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THE EFFECT OF STUDENTS' ATTITUDE TOWARDS SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS ON 21ST CENTURY LEARNING SKILLS: A STRUCTURAL EQUATION MODEL

Shao-Rui Xu,
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Abstract. *It is crucial to educate students on the basis of science, technology, engineering, and mathematics (STEM) education to develop 21st century learning skills. However, there is little research on the contribution of the attitude towards STEM specific discipline to 21st century learning skills. This study aimed to examine the extent to which students' attitude towards science, technology, engineering, and mathematics (STEM) contributes to 21st century learning skills. Data were collected from 779 students from three primary schools and two secondary schools with the S-STEM questionnaire. Quantitative data were analyzed with structural equation modelling. The results revealed that (a) students' science attitude, and engineering and technology attitude had positive effects on 21st century learning skills, and (b) students' science attitude and mathematics attitude positively affected 21st century learning skills indirectly through the mediating role of technology and engineering attitude, and (c) the school year partially played a moderating role. The finding highlights the importance of valuing STEM attitude across disciplines. In particular, students' engineering and technology attitude is more conducive to improving students' 21st century learning skills. It also suggests the need to pay attention to the changing effect of STEM attitude on 21st century learning skills driven by the school year.*

Keywords: *21st century learning skills, mediating role, STEM attitude, structural equation modelling*

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Introduction

The sustainability of economic growth and the achievement of prosperity for countries are facing more and more challenges in the 21st century. One of the challenges is the shortage of the highly-competent human resource with 21st century skills, such as creativity, critical thinking, collaboration and communication (the 4-Cs), to prepare individuals to survive and compete in the digital era (International Technology and Engineering Educators Association [ITEEA], 2020; Australian Education Council, 2015; Bybee, 2010). In the fields of science, engineering, mathematics, and technology (STEM), there is an increasing demand for creative individuals who can think, question, and produce. In the workforce market, it was reported that the demand for STEM occupations would increase by 8% between 2013 and 2025 (Caprile et al., 2015). However, the demand for the labor force in STEM-related fields is not being adequately met (Moakler & Kim, 2014). In contrast to the prospective demand in the labor market, there is a shortage of engineers in specific areas, such as software, electromagnetics, maintainability, structures, and manufacturing engineering (Xue & Larson, 2015). Although there is a likelihood that the statistics could be altered over time, the current statistics clearly demonstrate that a significant shortage of engineers would last for a long period unless more students are encouraged to engage in the engineering field.

It is argued that by integrating science, technology, engineering, and mathematics (STEM) education through innovative projects, 21st century learning skills will keep up with the development of society (Beswick & Fraser, 2019; Karahan, 2019). To equip students with 21st century learning skills, STEM education, whose goal is to develop students' skills in logical reasoning, problem solving and collaboration, is a good medium to train students to meet the need of the 21st century workforce (Moore, 2009). STEM education can synthesize the information that students have learned and strengthen their understanding. By integrating science, technology, engineering and technology, STEM education embodies interdisciplinary learning, which is the foundation of 21st century curricula. The demand for the development

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of 21st century learning skills requires the establishment of new pedagogical and content-based education objectives and promotes students' positive attitude towards STEM learning (Voogt et al., 2013). Based on these facts, it is crucial to educate students on the basis of STEM education to develop 21st century learning skills.

Literature Review

21st century learning skills

The 21st century is an era that increasingly requires students to possess the skills such as critical thinking, problem solving, collaboration and active learning, which are referred to as 21st century learning skills (Partnership for 21st century skills, 2006; 2021). Students need to prepare to solve different kinds of problems arising from unforeseen circumstances and handle issues that have not yet arisen. 21st century learning skills are considered as lifelong learning skills which could enable students to get familiar with their changing living conditions and become more responsive (OECD, 2005). The fundamental skills that individuals should possess in the 21st century are life and career skills, knowledge, media, and technology skills, and learning and innovation skills (Partnership for 21st century learning skills, 2019). Thus, 21st century learning skills are essential for personal and social success (Rotherham & Willingham, 2010).

In the 21st century, students should be evaluated not only by testing the ability of answering questions, but also by their level of knowledge and ability to apply their 21st century learning skills. According to the Metiri Group and NCREL (2003), 21st century learning skills can be useful when the younger generation faces challenges from the industrial society, the global economy, the influx of high technology, as well as the overflow of global information. The purpose of education is to prepare students for a future that needs constant learning and active use of 21st century learning skills (Krskova et al., 2020; Mutiani & Faisal, 2020; Park & Suh, 2020). Therefore, it is important to augment students' ability of 21st century learning skills in the current educational system, especially in STEM education.

STEM Pipeline Leakage

In recent years, leaks from current STEM pipelines have been reported in many countries (Ball et al., 2017; Doerschuk et al., 2016). The STEM pipeline is a common metaphor used to express the flow of students and culminate in STEM as a career (Allen-Ramdial & Campbell, 2014). As the school year grows, students tend to flee the STEM pipeline. A number of studies have reported that older graders' attitude towards STEM is less positive compared to younger graders' attitude (Potvin & Hasni, 2014a; Unfried et al., 2014). It is noted that in high education institutions, the number of students choosing STEM-related majors is not up to expectations (Shapiro & Sax, 2011). It is stated that more students abandon the STEM-related majors that they initially choose compared to other fields (Reinhold et al., 2018).

The leakage of STEM pipelines could occur in different K-12 school years. It is stated that compared with upper primary students, lower primary students have a more positive attitude towards STEM (Zhou et al., 2019). Unfried et al. (2014) concluded that attitude towards science became decreasing after a longitudinal study from primary school to middle school. Students' attitude towards STEM is evident at thirteen years old and boosting students' attitude towards STEM at a later age becomes difficult (Lindahl, 2007). Another longitudinal study has revealed a steady decline in students' attitude towards STEM as students transition into early high school (Speering et al., 1996). The school year which has been considered as an important influencing factor on STEM attitude (Wiebe et al., 2018), may be the source of leaks from the STEM learning pipelines.

STEM attitudes

Due to the continuous research on students' attitude, the understanding of students' attitude continues to deepen (Luo et al., 2019). From the perspective of the STEM field, the literature of the research concentrates on students' attitude not only towards STEM as a whole, but also towards an independent STEM discipline (Unfried et al., 2014). It is necessary to systematically collect data on the students' attitude across different STEM fields (Minner et al., 2012). An instrument was created by Erkut and Marx (2005) for assessing the attitude towards multiple STEM fields. With this instrument, Johnpaul et al. (2018) further measured students' attitude towards various STEM

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disciplines to understand their differences and similarities. Another instrument was developed by Faber et al. (2013) to investigate K-12 students' attitude towards STEM disciplines, as well as 21st century learning skills and STEM career pathways. Wiebe et al. (2018) addressed the gap by using the S-STEM questionnaire focusing on student attitudes towards all STEM subjects.

