JOURNAL OF BALTIC SCIENCE EDUCATION

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

This is an open access article under the Creative Commons Attribution 4.0 International License

STEM ATTITUDE DISPARITY: THE IMPACT OF LEARNING EXPERIENCES IN VOCATIONALLY-ORIENTED POLYTECHNIC AND UNIVERSITY ON STUDENTS' SELF-EFFICACY, EXPECTANCY-VALUE, AND CAREER INTEREST

Shao-Rui Xu,
Shao-Na Zhou

Abstract. *Learning experiences are widely recognized as crucial in developing students' attitudes towards science, technology, engineering and mathematics. Vocationally-oriented polytechnics and universities provide distinct learning experiences that may significantly influence students' STEM self-efficacy, expectancy-value and career interest. The study explores how the unique learning experiences shape students' STEM attitudes among 487 students during their fourth semester at vocationally-oriented polytechnic and university. The S-STEM survey was adopted as the measurement instrument. The result showed that university students displayed a more favorable overall STEM attitude compared to students enrolled in vocational-oriented polytechnic. University students demonstrated greater STEM self-efficacy than polytechnic students, but no significant difference in STEM expectancy-value was detected between the two groups. From the perspective of inter-group comparison, university education consistently fostered students a heightened sense of STEM self-efficacy, expectancy-value and career interest in science, whereas vocationally-oriented polytechnic education boasted its unique strengths in cultivating robust attitudes and career interests towards science and engineering/technology. However, students in both institutions exhibited a relatively less positive attitude towards learning mathematics. The findings highlight the importance of learning experiences in shaping students' STEM attitudes and career interests.*

Keywords: *career interest, expectancy-value, learning experiences, self-efficacy, STEM attitude*

Shao-Rui Xu
Guangdong Mechanical & Electrical Polytechnic, China
Shao-Na Zhou
South China Normal University, China

Introduction

Cultivating a strong contingent of proficient graduates in science, technology, engineering, and mathematics (STEM) is imperative, with a heightened focus on understanding and stimulating student engagement in these disciplines and related career pathways. As the job market increasingly leans on technological and engineering expertise, the necessity for STEM-educated professionals is poised to escalate further (World Economic Forum, 2017a). Projections highlight a significant growth differential between 2019 and 2029, with STEM occupations forecasted to expand by 8.0%, overshadowing the 3.4% growth anticipated for non-STEM positions (U.S. Bureau of Labor Statistics, 2020). However, the influx of college students pursuing STEM disciplines fails to match the surging demand within the STEM job sector (CPST, 2007; Lowell & Regets, 2006). Consequently, it is crucial to delve into the students' STEM attitudes, encompassing self-efficacy and expectancy-value in STEM domains in higher education, as well as career interests.

Learning experiences may play an important role in developing students' STEM self-efficacy, expectancy-value, and career interest, which are fundamental stepping stones towards achieving STEM career aspirations (Lent et al., 1994). Vocationally-oriented polytechnics and universities offer distinct learning experiences that may significantly influence the nurturing of students' STEM self-efficacy, expectancy-value and career interest. This investigation sheds light on the differences in STEM self-efficacy, expectancy-value, and career interests observed among students enrolled in the vocationally-oriented polytechnic versus the university. These varied experiences can either facilitate, enhance, or hinder the path towards obtaining a STEM degree. By unraveling these differences, educators gain insights to foster conducive connections and rectify impediments. Such understanding equips educators and policy makers with the tools they need to strategically address the evolving requirements of society.

https://doi.org/10.33225/jbse/24.23.979

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

Literature Review

STEM self-efficacy and expectancy-value

Students' attitude towards an academic domain is often construed as a composite of self-efficacy and expectancy-value beliefs, which serve as integral parts of their motivation for academic achievement (Eccles & Wigfield, 2002). Self-efficacy, which was introduced by Bandura (1977), encapsulates a student's conviction in their capacity to triumph within a designated task or learning area. When self-efficacy is applied to STEM, it refers to students' self-appraisal of their competence in mastering STEM-related subjects. Expectancy-value theory posits that an individual's impetus to undertake various activities is determined by two factors, which are the expectation of the likelihood of successfully accomplishing the task and the personal value he attributes to the task. STEM expectancy-value pertains specifically to how students continually gauge their possibility of excelling in particular STEM domains and evaluate the value derived from such achievements.

