stronger for the science domain and engineering/technology domain than the mathematics domain. No gender difference of the self-efficacy beliefs was detected except in the mathematics domain, and the result that lower primary students performed significantly better than upper primary students in the self-efficacy was also mainly contributed by the grade difference in the mathematics domain. Whereas no different expectancy-value beliefs existed across genders and grade levels in various STEM domains. The present results reported some unique performances by the primary school students compared to the elder group.*

Keywords: *expectancy-value, gender differences, grade levels, self-efficacy, STEM attitudes*

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K-12 school students (Business-Higher Education Forum, 2010; President's Committee of Advisors on Science and Technology [PCAST], 2010).

However, many countries around the world are facing a common challenge of decreasing numbers of students who show interest in the STEM-related disciplines (National Science Board [NSB], 2012; Osborne & Dillon, 2008). It is reported that more than three times as many graduates in humanities and social sciences than those in STEM-related major in the Organization for Economic Co-operation and Development (OECD) countries (OECD, 2015). It is noted that only a small number of students starting higher education have chosen STEM-related disciplines among the OECD countries (OECD, 2017). Additionally, compared with other fields, more students drop out of STEM disciplines which they have chosen in the first place (Reinhold et al., 2018). It is stated that the number of students in higher education institutions choosing STEM related majors is much lower than expected (Shapiro & Sax, 2011). As it has been reported by University of California at Los Angeles (UCLA), many K-12 and post-secondary students lost interest in STEM, with nearly half of engineering and science majors switched to other majors or failed to get a degree (Drew, 2011). Besides, according to previous research, the number of students who value STEM in universities in developing countries has also decreased over the years (Akgunduz, 2016).

Naturally, poor academic performance affects the number of students who complete higher education degrees and enter STEM-related professions (Christensen et al., 2014). Many capable students do not choose STEM-related fields as their careers in many countries such as United States. As a result, the rate of choosing STEM-related fields as a career is generally low (Kizilay, 2018). Globally, the demands about labor force in STEM-related fields are not being adequately met (Atkinson, 2013; Moakler & Kim, 2014). For example, only 300,000 students with STEM-related majors in the United States are graduating each year, while the demand for the workforce is expected to be close to one million (Holdren & Lander, 2012).

Literature Review

Due to the continuous extension of the research on students' attitudes, researchers' understanding of attitudes has been deepened, which leads to the continuous expansion and evolution of the definition of attitudes (Luo et al., 2019). Students' attitude towards a subject is considered to be an important correlation of achievement motivation, which consists of two important components, namely, self-efficacy belief and expectancy-value belief (Eccles & Wigfield, 2002). Self-efficacy was described by Bandura (1997) as an individual's confidence in their ability to accomplish a task. Researchers have found increasing evidence that self-efficacy could be considered as a predictor of academic achievement (Multon et al., 1991; Zimmerman & Bandura, 1994). According to the previous studies, students are more likely to continue postsecondary education in STEM domain if they show higher self-efficacy in math (Wang, 2013) or science (Scott & Mallinckrodt, 2005). As for expectancy-value theory, first proposed by Atkinson in the 1950s, it has since been expanded into educational field to address students' achievement-related choices (Wigfield & Eccles 2000). Expectancy-value theory holds that individuals periodically evaluate their likelihood of achieving certain goals and evaluate the specific value gained or lost in achieving those goals (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). According to the different connotations of expectancy-value belief, Bandura divided it into two sub-dimensions, that is, outcome expectations belief and efficacy expectations belief (Luo et al., 2019). Outcome expectations belief represents that certain behaviors will lead to certain outcomes (e.g., "the belief that practicing will improve one's performance") and efficacy expectations belief indicates whether individual is capable of performing effective behaviors necessary to generate outcome (e.g., "I can practice sufficiently hard to win the next tennis match"). Whether one has high expectations has been demonstrated to be closely related to one's adherence to advanced math and science courses (Fan, 2011; Simpkins et al., 2006). When studying career aspirations model, expectancy-value theory is regarded as a supplement to self-efficacy theory (Schunk, 1991; Wigfield & Eccles, 2000). For the purposes of the present research, students' attitudes are defined in alignment with Eccles and Wigfield's (2002) description focusing on self-efficacy and expectancy-value beliefs. In addition, this research takes interest in such beliefs towards STEM disciplines across genders and grade levels.