There is also an impressive amount of research literature on students' attitude towards independent STEM disciplines (Gardner, 1975; Osborn et al., 2003; Potvin & Hasni, 2014). Typically, researchers are primarily concerned with students' interest in mathematics or science. Regarding mathematics, the Attitudes towards Mathematics Survey (Miller et al, 1996) was developed to assess students' attitude towards mathematics. The Test of Science-Related Attitudes (TOSRA) was created to assess students' attitude towards science during secondary education (Fraser, 1978). Affective Elements of Science Learning Questionnaire is another instrument to investigate students' attitude towards science (Williams et al., 2011). However, few studies have looked at students' attitude towards technology and engineering fields (Johnpaul et al., 2018). The technology aspect of STEM is inclined to be treated as a toolkit that integrates technology into mathematics and science, rather than as an independent discipline of STEM (Kennedy et al., 2018). Lederman and Lederman (2013) posed a question of whether only mathematics and science were worthy of attention, instead of integrating technology and engineering as individual disciplines into STEM.

Factors influencing 21st century learning skills

The conceptual frameworks of 21st century learning skills are addressed by the organizations including the Metiri Group and NCREL (2003), the Organization for Economic Cooperation and Development (2005), the Partnership for 21st century skills (2006; 2021), and the American Association of Colleges and Universities (2007). All of the conceptual frameworks concentrate on the demand to combine 21st century learning skills with the core content of disciplines, including science, mathematics, technology and engineering. Increasing 21st century skills through STEM education has been focused among educators (Bybee, 2010; Jang, 2016; Li et al., 2019). The acquisition of 21st century learning skills calls for more innovative supports from STEM education to improve learning effectiveness. Li et al. (2019) posited that students can develop thinking skills in a new way in STEM education and that these new thinking skills are connected to 21st century skills. Accordingly, teachers are required to enhance learners' positive attitude through integrating science and engineering practices in their classrooms, which can explicitly improve students' 21st century learning skills (Kelley et al., 2020; NGSS Lead States, 2013; NRC, 2012).

According to a meta-analysis performed by Lent et al. (2018) using data from 143 studies, the social cognitive career theory (SCCT) model has been applied in disciplinary STEM education, and the relationships between attitude and career interest have received support overall. It has been reported that students' positive attitude towards STEM has a significant impact on the realization of STEM education objectives and 21st century learning skills acquisition (Luo et al., 2019; Mahoney, 2010; Tseng et al., 2013). For STEM attitude, the existing research mainly focuses on its effect on learning effectiveness (Han et al., 2021), or concentrates on the comparison of differences in STEM attitude (Zhou et al., 2019). The other research also concentrates on the functional description of the effect of STEM attitude on 21st century learning skills learning (Akcanca, 2020). Contemporary educational standards indicate that students can enhance 21st century skills and develop confidence through the integration of STEM subjects. As all of the conceptual frameworks of 21st century learning skills address the critical underpinning of each core content discipline, maintaining positive students' attitude towards STEM specific discipline is one of the crucial supports. Therefore, it is necessary to explore the effect of students' attitude towards independent STEM disciplines on 21st century learning skills.

Research Aim

From the literature review, there is little previous research on the effect of the attitude towards STEM specific discipline to 21st century learning skills. The extent to which students' attitude towards STEM specific discipline contributes to 21st century learning skills is a matter of concern for the present research. According to the current situation of the primary and secondary school curriculum, science and mathematics are always independent subjects, while technology and engineering are usually not. Few studies have looked at students' attitude towards technology and engineering (Johnpaul et al., 2018; Wiebe et al., 2018). However, in the teaching of science and mathematics, technical skills and engineering thinking are often permeated. It is worth evaluating whether students' attitude towards STEM specific discipline directly affects 21st century learning skills, while students' science

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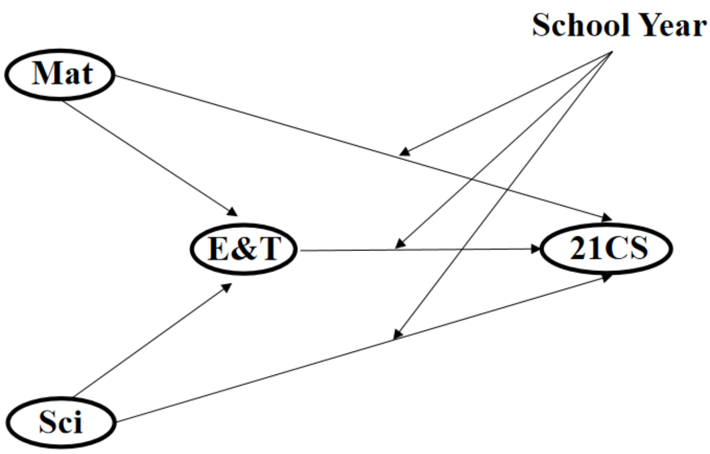
attitude and mathematics attitude also indirectly affect 21st century learning skills through the mediating role of technology and engineering attitude. Considering that students' technology attitude and engineering attitude were rarely separated in the previous studies (Johnpaul et al., 2018; Wiebe et al., 2018), those were integrated together as students' attitude towards technology and engineering in the present research.

Given that students may be inclined to flee the STEM pipeline as the school year grows, the impact of the school year is also an important factor. Whether the school year plays a moderating role in the effect of attitude towards mathematics, science, engineering, and technology on 21st century learning skills will be investigated as well.

The framework of factors influencing 21st century learning skills is shown in Figure 1. The following hypotheses were proposed in the current study:

- **H1**: Students' attitude towards mathematics, science, engineering, and technology has a positive direct effect on the attitude towards 21st century learning skills, and students' science attitude and mathematics attitude also affect 21st century learning skills through the mediating role of technology and engineering attitude.
- **H2**: School year plays a significant moderating role in the pathway of H1.

Figure1
The Framework of Factors Influencing 21st Century Learning Skills



Notes: The framework of factors influencing 21st century learning skills: Mat = mathematics attitude; E&T = engineering and technology attitude; Sci = science attitude; 21CS = 21st century learning skills.