The significance of self-efficacy and expectancy-value in shaping behavior renders them crucial elements influencing career interest. Extensive research has validated their importance in stimulating interest in STEM fields (Brown et al., 2016; Ferry et al., 2000), influencing decisions to embark on STEM careers (Halim et al., 2018; Moakler & Kim, 2014), and maintaining dedication to STEM pursuits (Chemers et al., 2011; Larson et al., 2015). Lent (2018) reported that a meta-analysis consolidating 196 studies grounded in social cognitive career theory highlighted the crucial role of self-efficacy and value-expectations in predicting STEM-related interests.

Assessing self-efficacy and expectancy-value within STEM domains poses challenges due to the diverse subdomains, and tasks may appear disconnected to novice learners (National Research Council, 2000). For instance, science, including subjects such as physics, biology and chemistry, shares fundamental skills and principles, yet these subjects diverge significantly in content. Engineering is similarly fragmented into specialties dealing with mechanics, electronics, chemicals, environmental studies and more. Mathematics, habitually treated as a single entity, comprises distinct competencies such as geometric proof, algebraic reasoning, and numerical understanding. Self-efficacy in executing one task does not automatically translate to proficiency in another domain, and the influence of self-efficacy on behavior varies across contexts (Eccles, 1994; Zimmerman, 2000). Furthermore, enhancements in self-efficacy within one academic area do not correlate with similar improvements in other areas (Bong & Skaalvik, 2003). This insight carries profound implications for educators striving to enhance self-efficacy towards STEM subjects.

Commonly in previous research, the STEM domain is approached as a unified whole when assessing students' self-efficacy and expectancy-value. A general method divides the STEM domain into its fundamental segments: science, engineering and technology, and mathematics, and independently evaluates students' self-efficacy and value expectations within three specialized areas. Notably, the link between self-efficacy, expectancy-value, and career interest exhibits variance across disciplines. Past studies (Hackett & Betz, 1989) have revealed that mathematics self-efficacy is positively correlated with intentions to pursue STEM careers. Luzzo et al. (1999) further substantiated the impact of both mathematics and science self-efficacy on career goals within STEM. Further exploration into specific STEM domains exposes that a positive attitude towards science is paramount, and engineering attitude also carried significant weight in shaping STEM career decisions. Additionally, it is revealed that both science and engineering attitude, along with mathematics interests to a lesser degree, constituted crucial elements in opting for a STEM profession. This research implies that the extent to which students' self-efficacy, expectancy value and level of interest predict their intention to pursue careers in STEM domains.

The impact of learning experience on STEM attitude

The acquisition of knowledge is a gradual process that unfolds through diverse learning experiences and contexts throughout time. These learning experiences mold an individual's comprehension of specific subjects, foster their interests and objectives, and impact their self-perception of abilities. Learning experiences, often manifested through in-class exercises within a school setting (Maltese & Tai, 2010), play an important role in determining both the content and methodology of learning. Nonetheless, it is the cumulative effect of these personal experiences, intertwined with individual values, beliefs, and the broader impacts of cultural environments, that collectively facilitate the growth of one's knowledge and the formation of their identity (Allen & Peterman, 2019).

Research has highlighted the significance of in-school STEM activities in fostering students' self-efficacy

https://doi.org/10.33225/jbse/24.23.979

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

and expectancy-value. Kang et al. (2018) emphasized that learning experiences across diverse settings uniquely contributed to the development of STEM career interest. Petersen's study (2014) within a college STEM environment revealed that robust classroom instruction paired with engagement in extracurricular activities significantly influenced students' decisions to embark on STEM pathways. Beier et al. (2018) further demonstrated that favorable early college learning experiences bolstered positive attitude towards STEM fields. More specifically, the STEM courses that bridge theory with practical applications in technology, computing, and engineering, were shown to enhance the likelihood of students pursuing STEM careers (Gottfried & Bozick, 2016; Sasson, 2020). Cumulatively, these findings underscore the importance of various learning experiences in cultivating a strong attitude towards STEM, and numerous students develop their interests as a direct outcome of their learning experiences in classroom.

In-school learning experiences, offering a range of course choices, highly qualified educators, well-resourced laboratories and classrooms, produce students who are better equipped for pursuing STEM field at the college level (Steenbergen-Hu & Olszewski-Kubilius, 2017; Thiry, 2019). The classroom stands out as a paramount arena where learning experiences transpire. It serves as a platform for students to grasp STEM concepts while concurrently shaping their perceptions and attitudes towards STEM. The classroom may improve students' attitude towards STEM through teacher interaction and mentorship, and the particular curriculum students undertake. However, despite exposure to STEM content, not all in-school experiences engender positive attitude among students. Given that the classroom is a universal access point for STEM education, it is crucial to comprehend the influence of different learning experiences in the higher education system.