Research on the attitudes towards various core STEM subjects

Since the 1970s, research on students' attitudes towards science and math has produced an impressive body of research literature (e.g., Aiken, 1970; Gardner, 1975; Osborn et al., 2003; Potvin & Hasni, 2014b; Simpson



& Oliver, 1990). The research literature has also emerged with surveys measuring students' attitudes towards a single STEM discipline (Unfried et al., 2014). Typically, students' interests and expectations in math or science are of primary concern to the researchers (Wiebe et al., 2018). For instance, the Test of Science-Related Attitudes (TOSRA) is an instrument that consists of seven subscales with 10 items each, measuring student attitudes towards science in the secondary education period (Fraser, 1978). Affective Elements of Science Learning Questionnaire is another assessment of student attitudes towards science (Williams et al., 2011). Another instrument is the Attitudes Towards Mathematics Survey (Miller et al, 1996), which aims at measuring student attitudes towards mathematics. In contrast to the literature that measures students' attitudes towards science and mathematics, less research has focused on students' attitudes towards technology and engineering areas (Johnpaul et al., 2018). Different tendencies of this kind of research have even led a part of researchers to a question whether science and mathematics alone are worthy of attention, rather than integrating technology and engineering as elements to be the whole of STEM area (Lederman & Lederman, 2013). Studies which focus on technology aspect of STEM, tend to view the technology itself as a toolbox of skills that could be applied to science and mathematics, rather than as a primary and unique domain of STEM (Kennedy et al., 2018). Unlike other instruments, Erkut and Marx (2005) developed an instrument for the survey of attitudes towards multiple STEM areas: science, math, and engineering/technology. This instrument could be applied to assess students' attitudes towards different STEM disciplines for understanding their similarities and differences (Johnpaul et al., 2018). It is necessary to systematically gather data of attitudes for young students across various STEM domains (Minner et al., 2012).

In the present research, the differences were examined, in attitudes towards all core STEM subjects (science, math and engineering/technology) and interests in STEM careers among 1st through 6th grade students. This research also focused on primary students' performances in self-efficacy and expectancy-value beliefs towards various STEM domains.

Student attitudes towards STEM across genders and grade levels

In terms of gender, it was found that contradictory evidence existed on student attitudes towards STEM (Toma & Greca, 2018). Most research studies suggested that boy students tended to have more positive attitudes towards STEM than girl students (Greenfield, 1996; Jarvis & Pell, 2005; Jones et al., 2000). On the contrary, some studies indicated that students did not exhibit significant difference in the attitudes towards STEM across genders (Akpınar et al., 2009; Zhou et al., 2019). Even, it has also been found that the attitude of boy students towards STEM was less positive compared to girl students (Boone, 1997). As well, other studies have examined gender differences in student attitudes towards STEM sub-disciplines (Wiebe et al., 2018), such as science (Akpınar et al., 2009; Toma & Greca, 2018), mathematics (Watt et al., 2012), engineering, and technology (Unfried et al., 2014). Eccles pointed out that the underlying reasons for the differences in STEM attitudes based on gender were nuanced (Eccles & Wigfield, 2002).

More specifically, recent reviews which covered gender differences across STEM disciplines found that gender differences in self-efficacy existed across most of the STEM domains (Eddy & Brownell, 2016; Cheryan et al., 2017). Cheryan et al. (2017) stated that gender differences in self-efficacy predicted the different participation rates for girls in STEM disciplines. Compared with girls, boys have higher expectations for success in STEM fields (Yee & Eccles, 1988). This difference could explain the decreased enrollment in STEM-related courses for girls (Watt et al., 2012). Gender differences in STEM achievement may be influenced by the amount of value that boys and girls place on STEM domains as well. However, many studies indicated no gender differences in the expectancy-value levels of STEM (Eccles, 2009). It can be seen that gender differences in students' attitude states in high school or college have been examined individually in prior studies, but not students' self-efficacy and expectancy-value beliefs in primary school. It is necessary to do further investigation among primary graders.