Research Methodology

Assessment Tool

There have been several instruments designed to measure K-12 students' attitude towards a single STEM subject, such as TOSRA (Fraser, 1978) and ATMS (Miller et al., 1996). Also, the assessment of students' attitude towards multiple subjects has been developed. Erkut and Marx (2005) created an instrument that measured 8th-grade students' attitude towards multiple STEM subjects including engineering, mathematics, and science. Unfried et al. (2015) developed two questionnaires (S-STEM) to measure students' attitude towards STEM including science, engineering and technology, mathematics, and 21st century learning skills. One of the questionnaires Upper Elementary S-STEM is used to test 4th-grade through 5th-grade students and the other questionnaire Middle/High S-STEM is used to test 6th-grade through 12th-grade students. Both S-STEM questionnaires consist of four subscales with 37 items. Four subscales are listed as mathematics attitude (items from 1 to 8), science attitude (items from 9 to 17), engineering and technology attitude (items from 18 to 26), and 21st century learning skills (items from 27 to 37). Attitude towards 21st century learning includes items measuring students' confidence in communication, collaboration, and self-directed learning. Each S-STEM questionnaire uses a 5-point Likert-type response scale from

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strongly disagree to strongly agree. The reliability and validity evidence on the S-STEM questionnaire have been confirmed by Cronbach alpha value and confirmatory factor analysis (Luo et al., 2019; Unfried et al., 2015). Then the Upper Elementary S-STEM questionnaire was extended by Zhou et al. (2019) to test the 1st-grade through 6th-grade students' attitude towards STEM and proved to adequately cover the whole K-12 education system. Therefore, S-STEM questionnaire was opted as an assessment tool for assessing the relation between students' attitude towards STEM and 21st century learning skills in the present study. The Elementary S-STEM was for students from grade 1 to 6, and the Middle/High S-STEM was for students from grade 7 to 12.

Participants

As the present study aimed to explore whether school year plays a significant moderating role in the relation between STEM attitude and 21st century learning skills, students from primary schools and secondary schools were recruited. The formal sample included first- to twelfth-grade students from three primary schools and two secondary schools. One primary school and one secondary school locate in a province of southern China, and the other two primary schools and one secondary school locate in a province of northern China. In total, 410 primary students in 12 classes from three primary schools and 435 secondary students in 12 classes from two secondary schools were recruited for the research. The research program was introduced by one of our authors with the support of headteachers of each school. Students were informed before doing the S-STEM questionnaire that their responses were only for research purposes and their personal information would not be released. By eliminating blank and invalid responses, a total of 779 students were included in the study, with 380 students in the primary school group and 399 students in the secondary school group. Table 1 illustrates the statistics of the valid sample from the two groups. The sample of participants in the primary schools included students from grade one to grade six (249 boys and 131 girls). Of the participants in the primary group, 65.5% were male and 34.5% were female. In the secondary schools, there were 213 boys and 186 girls participating in the study. Of the secondary participants, 53.3% were male and 46.7% were female. The participating primary and secondary schools are all national public schools. Students in these primary and secondary schools are taught in accordance with the curriculum established by the Ministry of Education (MOE) in China.

Table 1
Demographics of Students at Each Grade for the Research Sample

Group	Grade	No. of Sample	No. of Male	No. of Female
Primary	1st	24	21	3
	2nd	60	44	16
	3rd	61	41	20
	4th	82	58	24
	5th	44	23	21
	6th	109	62	47
Secondary	7th	39	18	21
	8th	75	33	42
	9th	57	30	27
	10th	78	43	35
	11th	69	44	25
	12th	81	45	36
Total		779	462	317

Data Analysis

Data analysis in this study was conducted using Mplus version 8.3. The Cronbach's alpha coefficient was firstly examined to confirm the reliability of the data. Then, confirmatory factor analysis (CFA) using the Structural Equation Modelling (SEM) technique was applied to confirm the reliability and validity of the measurement model for

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the assessment. SEM is a statistical method to measure the direct and indirect effects between latent variables. To test hypothesis 1, the structural model was applied to the data. In the structural model, the coefficient of the path between constructs indicates the strength of the relationship and the R^2 value explains the variation in the endogenous variable caused by exogenous variables. The path coefficient and R^2 value determine whether the data represent the constructing model well (Wu & Chen 2017). In hypothesis 2, to evaluate the moderating role of the school year in the moderated mediation model, the latent moderated structural equations (LMS) approach was used to estimate the direct and indirect interaction effects, with respect to the estimates and 95% confidence intervals (CI). The significance of the interaction effects was computed using bootstrapping procedures.

Research Results

Preliminary Analyses

Table 2 presents the descriptive statistics of measurement items of S-STEM questionnaire. In the primary group, the skewness values of each item ranged between - .304 and - .083 and the kurtosis values of each item ranged between - .859 and 1.18. In the secondary group, the skewness values of each item changed between - .890 and - .269 and the kurtosis values of each item changed between - .556 and 2.25. According to the guidelines provided by Kline (2005), the distribution of the data is considered as the univariate normality distribution if the absolute skew is less than 3 and the absolute kurtosis is less than 10. On this basis, the data meet the assumption of univariate normality.

The Cronbach's alpha coefficient was calculated to measure the internal consistency reliability of the S-STEM test. The Cronbach's alpha coefficients for four scales of the whole test in Primary and Secondary are presented in Table 2. Specifically, the Cronbach's alpha coefficients of four scales for two groups were all greater than .807. According to the results, it can be argued that a sufficient level of internal consistency reliability for the instruments from two groups was demonstrated ($\alpha < .5$ unacceptable, $.5 \le \alpha < .6$ poor, $.6 \le \alpha < .7$ acceptable, $.7 \le \alpha < .9$ good, $\alpha > .9$ excellent) (George & Mallery, 2003).