Different learning experiences in vocationally-oriented polytechnic and university

In the higher education system, the influence of learning experiences on STEM self-efficacy and expectancy-value illustrates differences across colleges. Vocationally-oriented polytechnic holds a significant position as a distinct non-university sector within the higher education of OECD countries, operating in parallel with traditional universities. In Finnish, the establishment of polytechnic primarily aimed to address emergent labor market demanding for specialized vocational competencies (Ministry of Education, 1990). Integral to the polytechnic reform was the dual objective of stimulating regional development and catering to localized higher education requirements (OECD, 2003). Germany introduced its polytechnics back in the 1960s, and the United Kingdom maintained an expansive polytechnic sector spanning from 1965 to 1992 (Pratt, 1997). By 1970, community colleges in the United States enrolled a notable proportion of post-secondary students, constituting around a quarter of the total enrollment (Gill & Leigh, 2000). The Netherlands established Hogescholen in 1986 through the integration of university colleges and secondary schools, and Norway founded many vocationally-oriented polytechnics in 1994 (Kyvik, 2002). Since the 1990s, China has embarked on a robust effort to establish a comprehensive modern vocational and technical education system. In some countries non-university higher education sector has expanded more recently. Usually, polytechnic degrees, emphasizing vocational training, are typically college-based programs completed within two to three years, in contrast to the four-year duration of a conventional university degree.

It is important to acknowledge that students enrolling in vocationally-oriented polytechnics versus universities often exhibit variations in their academic backgrounds and educational ambitions. Furthermore, they encounter dissimilar institutional settings due to the distinct educational configurations provided by two- or three-year programs at polytechnics and the traditional four-year curriculum at universities. University students, benefiting from a four-year curriculum, tend to be more inclined to transform their learning experiences with math and science into a keenness for choosing a STEM field compared with students in vocationally-oriented polytechnics. Polytechnic programs typically encompass a broad range of vocationally oriented education and prepare students for specific occupations. A key distinction from universities lies in their more pragmatic and hands-on approach, which is tailored to fulfill the immediate needs of local economies (Kyvik, 2004). Given the notable differences among students in terms of their academic and career objectives, expectations, and aspirations, it is logical to expect that students studying at polytechnics and universities would follow distinct developmental trajectories and pursue varied STEM paths (Cohen & Brawer 2008).

There were a number of informative studies contributing to our understanding of STEM education. However, a significant portion of these studies, such as those by Herrera and Hurtado (2011), Hurtado et al. (2012), and Herrera et al. (2011), concentrated primarily on interest and completion within four-year STEM programs. Empirical research in higher STEM education was largely skewed towards four-year universities, whereas scholarly literature inadequately represented polytechnics. As demonstrated by research by Bailey et al. (2003) and Wang (2009), polytechnic is a major entry point into higher education, and they represent a unique opportunity to train the future

https://doi.org/10.33225/jbse/24.23.979

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

STEM workforce, reflecting the diverse structure of a country's workforce (Dowd, 2012). A substantial portion of the effort to widen engagement in STEM fields depends on the vocationally-oriented polytechnic and studies examining the STEM educational pathway should necessarily take into account the integral role of polytechnic. Thus, the aim of this study was to explore the differences of STEM self-efficacy, expectancy-value and career interest among students who have equivalent preparatory knowledge but distinct learning experiences in vocationally-oriented polytechnic and four-year university.

Research Methodology

General Background

This study aimed to explore the differences in STEM attitudes, specifically self-efficacy and expectancy-value, among students with comparable academic backgrounds but different learning experiences in vocationally-oriented polytechnic and four-year university. In China, the National College Entrance Examination serves as a pivotal benchmark for assessing student proficiency. High school students taking the National College Entrance Examination are usually confronted with an alternative choice: those inclined towards art, humanities and social sciences must choose history as a compulsory curriculum, while those pursuing science, engineering and technology must choose physics as a mandatory subject. Focusing on students' STEM attitude, this study targeted participants who chose physics in the National College Entrance Examination. To accommodate students with different learning experiences, the study considers selecting students who have undergone nearly two years of study in the vocationally-oriented polytechnic or in the university. Consequently, those who enrolled in 2022 and were currently in their fourth semester were chosen as the research sample.