From the aspect of grade levels, a number of studies have paid attention to the grade differences in STEM attitudes involving students from primary school through university. Many studies have determined a common result that older graders have a less positive attitude towards STEM domains compared to younger graders (Potvin & Hasni, 2014a; Unfried et al., 2014). For instance, a group of international and Australian longitudinal studies showed that student attitudes towards STEM steadily declined due to students' transitioning to early high school (e.g., Speering & Rennie, 1996). Attitudes towards science have also been found to decline from upper primary school to middle school in a longitudinal study (Unfried et al., 2014). The previous research has determined that lower primary students performed much more positive attitudes than upper primary students



(Zhou et al., 2019). However, there were contradictory results in some existing studies, in which some showed no significant differences across grade levels, while others supported an increase in student attitudes towards STEM domains as the grade grew (Akpınar et al., 2009; Ali et al., 2013; Said et al., 2016). In addition, grade level has been considered to be a significant factor, having interactions with gender on STEM learning attitudes (Wiebe et al., 2018). In general, student attitudes towards STEM fields have been examined across grade levels for different graders in prior research. The prior research on primary students' attitudes towards STEM also contributed to the related literature (Zhou et al., 2019). A more nuanced research on differences of attitudes across various STEM disciplines is worthy of subsequent exploration. Further, it makes sense to investigate the grade level difference of students' self-efficacy and expectancy-value beliefs towards STEM domains in primary grades.

The relationship between self-efficacy belief and expectancy-value belief

There are various correlations among various variables of STEM attitudes in the literature. One research, on the one hand, found little relation between self-efficacy and outcome expectancy in STEM-related domains (Maddux et al., 1986). On the other hand, for the science attitudes, moderate correlations exist between the perceived usefulness of school science for scientific careers and each of self-efficacy, enjoyability, relevance, and intentions. For the mathematics attitudes, there is a moderate correlation between self-efficacy and enjoyability. As well, there are moderate correlations between the different attitudes towards design technologies (Johnpaul et al., 2018).

Regarding two essential components of student attitudes towards STEM, Bandura's self-efficacy theory focuses on expectancy for success based on expectancy-value theory and attribution theory (Luo et al., 2019). Manning and Wright (1983) found a strong correlation ($r=.75$) between self-efficacy and outcome expectancy. Self-efficacy was modeled as a determinant of outcome expectancies, interests, and intentions (Fouad & Smith, 1996). Self-efficacy is considered as a compelling predictor of STEM academic success and the willingness of students to set challenging goals like a STEM educational pathway. Wang (2013) found that a college student's intent to major in STEM was directly affected by his or her 12th-grade math achievement, exposure to math and science courses, and math self-efficacy beliefs. During high school, having high expectancy-value beliefs has been found to be associated with a student's persistence in taking both advanced science and mathematics courses (Simpkins et al., 2006). Research studies have shown that students were more likely to pursue postsecondary schooling in STEM fields if they had success in mathematics (Wang, 2012) or high self-efficacy in science (Scott & Mallinckrodt, 2005) in earlier grades.

Research Questions

In the early studies of the development of social psychology, researchers explored the impact of demographics including age, gender, and race on self-efficacy, outcome expectations, and career interests (Fouad & Smith, 1996). In one of the previous studies, the researchers studied the factors affecting students' attitudes towards STEM domains and found that gender had an interactive effect on attitudes and interests in STEM professions (Unfried et al., 2014). Recently, some studies have found a positive effect of STEM oriented interventions on students' STEM career interests (e.g., Peterman et al., 2016; Xie & Reider, 2014). The researchers have emphasized that self-efficacy and expectancy-value form a core structure that can influence motivation and persistence in the academic trajectory (Schunk, 1991; Wigfield & Eccles, 2000). What's more, relevant studies have demonstrated the need to distinguish differences between general self-efficacy and specific self-efficacy towards specific academic domains (Chen et al., 2000). However, there has been less related research about STEM attitudes involving primary students from grade one to grade three as emphasized in the previous research (Zhou et al., 2019). It suggests that there is a need to study the attitudes towards STEM among students through all grade levels in primary school. Therefore, the purpose of this research was to extend the previous research (Zhou et al., 2019) to examine differences of primary students' domain-specific STEM attitudes in terms of genders or grade levels, and to explore the correlation between students' STEM self-efficacy and expectancy-value beliefs. Three research questions were as follows:

1. What is the correlation between STEM domain-specific self-efficacy and expectancy-value beliefs?
2. Is there a significant difference of primary students' STEM domain-specific attitudes in terms of gender or grade level?