Table 2
Descriptive Statistics and Reliability

Groups	Categories	Min	Max	*M*	*SD*	Skewness	Kurtosis	Cronbach's alpha
Primary	Mathematics	8	40	29.39	6.44	- .220	- .859	.807
	Science	9	45	32.01	7.16	- .083	- .192	.885
	Engineering	9	45	33.71	7.14	- .304	- .242	.853
	21st century learning skills	11	55	42.69	8.57	- .301	1.180	.872
Secondary	Mathematics	8	40	26.94	7.48	- .269	- .469	.926
	Science	9	45	33.38	6.97	- .399	.431	.924
	Engineering	9	45	31.32	7.54	- .357	- .556	.930
	21st century learning skills	11	55	42.39	8.21	- .890	2.25	.944

Measurement Model

The measurement model was evaluated by construct reliability and convergent validity using confirmatory factor analysis (CFA). Construct reliability was assessed with composite reliability (CR) value and convergent validity was assessed with average variance extracted (AVE) index. Given that the distribution of the data was considered as the univariate normality distribution, the maximum likelihood (ML) estimation technique was applied for CFA. For the one-dimensional measurement model, the CR values of the students' attitude towards mathematics, science, engineering and technology, and 21st century learning skills were .891, .904, .893 and .909 respectively. All of the CR values were greater than the threshold value of .70 (Fornell & Larcker, 1981), indicating that the internal

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structure of the latent factor with multiple indicators was reliable. The AVE index of students' attitude towards mathematics, science, engineering and technology, and 21st century learning skills were .516, .517, .482 and .479 respectively. Although the AVE index of students' attitude towards engineering and technology and 21st century learning skills were less than .5, both of the CR values were greater than .6, suggesting that the convergent validity of the construct was still adequate (Lam, 2012). The reliability and convergent validity show that the measurement model is acceptable.

The fit of the model was commonly assessed with c^2 values, root mean square error of approximation (RMSEA), comparative fit index (CFI) and standardized root mean square residual (SRMR). A good fit is indicated by $0 \le c^2/df \le 3$, $0 \le$ RMSEA $\le .05$, $.95 \le$ CFI ≤ 1 and $0 \le$ SRMR $\le .05$ and an acceptable fit is indicated by $0 \le c^2/df \le 5$, $.05 \le$ RMSEA $\le .08$, $.90 \le$ CFI $\le .95$ and $.05 \le$ SRMR $\le .10$. The fit indices of the present model ($c^2 = 1719.9$, $df = 623$, $c^2/df = 2.76$, $p < .001$, RMSEA = .048, CFI = .926, and SRMR = .048) demonstrated that the measurement model was acceptable ($c^2/df < 5$, RMSEA < .08, CFI > .90 and SRMR < .10).

Structural Model

Testing for the Mediating Effect in Hypothesis 1

For Hypothesis 1, it was anticipated that students' attitude towards mathematics, science, engineering, and technology had positive effects on 21st century learning skills, and students' mathematics attitude and science attitude indirectly affect 21st century learning skills through the mediating role of engineering and technology attitude. As expected, the structural model for hypothesis 1 applied an acceptable fit to the data ($c^2 = 1719.9$, $df = 623$, $c^2/df = 2.76$, $p < .001$, RMSEA = .048, CFI = .926, and SRMR = .048). Figure 2 shows the structural model of factors influencing 21st century learning skills.

Figure 2
The Effect of the STEM Attitude on 21st Century Learning Skills

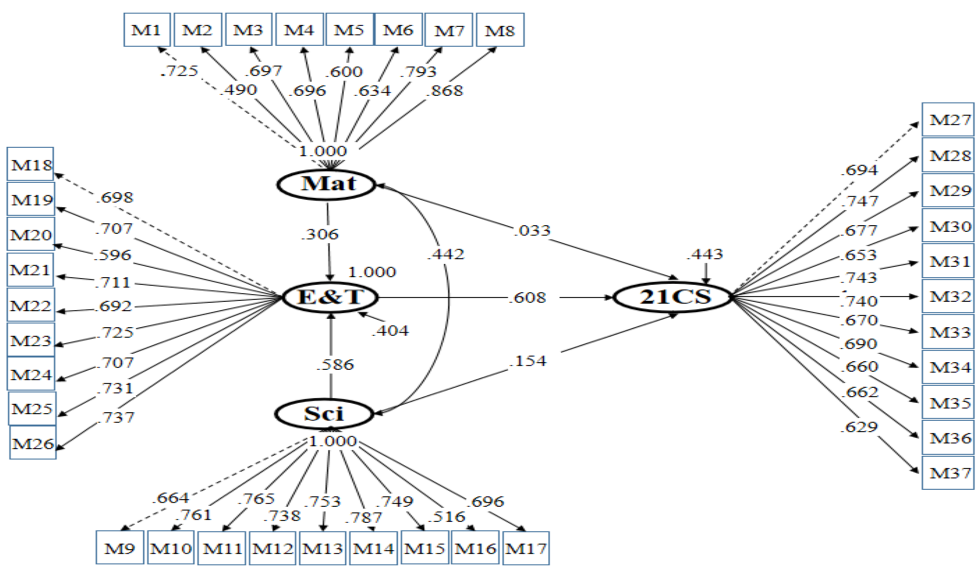

Table 3 illustrates the direct and indirect effects of students' attitude towards independent STEM disciplines on 21st century learning skills. According to Table 3, students' attitude towards engineering and technology (β = .608, $p < .0001$), and science attitude (β = .154, $p < .001$) were positively associated with 21st century learning skills. While students' mathematics attitude had insignificant direct relationship with 21st century learning skills (β = .033, $p = .363$). The Bootstrap method with 1000 resamples was applied to examine the mediating effect of

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engineering and technology attitude in the relationship between students' attitude towards mathematics and science and their 21st century learning skills. The indirect effect of mathematics attitude on 21st century learning skills with the mediating role of engineering and technology attitude was β = .186, $p < .001$, with 95% confidence interval [.134 .238]. The indirect effect of science attitude on 21st century learning skills with the mediating role of engineering and technology attitude was β = .356, $p < .001$, with 95% confidence interval [.278 .436]. The result suggested that both mathematics attitude and science attitude had positive effects on 21st century learning skills through attitude towards engineering and technology as a mediator.

Table 3
Results for the Direct and Indirect Effects in the Two Groups

Effects	Relationship	Point Estimate	95% bias-corrected CI
Direct Effect	E&T → 21st CS	.608***	[.490, .717]
	Mat → 21st CS	.033	[- .051, .121]
	Sci → 21st CS	.154**	[.043,.262]
Indirect Effect	Mat E&T → 21st CS	.186***	[.134, .238]
	Sci E&T → 21st CS	.356***	[.278, .436]

Notes: E&T = attitude towards engineering and technology; Mat = mathematics attitude; Sci = science attitude; 21st CS = 21st century learning skills; CI = confidence interval.
*$p < .05$, **$p < .01$, ***$p < .001$

The R^2 value for students' attitude towards mathematics, science, engineering, and technology to 21st century learning skills was .557; hence, 55.7% of the variance was explained. Based on the empirical analysis, it can be seen that the model of hypothesis 1 was a good fit and acceptable (Hayes 2013; Preacher & Hayes 2004). The result confirmed that attitude towards engineering and technology was both the dominant factor and the mediating factor for 21st century learning skills. And the evidence from the insignificant coefficient from mathematics attitude to 21st century learning skills attitude suggested that hypothesis 1 was partially supported.