Participants

The participant sample was drawn from a province in the Southern part of China, where 399,000 candidates sat for the physics as the mandatory examination in 2022. All of these students were channeled into either universities or vocationally-oriented polytechnics, with 58.3% of the students meeting the cutoff for undergraduate programs in four-year universities, while 41.7% qualified for vocationally-oriented polytechnics. However, even some students who achieved the threshold for university may opt for vocationally-oriented polytechnic. Finally, only approximately 49.7% of students enrolled in universities, indicating that roughly 10% of candidates who achieved the threshold for university elected to enroll in top-tier vocationally-oriented polytechnics. Consequently, the study selected students ranked approximately between the 45th and 55th percentiles in the province to ensure a comparable average level of knowledge. Among the participants, some enrolled in the university, forming the university group of this study, and others opted for the vocationally-oriented polytechnic, constituting the polytechnic group. Both the university and polytechnic groups consisted of students in science and engineering related majors. These students were all in the fourth semester of study, having not only completed nearly two years of coursework in the field of their majors, but also familiarized themselves with the teaching methodologies, practical training systems, and prospective career paths within their respective fields. The sample sizes for the university and the polytechnic groups stood at 248 and 239 respectively. After excluding invalid data, the university group comprised 226 students, with 183 males and 43 females, and the polytechnic group included 238 students, with 190 males and 48 females. The average age of participants in both groups was around 20 years old. All participants in the research were provided with informed consent before the survey.

Measurement Instrument

To explore students' STEM attitudes, this study adopted the S-STEM survey as the measurement instrument, encompassing self-efficacy and expectancy-value, as well as their career interest. The instrument was originally developed from North Carolina State University (Unfried et al., 2015) and extended by previous research (Xu & Zhou, 2022; Zhou et al., 2019; 2021) to cover the whole K-12 education system. The version of S-STEM was employed

https://doi.org/10.33225/jbse/24.23.979

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

in this research to explore students' attitudes towards STEM specific domains, including mathematics, science, engineering and technology, covering students' self-efficacy and expectancy-value in each domain. In line with the approaches used in previous research (Xu & Zhou, 2022; Zhou et al., 2019), engineering and technology were integrated together in the present study, named engineering/technology. Additionally, there was an item probing students' career interest in each STEM specific domain. Consequently, through students' self-assessments on the survey, the study can understand their STEM attitudes across domains, including domain-specific self-efficacy, expectancy-value, and career interest.

Data Analysis

For the inter-group analysis, an independent t-test was employed to analyze differences in STEM attitudes between the university and polytechnic groups. Meanwhile, within each group, ANOVA (analysis of variance) test was used to examine variations in students' attitudes towards individual domains. To ensure adequate statistical reliability, the G*Power was utilized to determine that a minimum of 86 participants per group would be required for an independent t-test to detect a medium effect size of .50 at a 90% power level with a significance level (α) at .05 for comparisons between the university and polytechnic groups. Furthermore, ANOVA test was employed to examine the differences in STEM attitudes and interests towards the three domains of mathematics, science, engineering and technology within each group. A minimum of 207 participants per group was required to detect a moderate effect size of .25, ensuring 90% statistical power while maintaining a significance level (α) at .05. The sample size of the current study, with 238 valid participants in the university group and 226 in the polytechnic group, satisfied the statistical power requirements and ensures reliability and accuracy of the research findings.

Research Results

Horizontal Comparison of STEM Attitudes between Polytechnic Group and University Group

Table 1 presents the horizontal comparison of students' STEM attitudes between the polytechnic group and the university group. Overall, university students exhibited a more positive attitude towards STEM ($M = 3.58$, $SD = .38$) compared to polytechnic students ($M = 3.41$, $SD = .43$) ($t = 4.403$, $p < .001$). University students demonstrated greater perceived competence in studying STEM domains and had higher self-efficacy ($t = 8.752$, $p < .001$). However, it is noteworthy that no significant difference was detected between the two groups concerning their STEM expectancy-value.

In terms of learning attitudes across various academic disciplines, student performances varied depending on different disciplines between the polytechnic group and the university group. Regarding mathematics attitude, there was no significant difference between the two groups ($t = 1.484$, $p = .139$). Although university students reported significantly higher self-efficacy in mathematics ($t = 3.393$, $p < .001$), there was no significant difference between the two groups in their expectancy-value of mathematics ($t = 0.307$, $p = .759$). It suggests that undergraduates from university perceived themselves as better equipped to learn mathematics, but their expectations regarding learning outcomes did not exceed those of polytechnic students, implying that higher self-assessment self-efficacy does not necessarily equate to higher expectation-value belief.

In terms of science attitude, the polytechnic group scored significantly lower than the university group ($t = 7.184$, $p < .001$). Similarly, the polytechnic group showed significantly lower self-efficacy and expectation-value in science compared to the university group ($t = 6.246$, $p < .001$ and $t = 6.893$, $p < .001$, respectively).