Research Methodology

General Background

The present research was an extension of the previous research (Zhou et al., 2019), which explored the performance of primary students in overall STEM attitude and the improvement of students' STEM attitude after receiving a twelve-week integrated STEM project. In this previous research, STEM attitude was regarded as a unified disciplinary attitude, which was not divided neither according to the different domains of STEM nor according to the dimensions of self-efficacy belief and expectancy-value belief. The present research also took primary school students as the research object but focused on understanding more multi-layered states of students' STEM attitudes. The data for this research were excavated from the same research program in the previous research (Zhou et al., 2019), in which the data were collected in 2018, and the in-depth data mining was conducted during the period 2019-2020. From the perspective of different domains, it is worth exploring whether there were differences in students' attitudes towards STEM in various STEM domains and extracting gender differences and grade level differences on this basis. In addition, from different dimensions of STEM attitude, this research also aimed to explore whether there were differences in the self-efficacy belief and expectancy-value belief of primary school students, and whether the difference was found in different STEM fields, different genders, and different ages.

Sample Selection

In order to study how primary students exhibit different attitudes towards STEM according to gender and grade level, and to explore the relationship between primary students' STEM self-efficacy and expectancy-value, the participants were selected from grade one through grade six in primary school in China. The primary school is an ordinary one in a Guangdong Province in China, with no special teaching intervention in STEM education beyond the curriculum standards of the Ministry of Education (MoE) of China. All the students voluntarily participated in the present research and with the consent of their parents. Based on the above principles, the participants and the ratio of boys to girls in different grades were different. The population contained 127 boys and 54 girls, with a total number of 181 primary school students. The distribution of boys and girls in different grades is shown in Table 1.

Table 1

The Distribution of Boys and Girls in Different Grades in the Research

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Total
Boys	7	17	34	36	11	22	127
Girls	5	4	14	15	10	6	54
Total	12	21	48	51	21	28	181

Instrument and Procedures

There have been many studies designed to provide validity evidence for evaluating students' attitudes towards a single discipline or integrated STEM areas at different levels of the education system (e.g., Adams et al., 2006; Lent et al., 2008). Although there were a limited number of studies attempting to investigate students' STEM attitudes during the K-12 school year, some new assessments still show promise (e.g., Unfried et al., 2015).

In the previous research, the S-STEM survey which developed from North Carolina State University was used to assess primary students' STEM attitudes (Unfried et al., 2015; Zhou et al., 2019). Within the entire S-STEM survey, there are 26 items assessing students' STEM attitudes based on three dimensions: science (9 items), math (8 items), and engineering and technology (9 items) (Yerdelen et al., 2016). The survey also contains 11 items assessing students' 21st century skills. As this subscale was not relevant to the present research, it was not introduced and analyzed below. Each dimension consists of both self-efficacy items, such as 'I am sure I could



do advanced work in math', and expectancy-value items such as 'I will need a good understanding of math for my future work' (Wiebe et al., 2018). Table 2 describes items representing the attitudes towards different disciplines and the statements comprising categories. The S-STEM survey uses a five-point Likert scale from strongly disagree to strongly agree on a scale of 1 to 5.

Table 2

Descriptions and Categories of Items in S-STEM Survey

Discipline categories	Statements comprising categories	
	Self-efficacy	Expectancy-value
Math	1,3,4,5,7,8	2,6
Science	9,14,16	10,11,12,13,15,17
Engineering and Technology	18,20,21,23,26	19,22,24,25

The S-STEM survey has an upper primary version for 4th and 5th graders in primary schools as described in the previous research (Wiebe et al., 2018). The validity evidence on the S-STEM survey has been proved by previous research studies (Unfried et al., 2015; Luo et al., 2019). In the present research, this version has been translated into Chinese as simple and suitable, as possible for lower primary graders by two of the researchers. It took each student about 20 minutes to complete the S-STEM survey. Especially for first and second graders, the teacher needed to read each item when necessary to make sure the meanings of all items were understood by students (Zhou et al., 2019).

Data Analysis

SPSS Statistics was applied for the test on S-STEM to establish their reliability evidence. The reliability (Cronbach's alpha) coefficient was .896, indicating sufficient consistencies in the outcome of the test in present research. The data support the use of the S-STEM survey for the investigation. Besides, various categories of student attitudes towards STEM across genders and grades (lower primary students and upper primary students) are compared, using the analysis of variance (ANOVA) statistic and the independent sample *t*-test statistic. Also, the correlation analysis and linear regression analysis were used to test the correlation between primary students' self-efficacy and expectancy-value beliefs towards STEM subjects.