Testing for the moderating effect of the school year in Hypothesis 2

Further analysis then shifted to estimating the moderating role of the school year, which constituted the second hypothesis of the current study. Hypothesis 2 predicted that the school year would moderate pathways in the mediation process of hypothesis 1. Considering that the direct effect of mathematics was not significant in hypothesis 1, the moderating effect of the school year was examined in the pathways of the relationships between science attitude and 21st century learning skills, and between engineering and technology attitude and 21st century learning skills. According to Table 4, the interaction term (Sci × School Year) had a significant positive impact on 21st century skills (β = .097, $p < .05$), indicating that the effect of science attitude on 21st century learning skills was moderated by different school years. Meanwhile, another interaction term (E&T × School Year) had a significant negative impact on 21st century learning skills (β = - .235, $p < .001$), indicating that the effect of students' attitude towards engineering and technology on 21st century learning skills was also moderated by different school years. Figure 4(a) displays the interaction of science attitude and school year in predicting 21st century learning skills and shows a greater predictive effect with the higher school year. For students at higher school year, a higher level of science attitude was related to higher 21st century learning skills. While Figure 4(b) displays the interaction of engineering and technology attitude and school year in predicting 21st century learning skills and the analysis of the slope indicated the relation between engineering attitude and 21st century learning skills weakened as the school year increased. For students at higher school year, a higher level of engineering and technology attitude was related to lower 21st century learning skills.

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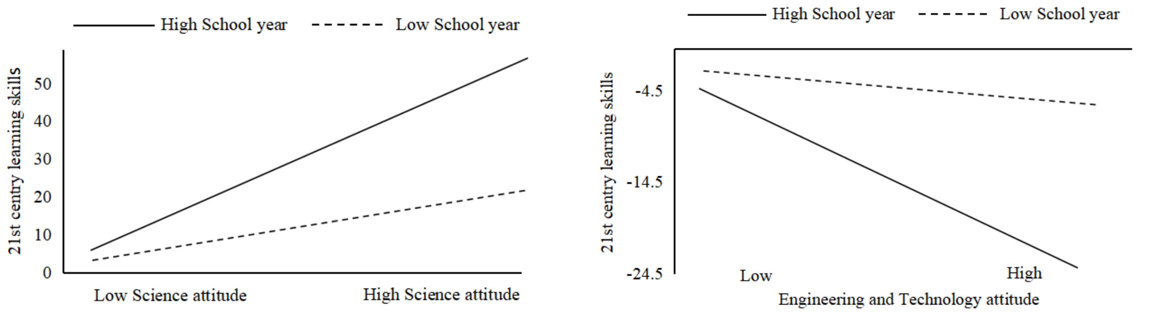
Table 4
Conditional Process Analysis

	Path Coefficient	Boot SE	*p*	95% CI
Outcome: 21st CS				
Predictor:				
School Year	.961	.200	<.001	[.787, 1.729]
E&T × School Year	- .235	.038	<.001	[- .333, -. 156]
Sci × School Year	.097	.042	.020	[.014, .178]

Figure 4
The Moderating Role of the School Year



(a) the interaction of science attitude and school year in predicting 21st century learning skills

(b) the interaction of engineering and technology attitude and school year in predicting 21st century learning skills

Further detailed data demonstrated different effects of students' STEM attitude on 21st century learning skills in the primary group and the secondary group. In general, the structural model fits were satisfactory with $c^2 = 1027$, $df = 623$, $c^2/df = 1.67$, $p < .001$, RMSEA = .041, CFI = .924, and SRMR = .050 for the primary group, with $c^2 = 1458$, $df = 623$, $c^2/df = 2.34$, $p < .001$, RMSEA = .058, CFI = .927, and SRMR = .058 for the secondary group (see Table 5).

Table 5
CFA Goodness-of-Fit Indices

Group	χ^2	*df*	χ^2/df	*p*	RMSEA	CFI	SRMR
Primary	1027	623	1.67	<.001	.041	.924	.050
Secondary	1458	623	2.34	<.001	.058	.927	.058

As seen in Table 6, in terms of direct effects, students' attitude towards engineering and technology was positively directly associated with 21st century learning skills in both the primary group ($\beta = .721$, $p < .0001$) and the secondary group ($\beta = .549$, $p < .001$). While Mathematics attitude significantly predicted 21st century learning skills for the primary group ($\beta = .160$, $p < .01$), but not for the secondary group ($\beta = -.049$, $p > .05$). In contrast, science attitude significantly predicted 21st century learning skills for the secondary group ($\beta = .269$, $p < .001$), but not for the primary group ($\beta = -.027$, $p > .05$). The results indicated that direct effects of mathematics attitude and science attitude on 21st century learning skills were not identical in different school years. In terms of indirect effects, the effect of students' mathematics attitude on 21st century skills through the mediating role of engineering and technology attitude was significant both in the primary group ($\beta = .127$, $p < .01$) and in the secondary group ($\beta = .177$, $p < .001$). As well, the indirect effect of students' science attitude on 21st century skills through the mediating role of engineering and technology attitude was significant both in the primary group ($\beta = .475$, $p < .001$) and in the secondary group ($\beta = .318$, $p < .001$).

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Table 6
Results for the Direct and Indirect Effects in Two Groups

Group	Effects	Relationship	Point Estimate	95% bias-corrected CI
Primary	Direct Effect	E&T → 21st CS	.721***	[.534, .855]
		Mat → 21st CS	.160**	[.046, .270]
		Sci → 21st CS	- .027	[- .160, .131]
	Indirect Effect	Mat → E&T → 21st CS	.127**	[.045, .230]
		Sci → E&T → 21st CS	.475***	[.350, .610]
Secondary	Direct Effect	E&T → 21st CS	.549***	[.386, .708]
		Mat → 21st CS	- .049	[- .178, .074]
		Sci → 21st CS	.269***	[.118, .429]
	Indirect Effect	Mat → E&T → 21st CS	.177***	[.113, .252]
		Sci → E&T → 21st CS	.318***	[.216, .432]

Notes: E&T = attitude towards engineering and technology; Mat = mathematics attitude; Sci = science attitude; 21st CS = 21st century learning skills; CI = confidence interval.
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Discussion

This present study aimed to identify the extent to which students' attitude towards STEM specific disciplines contributes to 21st century learning skills. The study hypothesized that students' attitude towards mathematics, science, engineering, and technology has a positive direct effect on the attitude towards 21st century learning skills, and students' science attitude and mathematics attitude also affect 21st century learning skills through the mediating role of technology and engineering attitude, as well the school year plays a moderating role in the above relationships.