Regarding the attitude towards engineering/technology, the polytechnic group was more positive than the university group, with a statistically significant effect observed ($t = 2.029$, $p < .05$). More detailed evidence reveals that the difference in self-efficacy belief towards engineering and technology was minimal between the two groups ($t = .394$, $p = .694$), yet the polytechnic group held significantly higher expectation-value belief towards engineering/technology compared to the university group ($t = 3.643$, $p < .001$). It can be seen that self-efficacy belief does not lead to expectation-value belief.

https://doi.org/10.33225/jbse/24.23.979

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

Table 1
Students' STEM Attitudes between Polytechnic Group and University Group

	STEM attitudes *M (SD)*		Self-efficacy *M (SD)*		Expectancy-value *M (SD)*	
	Vocational College Group	University Group	Vocational College Group	University Group	Vocational College Group	University Group
N	**238**	**226**	**238**	**226**	**238**	**226**
Overall	3.41(.43)	3.58(.38)	3.18(.45)	3.54(.44)	3.57(.45)	3.63(.40)
t (p)	-4.403(<.001)		-8.752(<.001)		-1.522(.129)	
Mathematics	3.15 (.77)	3.26(.75)	3.20(.86)	3.47 (.84)	3.00(.80)	2.98(.88)
t (p)	-1.484(.139)		-3.393(<.001)		0.307(.759)	
Science	3.52(.62)	3.91(.54)	3.42(.61)	3.77(.60)	3.57(.69)	3.98(.57)
t (p)	-7.184(<.001)		-.6.246(<.001)		-6.893(<.001)	
Engineering/ Technology	3.54(.43)	3.46(.44)	3.50(.50)	3.48 (.55)	3.59(.49)	3.43(.46)
t (p)	2.029(<.05)		.394(.694)		3.643(<.001)	

Longitudinal Comparison of STEM Attitudes among Specific Domains in both Polytechnic Group and University Group

The longitudinal comparison of students' STEM attitudes among specific domains in both the polytechnic group and the university group is shown in Table 2. Among vocationally-oriented polytechnic students, there were significant differences in STEM attitudes across the domains of mathematics, science, and engineering/technology ($F = 29.08$, $p < .001$, $\eta^2 = .08$), reaching a medium effect size. Post hoc multiple comparisons indicate that polytechnic students held a lower attitude towards mathematics compared to both science ($p < .001$) and engineering/technology ($p < .001$). It suggests that polytechnic students have the least positive attitude towards mathematics. Meanwhile, there was almost no difference between their attitudes towards science and engineering/technology ($p = .974$).

In terms of career interest, the trends across various domains in the polytechnic group were consistent with that of STEM attitudes. There were also significant differences in the three domains ($F = 21.70$, $p < .001$, $\eta^2 = .06$), indicating a moderate effect size. Post hoc multiple comparisons revealed that students' perceptions of career interests related to science and engineering/technology were exceedingly similar ($p = 1.000$) and notably higher than their interest in mathematics professions ($p < .001$).

In terms of the university group, there were also significant differences in STEM attitudes across different domains with a large effect size ($F = 72.32$, $p < .001$, $\eta^2 = .18$). Post hoc multiple comparisons reveal that university students also held a lower attitude towards mathematics compared to both science ($p < .001$) and engineering/technology ($p < .001$). Unlike the polytechnic group, university students demonstrated a significantly higher attitude towards science than engineering/technology ($p < .001$). Overall, among the three domains, students exhibited the most positive attitude towards science, followed by engineering/technology, with the least positive attitude towards mathematics in the university group.

From the perspective of STEM career interest, there were also significant differences among mathematics, science and engineering/technology with a large effect size ($F = 54.16$, $p < .001$, $\eta^2 = .14$). Post hoc multiple comparisons demonstrate that the university group had the highest career interest in science, significantly higher than in the mathematics domain ($p < .001$) and the engineering/technology domain ($p < .001$). However, the difference in their career interests between mathematics and engineering/technology was not statistically significant ($p = .073$).

https://doi.org/10.33225/jbse/24.23.979

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

Table 2
Students' STEM Attitudes among Specific Domains in both Polytechnic Group and University Group

		STEM attitudes					Career interest			
	Specific Domains	F	p-value	η^2	Post hoc	M (SD)	F	p-value	η^2	Post hoc
Vocational College Group	Mat	N=238	29.08	<.001	.08	Mat<Sci (p<.001) Mat<E&T (p<.001) Sci=E&T (p=.974)	2.95 (.89)	21.70	<.001	.06	Mat<Sci (p<.001) Mat<E&T (p<.001) Sci=E&T (p=1.000)
	Sci						3.42(.90)				
	E&T						3.43(.96)				
University Group	Mat	N=226	72.32	<.001	.18	Mat<Sci (p<.001) Mat<E&T (p=.002) Sci>E&T (p<.001)	2.98 (.97)	54.16	<.001	.14	Sci>Mat (p<.001) Sci>E&T (p<.001) E&T=Mat (p=.073)
	Sci						3.80 (.86)				
	E&T						3.13 (.8)				

Notes: Mat = mathematics attitude; Sci = science attitude; E&T = attitude towards engineering/technology.