Research Results

Students' STEM Domain-specific Self-efficacy and Expectancy-value Beliefs

The overall mean score of the whole population in the STEM survey was higher than 3 ($M=3.61$, $SD=.81$), indicating a positive exhibition of students' STEM attitudes. One of the research aims was to explore whether primary students exhibited different attitudes towards three sub-dimensions as science, mathematics, and engineering/technology. Therefore, this research compared students' performances on the overall STEM attitudes and different categories of attitudes including self-efficacy and expectancy-value, across three different sub-dimensions of STEM areas.



Table 3*Correlation Matrix for Attitudinal Constructs within Students' STEM Domain-specific Attitudes Profile*

	<i>N</i>	STEM attitudes Mean Score (SD)	Self-efficacy Mean Score (SD)	Expectancy-value Mean Score (SD)	Correlation coefficient between Self-efficacy and Expectancy-value
Total		3.61(.81)	3.64(.88)	3.54(.95)	
Mathematics	181	3.61(.81)	3.66(.92)	3.45(1.02)	.374**
Science		3.52(.81)	3.55(.88)	3.50(.91)	.628**
Engineering/ Technology		3.69(.81)	3.70(.85)	3.68(.90)	.742**
F		2.14	1.37	2.84	
p-value		.118	.255	.059	
η^2		.008	.005	.010	

** $p < .01$

Table 3 illustrates the descriptive statistics of students' performances on the sub-dimensions of students' STEM attitudes. The mean (*M*) and standard deviation (*SD*) of the scores are presented, along with the results of analysis of variance (ANOVA) statistic. For the overall STEM attitudes, students achieve a little higher mean score in engineering/technology domain than those in the science and mathematics areas. As shown in table 3, students' performance in engineering/technology domain has the highest construct average ($M=3.69, SD=.81$), followed by the mathematics domain ($M=3.61, SD=.81$), while student performance in science domain has the lowest average ($M=3.52, SD=.81$). However, no significant effect was detected on STEM domains for overall STEM attitudes ($F(2,540)=2.14, p=.118, \eta^2=.008$). Although students performed a little better in engineering/technology domain than in both mathematics and science domains, there were no detected significant effects for the self-efficacy category ($F(2,540)=1.37, p=.255, \eta^2=.005$) and for the expectancy-value category ($F(2,540)=2.84, p=.059, \eta^2=.010$) among three different sub-dimensions of STEM areas.

Another aim of this research was to examine the correlation between self-efficacy belief and expectancy-value belief in STEM academic domains. In order to explore whether there was a correlation between primary students' STEM self-efficacy and expectancy-value beliefs, a liner correlation analysis was applied. From the results of the correlation test in Table 3, for the science attitudes, there was a moderate correlation between self-efficacy and expectancy-value beliefs ($r=.628^{**}$). Also, a significant positive correlation existed between self-efficacy and expectancy-value beliefs for attitudes towards engineering/technology domain ($r=.742^{**}$). In addition, the correlation between mathematics self-efficacy and expectancy-value beliefs was much more weaker ($r=.374^{**}$).

Differences of Students' STEM Domain-specific Attitudes in terms of Genders or Grade levels

The second goal of the research was to explore whether primary students exhibited different attitudes towards various STEM domains among groups in terms of genders or grade levels. Thus, students' performances were compared not only on the overall STEM attitude, but also on both the self-efficacy category and the expectancy-value category according to gender and grade level. In terms of grade levels, as introduced in the previous research (Zhou et al., 2019), students in the primary level were categorized as lower primary group with students from grade one to grade three and upper primary group with students from grade four to grade six.



Table 4
The Mean Score for Each Group of Students and the T-test Statistic Results