The findings confirmed that STEM attitude positively affected 21st century learning skills, with a total direct effect of .795, indicating that students' positive attitude towards STEM had a significant impact on their development of 21st century learning skills. This result supports the previous research (Akcanca, 2020), which emphasized the importance of focusing on students' STEM attitude in developing their 21st century learning skills. By comparing students' STEM discipline-specific attitude, both science attitude and attitude towards engineering and technology had positive effects on 21st century learning skills, while mathematics attitude had no significant effect on 21st century learning skills. Previously, researchers have argued that attitude towards different STEM disciplines may lead to varied effects, and it is necessary to systematically look at data on attitude of students in different STEM fields (Minner et al., 2012). This viewpoint is clearly supported by the results of the hypothesis in the present research. The current finding is consistent with previous research highlighting the importance of valuing STEM attitude across disciplines. As Johnpaul et al. (2018) emphasized, trends of students' attitude towards different STEM disciplines are not identical, so it is critical to attach importance to the STEM attitude of each discipline. From the results of the research, students' STEM attitude towards different disciplines contributes differently to 21st century learning skills. In particular, students' attitude towards engineering and technology dominates the impact on 21st century learning skills with a coefficient of .608. It can be argued that students' attitude towards engineering and technology is more conducive to improving students' 21st century learning skills.

According to the first hypothesis, another aim was to verify the mediation model with the engineering and technology attitude as a mediator. The outcomes demonstrated that both students' mathematics attitude and science attitude had positive effects on 21st century learning skills through attitude towards engineering and technology as a mediator. The results of path analysis from students towards science attitude to engineering and technology attitude (0.586) and from engineering and technology attitude to 21st century learning skills (0.608) were both found to be significant. Therefore, the mediating effect of engineering and technology attitude between science attitude and 21st century learning skills was significant. The outcome supports the fact that improving students' science attitude could promote their 21st century learning skills by emphasizing their engineering and technology

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attitude. Besides, the path coefficients from students' mathematics attitude to engineering and technology attitude (0.306) and from engineering and technology attitude to 21st century learning skills were both significant (0.608). It suggests that although the direct effect of mathematics attitude on 21st century learning skills is not significant, its indirect effect is significant through the mediating role of engineering and technology attitude. This result emphasizes the contribution of engineering and technology attitude to 21st century learning skills, not only in terms of the direct effect but also in terms of the mediating effect. It could reduce the doubt of the previous study on whether attitude towards engineering and technology should be treated as an independent disciplinary attitude (Lederman & Lederman, 2013). Lederman and Lederman (2013) posed a question of whether only mathematics and science were worthy of attention, instead of integrating technology and engineering as individual disciplines into STEM. The concern is related to the lack of research on engineering and technology attitude as a STEM disciplinary attitude (Johnpaul et al., 2018). This research supports that attitude towards engineering and technology is important for 21st century learning skills and should be studied as an important dimension of STEM disciplinary attitude (Erkut & Marx, 2005; Johnpaul et al., 2018; Zhou et al., 2019; 2021). As well, it emphasizes the significance of the relationship between disciplines, in particular, the important role of engineering and technology attitude between science attitude and mathematics attitude and 21st century learning skills.

On the basis of previous outcomes, further research results confirmed the second hypothesis that school year partially moderated pathways in the mediation process of the first hypothesis. It can be seen that the direct effects of students' science attitude and engineering and technology attitude on 21st century learning skills were moderated by different school years. Given the dominant effect of engineering and technology attitude on 21st century learning skills and its decreasing effect with school year, it may mostly contribute to leaks from current STEM pipelines (Ball et al., 2017; Doerschuk et al., 2016). Since the effect of engineering and technology attitude on 21st century learning skills was negatively moderated by school year, it was not only directly weakened its direct effect on 21st century learning skills, but also indirectly weakened the effect of science attitude and mathematics on 21st century learning skills due to its mediating effect. The moderating role of the school year should not be ignored in the indirect pathway with the mediating role of engineering and technology attitude. As many studies have highlighted the fact that older students are less likely to have positive STEM attitudes than younger students, it is critical to pay close attention to the changing effect of learning attitude on 21st century learning skills driven by the school year (Potvin & Hasni, 2014a; Unfried et al., 2014).

Conclusions and Implications

This study aimed to examine the extent to which students' attitude towards science, technology, engineering, and mathematics (STEM) contributes to 21st century learning skills. The results of structural equation modelling analysis revealed that (a) students' science attitude, and engineering and technology attitude had positive effect on 21st century learning skills, and (b) students' science attitude and mathematics attitude positively affected 21st century learning skills indirectly through the mediating role of technology and engineering attitude, and (c) the school year partially played a moderating role. The results highlight the importance of valuing STEM attitude across disciplines. In particular, students' engineering and technology attitude is more conducive to improving students' 21st century learning skills. The finding further emphasizes the important role of engineering and technology attitude between science attitude and 21st century learning skills and between mathematics attitude and 21st century learning skills. It also suggests the need to pay close attention to the change in the impact of STEM learning attitude on 21st century learning skills driven by the school year.

Future work can be further expanded in the following three aspects: (1) The sample data covers a large span through k - 12, with a limited number of participants in each school year group. Future studies could increase the number of participants in each school year group to test for higher measurement reliability. (2) The impact of attitude towards engineering and technology on 21st century learning skills without considering the effect of gender as a moderating variable. Future research will continue to test whether gender plays a moderating role in the moderated mediation model. (3) The data for evaluating 21st century learning skills were obtained by students' self-report from a subjective point of view. In the later research, it is worth retrieving multi-dimensional data through the evaluation of students from their teachers and parents, or students' mutual evaluation. Efforts can also be made to design project-based programs for the evaluation of students' 21st century learning skills through practical problem-solving.

There were still some limitations in this study. Due to the lack of literacy and understanding ability of students

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in grades one and two, it was difficult to complete every item of the questionnaire independently. Hence, providing explanations for the questions to the first and the second graders may result in certain influences and limitations on the consistency of the research data. In addition, the research data of each sample group were only collected from two or three schools. The result only reflects the attitude and skills of students at a certain level, but not the evaluation of a larger span of population, nor the attitude and skill differences of students at a finer level. Moreover, the imbalance in the number of male and female students in the first grade will lead to the loss of reliable support for the design of taking gender as an adjusting variable in the subsequent study.