Discussion

In the present study, university students' overall attitude towards STEM was more positive than those of vocationally-oriented polytechnic students, indicating that students had different attitudes towards STEM under two different learning experiences. The learning experience in university seems to have brought a more positive STEM attitude to the students. The participants in the university group and the polytechnic group initially exhibited comparable academic performance in the National College Entrance Examination, which is widely recognized as a nationwide academic selective examination in China. However, a divergence in students' STEM attitude emerged following nearly two years of learning experiences in their respective institutions. It suggests that varying educational experiences shape students' different STEM attitudes. This result aligns with the viewpoints in the previous research (Beier, 2018; Kang, 2018; Petersen, 2014). Kang et al. (2018) argued that learning experiences in different environments played a significant and unique role in the development of student STEM identity. Petersen suggested that strong STEM classroom experiences and participation in activities were important factors for students to decide to pursue STEM (Petersen, 2014). Beier et al. (2018) also indicated that positive learning experiences lead to a better attitude towards STEM. It should be noted that students are presented with diverse learning experiences, such as different institutional environments and varying curricula in universities and polytechnics, which would contribute to the differences in their STEM attitudes.

Specifically, university students tended to have a more positive attitude towards science than engineering/technology in the study, while those from vocationally-oriented polytechnic had a similar attitude towards both science and engineering/technology. Generally, students from four-year universities are more inclined to cultivate a positive STEM attitude towards science, driven by their exposure to cutting-edge scientific developments and research achievements. A distinguishing characteristic of vocationally-oriented polytechnics is the emphasis on practical training with a diverse array of vocational education courses tailored to meet specific career demands (Kyvik, 2004). Consequently, students enrolled in vocationally-oriented polytechnics tended to exhibit a more favorable attitude towards engineering/technology.

Another significant finding of this study was that regardless of the educational learning experience of students from vocationally-oriented polytechnic and university, their mathematics attitude consistently ranked the lowest. The reason might be related to the students' level of proficiency in mathematics. The participants in the present study ranked between 45% and 55% among approximately 400,000 candidates in the whole province. As a fundamental domain, mathematics requires students to focus on in-depth theoretical learning, but participants at this particular level may not be particularly captivated by intricate mathematical theories. Students may struggle to gain a sense of accomplishment in mathematics learning and do not anticipate substantial mathematical achievements. This finding aligns with the arguments made by Bong and Skaalvik (2003). Bong and Skaalvik (2003) demonstrated that variations in self-efficacy in a specific academic domain do not necessarily correlate with changes in self-efficacy in another. Therefore, regardless of whether the learning experience is more theoretical in universities or more practical in polytechnic, neither is particularly effective in fostering a more positive learning attitude towards mathematics among the present participants. Since learning attitude in a domain is often the primary motivating

https://doi.org/10.33225/jbse/24.23.979

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

factor behind choosing to study it, fostering students' positive attitude in mathematics becomes a crucial point of intervention for policies and practices aimed at broadening the STEM pipeline. It is apparent that enhancing students' mathematical proficiency, exposing them to a more diverse array of mathematics courses, and fostering a positive mathematics attitude are all essential paths forward.

The differences in students' STEM self-efficacy and expectancy-value between university and polytechnic students were intricate across various domains. As noted in prior research, due to the inherently robust theoretical foundation in mathematics, university education excels in fostering students' mathematical theory and enhancing their proficiency in mathematical modeling, thereby facilitating their more proficient mastery of mathematics. Furthermore, it has been reported that STEM activities in schools are pivotal in fostering students' STEM self-efficacy and expectancy-value (Halim et al., 2018). In this study, the university group exhibited a higher self-efficacy of mathematics compared to the polytechnic group, indicating a greater confidence in their ability to master the mathematics. However, there was no significant difference in students' expectancy-value of mathematics between the two groups, indicating that the university group did not demonstrate a superiority in forecasting their mathematics learning outcomes over polytechnic students. On the other hand, while university education consistently fostered a high sense of students' STEM self-efficacy and expectancy-value in science, polytechnic education also boasted its own unique benefits that offered richer educational scenarios and case studies closely tied to engineering/technology. Although polytechnic students maintained similar perceptions as those under university education when assessing their ability to achieve good performances in engineering/technology, a greater number of polytechnic students believed that they had a more positive expectancy-value of their learning outcomes in this domain of engineering/technology. In summary, university education cultivates a sense of proficiency in science, whereas polytechnic education affords students a deeper and more thorough evaluation of their accomplishments in engineering/technology.