	N	STEM attitudes Mean Score (SD)				Self-efficacy Mean Score (SD)				Expectancy-value Mean Score (SD)			
		Boys	Girls	Lower primary group	Upper primary group	Boys	Girls	Lower primary group	Upper primary group	Boys	Girls	Lower primary group	Upper primary group
Overall		3.64(.63)	3.52(.53)	3.71 (.59)	3.52 (.60)	3.69(.89)	3.53 (.85)	3.74 (.87)	3.56 (.89)	3.55(.97)	3.53(.91)	3.62 (.96)	3.48 (.94)
t (p)		1.25(.211)		2.07(.040)		1.86(.064)		2.26(.024)		.141(.888)		1.75(.080)	
Mathematics		3.69(.83)	3.43(.73)	3.76(.73)	3.49(.85)	3.78(.94)	3.40 (.84)	3.85(.83)	3.52(.97)	3.43(1.04)	3.51(.99)	3.51(1.06)	3.41(1.00)
t (p)		2.02(.045)		2.32(.022)		2.55(.012)		2.42(.016)		-.480(.631)		.627(.531)	
Science	181	3.52(.84)	3.49(.76)	3.57(.84)	3.47(.79)	3.54(.87)	3.58(.90)	3.54(.95)	3.57(.81)	3.51(.95)	3.45(.82)	3.58(.95)	3.43(.88)
t (p)		.227(.821)		.769(.443)		-.259(.796)		-.267(.790)		.457(.649)		1.15(.250)	
Engineering/ Technology		3.72(.82)	3.63(.80)	3.80(.74)	3.60(.86)	3.74(.87)	3.62 (.80)	3.82(.79)	3.60(.89)	3.69(.90)	3.64(.91)	3.77(.85)	3.60(.94)
t (p)		.688(.492)		1.66(.099)		.871(.385)		1.75(.082)		.368(.714)		1.32(.190)	

Table 4 presents the mean score for each group of students and the results of t-test statistic. In terms of genders, there was no significant difference between boy students and girl students in the overall STEM attitudes, the overall self-efficacy beliefs, and the overall expectancy-value beliefs, regardless of different STEM domains. While in terms of grade levels, lower primary students performed significantly better than upper primary students not only in the overall self-efficacy category ($t=2.26$, $df=179$, $p=.024$), but also in the overall STEM attitude ($t=2.07$, $df=179$, $p=.040$), with the later result clearly identified in the previous result (Zhou et al., 2019). However, in the overall expectancy-value category, although lower primary students ($M=3.62$, $SD=.96$) achieved a little higher mean score than upper primary students ($M=3.48$, $SD=.94$), no statistically significant difference was consistently detected between the two groups ($t=1.75$, $df=179$, $p=.080$).

In regard to student attitudes towards various STEM domains, the statistical data in science and engineering/technology domains indicated that there was no significant difference either between boy students and girl students or between lower primary students and upper primary students in the overall STEM attitude, the overall self-efficacy category, and the overall expectancy-value category.

However, considering the mathematics attitude, the statistical value indicated that there was a significant difference ($t=2.02$, $df=179$, $p=.045$) between boy students and girl students, with better performance of boy students ($M=3.69$, $SD=.83$) than that of girl students ($M=3.43$, $SD=.73$). Meanwhile, a significant effect was detected in terms of grade levels of mathematics attitude ($t=2.32$, $df=179$, $p=.022$), indicating that students in lower primary group ($M=3.76$, $SD=.73$) performed much better than students in upper primary group ($M=3.49$, $SD=.85$). Obviously, the differences were mainly reflected in the mathematics self-efficacy beliefs among groups in terms of genders ($t=2.55$, $df=179$, $p=.012$; boys: $M=3.78$, $SD=.94$; girls: $M=3.40$, $SD=.84$) and grade levels ($t=2.42$, $df=179$, $p=.016$; lower: $M=3.85$, $SD=.83$; upper: $M=3.52$, $SD=.97$), with higher scores of boy students and students in the lower primary group. According to the analysis, boy students were more confident in mathematics than girl students, as well as students in lower primary group showed more confidence in mathematics than those in upper primary group. Besides, no statistical significance was detected in mathematics expectancy-value beliefs, regardless of gender or grade level.

Discussion

Discussion on Students' STEM Domain-specific Self-efficacy and Expectancy-value Beliefs