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Declaration of Interest

The authors declare no competing interest.

References

Akcanca, N. (2020). 21st century learning skills: The predictive role of attitudes regarding STEM education and problem-based learning. *International Journal of Progressive Education*, *16*(5), 443-458. https://doi.org/10.29329/ijpe.2020.277.27

Allen-Ramdial, S., & Campbell, A.G. (2014). Reimagining the pipeline: Advancing STEM diversity, persistence, and success. *Bioscience*, *64*(7), 612. https://doi.org/10.1093/biosci/biu076

American Association of Colleges and Universities. (2007). *College learning for the new global century*. Washington.

Australian Education Council. (2015). *National STEM School Education Strategy 2016-2026*. http://www.educationcouncil.edu.au/site/DefaultSite/filesystem/documents/National%20STEM%20School%20Education%20Strategy.pdf

Ball, C., Huang, K. T., Cotten, S. R., & Rikard, R. V. (2017). Pressurizing the STEM pipeline: An expectancy-value theory analysis of youths' STEM attitudes. *Journal of Science Education and Technology*, *26*(4), 372-382. https://doi.org/10.1002/sce.21108

Beswick, K., & Fraser, S. (2019). Developing mathematics teachers' 21st century competence for teaching in STEM contexts. *ZDM*, *51*(6), 955-965. https://doi.org/10.1007/s11858-019-01084-2

Bybee, R. W. (2010). Advancing STEM Education: A 2020 Vision. *Technology and Engineering Teacher*, *70*(1), 30–35.

Caprile, M., Palmen, R., Sanz, P., & Dente, G. (2015). *Encouraging STEM studies for the labour market*. Brussels: European Parliament. http://www.europarl.europa.eu/RegData/etudes/STUD/2015/542199/IPOL_STU%282015%29542199_EN.pdf

Doerschuk, P., Bahrim, C., Daniel, J., Kruger, J., Mann, J., & Martin, C. (2016). Closing the gaps and filling the STEM pipeline: A multidisciplinary approach. *Journal of Science Education and Technology*, *25*(4), 682-695. https://doi.org/10.1007/s10956-016-9622-8

Erkut, S., & Marx, F. (2005). *4 schools for WIE (Evaluation report)*. Wellesley College, Center for Research on Women. http://www.coe.neu.edu/Groups/stemteams/evaluation.pdf

Faber, M., Unfried, A., Wiebe, E. N., Corn, J., Townsend, L. W., & Collins, T. L. (2013, June). *Student attitudes toward STEM: The development of upper elementary school and middle/high school student surveys*. In 2013 ASEE Annual Conference & Exposition (pp. 23-1094). Atlanta, GA, United States. https://peer.asee.org/student-attitudes-toward-stem-the-development-of-upper-elementary-school-and-middle-high-school-student-surveys

Fraser, B. (1978). Development of a test of science-related attitudes. *Science Education*, *62*, 509-515. https://doi.org/10.1002/sce.3730620411

Gardner, P. L. (1975). Attitudes to science: a review. *Studies in Science Education*, *2*, 1-41. https://doi.org/10.1080/03057267508559818

George, D., & Mallery, P. (2003). *SPSS for windows step by step: a simple guide and reference*. Boston.

Hayes, A. (2013). *Introduction to mediation, moderation, and conditional process analysis*. New York.

Han, J., Kelley, T. & Knowles, J. (2021). Factors influencing student STEM learning: Self-efficacy and outcome expectancy, 21st century skills, and career awareness. *Journal for STEM Educational Research*, *4*, 117–137. https://doi.org/10.1007/s41979-021-00053-3

International Technology and Engineering Educators Association (ITEEA). (2020). *Standards for technological and engineering literacy: Defining the role of technology and engineering in STEM education*. Reston.

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology*, *25*(2), 284-301. https://doi.org/10.1007/s10956-015-9593-1

Johnpaul, K., Frances, Q., & Terry, L. (2018). The keys to STEM: Australian year 7 students' attitudes and intentions towards science, mathematics, and technology courses. *Research in Science Education*, *50*(5), 1805-1832. https://doi.org/10.1007/S11165-018-9754-3

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Karahan, E. (2019). *Stem education approach*. In A. G. Balım (Ed.), New Approaches in Science Education (pp. 171-186).

Kelley, T. R., Knowles, J. G., Holland, J. D., & Han, J. (2020). Increasing high school teachers' self-efficacy for integrated STEM instruction through a collaborative community of practice. *International Journal of STEM Education*, *7*, 1–13. https://doi.org/10.1186/s40594-020-00211-w

Kennedy, J., Quinn, F., & Lyons, T. (2018). Australian enrolment trends in technology and engineering: putting the T and E back into school STEM. *International Journal of Technology and Design Education*, *28*(2), 553-571. https://doi.org/10.1007/s10798-016-9394-8

Kline, R. B. (2005). *Principles and practice of structural equation modeling*. New York.

Krskova, H., Wood, L. N., Breyer, Y. A. & Baumann, C. (2020). *F.I.R.S.T: Principles of discipline for 21st century learning skills*. In L. Wood, L. P. Tan, Y. A. Breyer, & S. Hawse (Eds.), Industry and Higher Education: Case Studies for Sustainable Futures (pp. 265-289). Singapore. https://doi.org/10.1007/978-981-15-0874-5_12

Lam, L. W. (2012). Impact of competitiveness on salespeople's commitment and performance. *Journal of Business Research*, *65*(9), 1328-1334. https://doi.org/10.1016/j.jbusres.2011.10.026

Lederman, N. G., & Lederman, J. S. (2013). Is it STEM or "S & M" that we truly love? *Journal of Science Teacher Education*, *24*(8), 1237-1240. https://doi.org/10.1007/s10972-013-9370-z

Lent, R. W., Sheu, H. B., Miller, M. J., Cusick, M. E., Penn, L. T., & Truong, N. N. (2018). Predictors of science, technology, engineering, and mathematics choice options: A meta-analytic path analysis of the social–cognitive choice model by gender and race/ethnicity. *Journal of Counseling Psychology*, *65*(1), 17–35. https://doi.org/10.1037/cou0000243

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, L. D. (2019). On thinking and STEM education. *Journal for STEM Education Research*, *2*, 1–13 https://doi. org/10.1007/s41979-019-00014-x

Lindahl, B. (2007). *A longitudinal Study of students' attitudes towards science and choice of career*. Paper presented at NARST Annual Conference, April 15-18, 2007, New Orleans.