Among university and polytechnic students, there existed a discernible correlation between their STEM attitude and career interest across various specific domains. Students from vocationally-oriented polytechnic demonstrated a preference for both science and engineering/technology as potential career choices, showing little distinction between the two. However, they held a less favorable opinion when considering mathematics as a future career path. Conversely, university students exhibited a more optimistic outlook towards future career interest in science-related fields, with a higher willingness to pursue such paths. However, they tended to be less inclined towards mathematics and engineering/technology. This reveals that students do not automatically equate their proficiency in a STEM specific domain with their desire to pursue a career in such a domain.

Upon considering students' STEM attitudes across various domains and their aspirations for future careers, it emerges that learning attitudes towards mathematics and science hold high predictive power in shaping students' career interests. Specifically, both university and polytechnic students who exhibited a less favorable learning attitude towards mathematics, characterized by low self-efficacy and expectancy-value, tended to have a lower chance of choosing mathematics as their future career path. This observation is in line with previous research (Betz & Hackett, 1983; Scott & Mallinckrodt, 2005), which posited that an individual's beliefs in their mathematics self-efficacy correlated with their choice of majors within STEM fields. Likewise, students from both university and vocationally-oriented polytechnic tended to rate their science learning attitude highly, and they also demonstrated a strong inclination towards pursuing careers that are science-related. Notably, science self-efficacy serves as a positive indicator, predicting stronger intentions towards STEM careers. The present results confirm the claim of Luzzo et al. (1999), who established that both mathematics and scientific self-efficacy had a significant impact on individuals' aspirations for STEM careers.

Additionally, university students tended to have a more favorable learning attitude towards engineering/technology than mathematics, but their interest in pursuing engineering-related careers was not significantly higher than that in mathematics-related careers. Existing research also indicates that the predictive value of expected engineering/technology outcomes is relatively low. The finding highlights disparities in the extent to which students' confidence in their success across diverse STEM domains and their anticipation of employing different STEM domains in their professions can predict their intention to pursue STEM specific domain-related careers. In other words, having a good learning attitude towards a particular domain, such as engineering/technology does not necessarily lead to a tendency for students to choose it as their future career. Students may harbor positive sentiments towards multiple domains, but when contemplating their future professional paths, they must ultimately choose the domain that offers the highest self-efficacy and value expectancy among the various options.

https://doi.org/10.33225/jbse/24.23.979

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

Conclusions

The study delved into exploring variations in STEM self-efficacy, expectancy-value, and career interest among students with equivalent preparatory knowledge but differing in learning experiences at vocationally-oriented polytechnic and university. Following approximately two years of diverse educational experiences, university students exhibited a more positive overall STEM attitude compared to those at vocational-oriented polytechnic. To be specific, university students demonstrated greater STEM self-efficacy than polytechnic students, but no significant difference in STEM expectancy-value was detected between the two groups. It is worth noting that the university group performed significantly higher than the polytechnic group in science attitude, while the polytechnic group was more positive than the university group in engineering/technology attitude. From the perspective of inter-group comparison, university education consistently cultivated a high level of STEM self-efficacy and expectancy-value in science among students, while polytechnic education boasted its own advantages in fostering strong attitudes towards both science and engineering/technology. Both university and polytechnic students displayed a less enthusiastic learning approach towards mathematics. In terms of career interest, students from vocational-oriented polytechnic favored both science and engineering/technology as potential career paths. In contrast, university students showed a more optimistic view towards future career interests in science-related fields. Both groups held a less favorable stance when considering mathematics as a potential career choice. This finding highlights the disparities in how students' confidence in their success across various STEM domains and their anticipation of utilizing these domains in their professions can predict their intention to pursue STEM-specific careers.

There are also certain limitations in the present research. Firstly, the selection of participants was solely based on the National College Entrance Examination scores, focusing on students' overall comparable academic performance, rather than considering their specific achievements in a particular STEM domain. Secondly, the sample size comprised just 464 college students, therefore, the conclusions drawn from the study need to be validated through further research with a more diverse participant pool. Moreover, the study did not delve into the details of students' varying learning experiences during their nearly two-year stay in vocational-oriented polytechnic and university, including the specific learning contents, methodologies, and the teaching interaction between teachers and students. Further, the study has not been concerned with the potential consequences of individual differences in students' physiology and personality, which are avenues for deeper investigation in subsequent research endeavors.