Given that most studies have concentrated in assessing students' overall STEM attitudes or the attitudes towards individual STEM discipline, the present research aimed to address some of the gap in the literature review by surveying primary school students' attitudes towards various STEM domains including science, mathematics, and engineering/technology. The results suggest that there is no significant effect not only on overall STEM attitudes but also on both the overall self-efficacy beliefs and overall expectancy-value beliefs among these three domains for primary school students. It has been mentioned above that little research has focused on STEM attitudes involving primary students, especially the lower graders (Zhou et al., 2019). In the literature database, there is a small part of studies focusing on middle school students' STEM attitudes (Wiebe et al., 2018; Unfried et al., 2014), while a large part of studies concentrate on measuring STEM attitudes of high school students and college students (Fraser, 1978; Simpkins et al., 2006; Speering & Rennie, 1996; Wang, 2012; 2013), possibly because the latter population is directly related to career choice after graduation. As revealed in previous studies, middle-school students considered science more difficult and unpleasant than other STEM domains (Mooney & Laubach, 2002). As well, another research found that middle school students had less career interest in engineering than mathematics and science (Lederman & Lederman, 2013). When comparing the present results of STEM domain-specific attitudes among primary school students with the related results in previous studies involved other graders, inconsistencies are found. It is important to note in the present research that students in primary school showed no difference on both the self-efficacy beliefs and expectancy-value beliefs. After further analyzing the career interest within the expectancy-value beliefs of mathematics (item 2: "When I am older, I might choose a job that uses math"), science (item 10: "I might choose a career in science"), and engineering/technology (item 26: "I believe I can be successful in engineering"), it is found that there is a significant effect ($F(2,540)=4.86, p=.008, \eta^2=.018$) among different STEM subjects in terms of career interest, with lower mean scores in math domain ($M=3.24, SD=1.24$) and science domain ($M=3.39, SD=1.36$), and a higher mean score in engineering/technology domain ($M=3.66, SD=1.23$). Post-hoc comparisons identified that student's career interest in engineering/technology domain is significantly higher than math domain and science domain. In other words, the engineering/technology area is the most popular among primary school students. The possible reason is that mathematics and science have long been regarded as the most fundamental disciplines, belonging to the accumulation and reserve of basic knowledge of other disciplines; engineering and technology, on the other hand, are highly technical fields, which are popular career choices in China.

From the perspective of the relationship between primary students' STEM self-efficacy and expectancy-value beliefs, there are different correlations between these two categories of STEM attitudes regarding to different STEM domains. Most encouraging, self-efficacy and expectancy-value beliefs are strongly correlated for engineering/technology domain. Moreover, a borderline strong correlation is shown between self-efficacy and expectancy-value beliefs for science domain. Note that a weaker correlation for mathematics suggests that students' mathematics expectancy-value is not strongly associated with their self-efficacy beliefs comparing to science and engineering/technology. In comparison, having been reported in the previous studies, there were moderate or even negative correlations among various variables of STEM attitudes (Johnpaul et al., 2018). Also, little relation has been found between self-efficacy and outcome expectancies in STEM-related domains (Maddux et al., 1986). However, based on the evidence of the positive correlations in the present research, it appears to have strong association between self-efficacy and expectancy-value in the science domain and engineering/technology domain in the primary population. It suggests that primary students are more likely to show expectancy-value in STEM fields if they have success in science or high self-efficacy in engineering/technology. These results provide evidence to support that STEM self-efficacy could be considered as a predictor of expectancy-value (Fouad & Smith, 1996) and it is in line with the viewpoint that having high expectancy-value beliefs is associated with the student's STEM academic success (Scott & Mallinckrodt, 2005), mainly in science and engineering/technology domains.

Discussion on the Differences of Students' STEM Domain-specific Attitudes in Terms of Genders or Grade Levels

As demonstrated in the previous research, there was no gender difference in students' overall STEM attitudes, but lower primary students exhibited better STEM attitudes than upper primary students (Zhou et al., 2019). The current research is a more progressive analysis of student performances on STEM domain-specific attitudes.



As evident from the data, the grade difference in overall STEM attitude was contributed by grade difference in mathematics attitude, as primary students did not perform significant difference in both science attitude and engineering/technology attitude in terms of grade level. Consistently, the grade difference in overall self-efficacy beliefs was only caused by grade difference in mathematics self-efficacy beliefs. As well, although no significant difference was found between boy students and girl students in the overall STEM attitudes and the self-efficacy beliefs, gender difference still remained significant in mathematics overall attitudes and self-efficacy beliefs. This finding has been confirmed in the previous literature reviews (Eddy & Brownell, 2016; Cheryan et al., 2017).