Luo, W., Wei, H. R., Ritzhaupt, A. D., Huggins-Manley, A. C., & Gardner-Mccune, C. (2019). Using the s-stem survey to evaluate a middle school robotics learning environment: validity evidence in a different context. *Journal of Science Education and Technology*, *28*(4), 429-443. https://doi.org/10.1007/s10956-019-09773-z

Mahoney, M. P. (2010). Students' attitudes toward STEM: development of an instrument for high school STEM-based programs. *Journal of Technology Studies*, *36*(1), 24–34. https://doi.org/10.21061/jots.v36i1.a.4

Metiri Group & NCREL. (2003). *enGauge 21st century learning skills: Digital Literacies for a Digital Age*. Chicago.

Miller, R. B., Greene, B. A., Montalvo, G. P., Ravindran, B., & Nichols, J. D. (1996). Engagement in academic work: The role of learning goals, future consequences, pleasing others, and perceived ability. *Contemporary Educational Psychology*, *21*(4), 388–422. https://doi.org/10.1006/ceps.1996.0028

Minner, D., Ericson, E., Wu, S., & Martinez, A. (2012). *Compendium of STEM Student Instruments PART II: Measuring Students' Content Knowledge, Reasoning Skills, and Psychological Attributes*. Abt Associates. https://cadrek12.org/sites/default/files/Compendium%20of%20STEM%20instruments%20Part%202_11-20-12.pdf

Moakler, M. W., & Kim, M. M. (2014). College major choice in STEM: Revisiting confidence and demographic factors. *Career Development Quarterly*, *62*(2), 128–142. https://doi.org/10.1002/j.2161-0045.2014.00075.x

Moore, B. (2009). Emotional intelligence for school administrators: A priority for school reform? *American Secondary Education*, *37*(3), 20-28. https://www.jstor.org/stable/41406313

Mutiani, M. & Faisal, M. (2020). Urgency of the 21st century learning skills and social capital in social studies. *The Innovation of Social Studies Journal*, *1*(1), 1-11. https://doi.org/10.20527/iis.v1i1.1256

National Institute of Literacy and the Small Business Administration. (1999). *21st century learning skills for 21st Century Jobs*. Washington.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

NGSS Lead States. (2013). *Next generation science standards*. National Academies Press.

OECD. (2005). *The definition and selection of key competencies executive summary*. Accessed 20 April 2019. https://www.oecd.org/pisa/35070367.pdf

Organization for Economic Cooperation and Development. (2005). *The definition and selection of key competencies: Executive summary*. Paris.

Park, E. K. & Suh, J. K. (2020). *Active learning using google suites for education to promote 21st-century learning skills*. Transforming Teaching Through Active Learning A National Symposium, Miami, Florida.

Partnership for 21st century skills. (2006). *A state leader's action guide to 21 st century skills: A new vision for education*. Tucson.

Partnership for 21st century Skills. (n.d.) http://www.p21.org/framework.

Potvin, P., & Hasni, A. (2014a). Analysis of the decline in interest towards school science and technology from grades 5 through 11. *Journal of Science Education and Technology*, *23*(6), 784-802. https://doi.org/10.1007/s10956-014-9512-x

Potvin, P., & Hasni, A. (2014b). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85-129. https://doi.org/10.1080/03057267.2014.881626

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers*, *36*(4), 717–731. https://doi.org/10.3758/BF03206553

Reinhold, S., Holzberger, D., & Seidel, T. (2018). Encouraging a career in science: A research review of secondary schools' effects on students' STEM orientation. *Studies in Science Education*, *54*(1), 1-35. https://doi.org/10.1080/03057267.2018.1442900

https://doi.org/10.33225/jbse/22.21.706

Rotherham, A. J., & Willingham, D. T. (2010). 21st-century skills. *American Educator*, *17*(1), 17-20.

Shapiro, C., & Sax, L. (2011). Major selection and persistence for women in STEM. *New Directions for Institutional Research*, *2011* (152), 5-18. https://onlinelibrary.wiley.com/doi/10.1002/ir.404

Speering, W., & Rennie, L. (1996). Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Education*, *26*(3), 283-298. https://link.springer.com/article/10.1007/BF02356940

Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(1), 87-102. https://doi.org/10.1007/s10798-011-9160-x

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (s-stem). *Journal of Psychoeducational Assessment*, *33*(7), 622-639. https://journals.sagepub.com/doi/10.1177/0734282915571160

Unfried, A., Faber, M., & Wiebe, E. (2014). *Gender and student attitudes toward STEM*. Presented at the AERA Annual Meeting, Philadelphia, PA. https://eval.fi.ncsu.edu/wp-content/uploads/2016/03/AERA-2014-Unfried-Faber-Wiebe.pdf

Wiebe, E., Unfried, A., & Faber, M. (2018). The relationship of STEM attitudes and career interest. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(10), em1580. https://doi:10.29333/ejmste/92286

Williams, K., Kurtek, K., & Sampson, V. (2011). The affective elements of science learning: A questionnaire to assess-and improve-student attitudes toward science. *Science Teacher*, *78*(1), 40-45. https://www.proquest.com/scholarly-journals/affective-elements-science-learning/docview/860711736/se-2?accountid=13741

Xue, Y., & Larson, R. C. (2015). *STEM crisis or STEM surplus? Yes and yes*. Monthly labor review.

Voogt, J., Erstad, O., Dede, C. & Mishra, P. (2013). Challenges to learning and schooling in the digital networked world of the twenty-first century. *Journal of Computer Assisted Learning*, *29*, 403-413. https://doi.org/10.1111/jcal.12029

Zhou, S., Zeng, H., Xu, S., Chen, L., & Xiao, H. (2019). Exploring changes in primary students' attitudes towards science, technology, engineering and mathematics (stem) across genders and grade levels. *Journal of Baltic Science Education*, *18*(3), 466-480. https://dx.doi.org/10.33225/jbse/19.18.466

Zhou, S., Chen, L., Xu, S., Lu, C., Li, Q., & Li, D. (2021). Primary students' performance of STEM domain-specific self-efficacy belief and expectancy-value belief. *Journal of Baltic Science Education*, *20*(4), 677-690. https://doi.org/10.33225/jbse/21.20.677

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