However, as detailed earlier in the review of grade difference of various STEM disciplines attitudes, there was a general decline in science and engineering/technology attitudes as school progress for elder students (Ali et al., 2013; Potvin & Hasni, 2014a; Said et al., 2016), but mathematical attitude was relatively stable over time from upper primary school through higher grades (Unfried et al., 2014). It is worth noting that the present result in primary school population is inconsistent with, or even contrary to, the previous findings in the elder group. The underlying reason for the differences in STEM domain-specific attitudes may be the different teaching standards and assessment standards set by the Ministry of Education (MoE) for various STEM disciplines in primary school in China. Mathematics, along with Chinese and English, is positioned as the key discipline for teaching assessment at each school year and selection of outstanding students at the end of primary school. With the growth of grade, the increasing learning difficulty of mathematics might be directly associated to the decline of students' attitude of mathematics. Whereas, science and engineering/technology are relatively inferior disciplines, which are not included in the assessment and selection requirements from grade 1 through grade 6 in primary school. Therefore, students' attitudes towards science and engineering/technology are comparatively stable throughout the primary school years, as most students consider these disciplines to be less formal. In addition, gender had an impact on primary students' mathematics attitude but not their science and engineering/technology attitudes. The analysis of gender and grade differences in STEM domain-specific attitudes among primary students, which was not covered in the previous literature (Zhou et al., 2019; Unfried et al., 2014), may serve as an extension of the related research.

In the aspect of expectancy-value beliefs of STEM attitudes, it is found that primary students showed no different value in their expectancy beliefs across genders and grade levels in various STEM domains. Although lower and upper primary students showed different levels of self-efficacy beliefs, they did not differ in how much they value STEM domains. For genders, the present findings support the view of no gender differences in the expectancy-value levels of STEM (Eccles, 2009). Especially in mathematics, students' different senses of self-efficacy in terms of genders or grade levels did not influence their mathematics expectancy-value beliefs. However, it has been pointed out that boy students achieved higher level STEM expectancy-value beliefs as school progress (Watt et al., 2012; Yee & Eccles, 1988). Thus, it still needs to advocate that both self-efficacy and expectancy-value should deserve enough attention. It has been identified in most studies that the majority of students who major in STEM fields were directly affected by their growing STEM attitudes in late childhood and early adolescence (Wang 2013). The formation and cultivation of students' STEM self-efficacy and expectancy-value in the early school are associated to their later STEM degrees and STEM career aspirations.

Conclusions

The present analysis extends the previous research to gender and grade differences of students' STEM domain-specific attitudes including self-efficacy beliefs and expectancy-value beliefs in primary school years, and their correlations. On the one hand, the results suggest there are no significant effects among these three STEM domains in the overall attitudes, the overall self-efficacy beliefs, and the overall expectancy-value beliefs for primary students. The correlations between self-efficacy and expectancy-value are much stronger for the science domain and engineering/technology domain than the mathematics domain. On the other hand, no gender difference of the self-efficacy beliefs was detected except in the mathematics domain, and the result that lower primary students performed significantly better than upper primary students in the self-efficacy was also mainly contributed by the grade difference in the mathematics domain. However, no different expectancy-value beliefs existed across genders and grade levels in various STEM domains.

The present research reported some inconsistent results in the primary school year with those in the elder group. For example, it was addressed in the previous result that middle-school students considered science more difficult and unpleasant than other STEM domains, but no significant effect has been found among STEM domain-specific attitudes in primary school. For another example, it has been pointed out that boy students achieved higher



level STEM expectancy-value beliefs as school progress, whereas the present finding showed no gender differences in STEM expectancy-value levels across genders for primary students. In addition, as detailed earlier in the review, there was a stable mathematical attitude and a general decline in science and engineering/technology attitudes as grade grow, while the grade difference of STEM attitudes was only caused by grade difference in mathematics attitude in the present research. Except for the underlying reasons towards the STEM educational reality in China that has been addressed above, more attention should be paid to the primary school population, especially the lower graders, because the period of primary school plays an essential role in their future choices of STEM courses and their interests in STEM careers.

Obviously, the present research also has its limitations. For example, the participants of this research were from a primary school in a province of China, and there is a lack of data collection in a wider scope to enhance the credibility of the research conclusions. In addition, the research did not track and record the performances of primary school students' STEM domain-specific self-efficacy and expectancy-value beliefs with the development of grade in a long-term way, therefore it is impossible to know how the STEM domain-specific attitudes of the same participant groups change with the increase of age. These limitations are expected to be fully explored and improved in future research.

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Declaration of Interest

Authors declare no competing interest.

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