Acknowledgements

The authors would like to acknowledge the help of the anonymous reviewers. The research is supported in part by the Guangdong Planning Project of Philosophy and Social Sciences on Young Fund under the Grant No. GD23YJY10, the 2024 Guangzhou Planning Project of Philosophy and Social Sciences under the Grant No. 2024GZGJ117, the Guangdong Planning Project of Philosophy and Social Sciences under the Grant No. GD23XJY63, the 2022 Training Program for top students in basic disciplines 2.0 under the Grant No. 20222152, and the 2022 Guangdong Educational Science Planning Project (Special for Higher education) under the Grant No. 2022GXJK175, and the 2023 Guangdong Provincial Undergraduate Colleges and Universities Teaching Quality and Teaching Reform Project (No. 611).

Declaration of Interest

The authors declare no competing interest.

References

Allen, S., & Peterman, K. (2019). Evaluating informal STEM education: Issues and challenges in context. *New Directions for Evaluation*, *2019*(161), 17–33. https://doi.org/10.1002/ev.20354

Bailey, T. R., Leinbach, D. T., Scott, M., Alfonso, M., Kienzl, G. S., & Kennedy, B. (2003). *The characteristics of occupational sub-baccalaureate students entering the new millennium*. Columbia University.

Bandura, A. (1997). Self-efficacy: The exercise of control. *Personnel psychology, 50*(3), 801.

Beier, M. E., Kim, M. H., Saterbak, A., Leautaud, V., Bishnoi, S., & Gilberto, J. M. (2018). The effect of authentic project-based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching, 56*(1), 3–23. https://doi.org/10.1002/tea.21465

https://doi.org/10.33225/jbse/24.23.979

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

Betz, N. E., & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to selection of science-based college majors. *Journal of Vocational Behavior, 23*(3), 329–345. https://doi.org/10.016/0001-8791(83)90046-5

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational psychology review, 15*(1), 1–40. https://doi.org/10.1023/A:1021302408382

Brown, P. L., Concannon, J. P., Marx, D., Donaldson, C. W., & Black, A. (2016). An examination of middle school students' STEM self-efficacy with relation to interest and perceptions of STEM. *Journal of STEM Education, 17*(3), 27–38. https://www.jstem.org/jstem/index.php/JSTEM/article/view/2137

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Social Issues, 67*(3), 469-491. https://doi.org/10.1111/j.1540-4560.2011.01710.x

Cohen, A., & Brawer, F. (2008). *The American community college (5th ed.)*. Jossey-Bass.

Commission on Professionals in Science and Technology-CPST. (2007). *Is US science and technology adrift?* CPST. https://www.careercornerstone.org/workforce/techadrift.htm

Dowd, A. C. (2012). Developing supportive STEM community college to four-year college and university transfer ecosystems. *Community colleges in the evolving STEM education landscape: Summary of a summit*, 107–134.

Eccles, J. S. (1994). Understanding women's educational and occupational choices: Applying the Eccles et al. model of achievement-related choices. *Psychology of Women Quarterly, 18*(4), 585–609. https://doi.org/10.1111/j.1471-6402.1994.tb01049.x

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109–132.

Ferry, T. R., Fouad, N. A., & Smith, P. L. (2000). The role of family context in a social cognitive model for career-related choice behavior: A math and science perspective. *Journal of Vocational Behavior, 57*(3), 348–364. https://doi.org/10.1006/jvbe.1999.1743

Gill, A., & Leigh, D. (2000). College enrollment, college major, and the gender wage gap. *Industrial and Labor Relations Review, 54*(1), 163-181.

Gottfried, M. A., & Bozick, R. (2016). Supporting the STEM pipeline: Linking applied STEM course-taking in high school to declaring a STEM major in college. *Education Finance and Policy, 11*(2), 177-202. https://doi.org/10.1162/EDFP_a_00185

Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education, 20*(3), 261–273. https://doi.org/10.2307/749515

Herrera, F. A., & Hurtado, S. (2011, April). *Maintaining initial interests: Developing science, technology, engineering, and mathematics (STEM) career aspirations among underrepresented racial minority students*. Paper presented at the Association for Educational Research annual meeting, New Orleans, LA. https://www.mendeley.com/catalogue/68f5923e-3413-3de9-9de1-f29e3d1aa011

Herrera, F. A., Hurtado, S., & Chang, M. (2011). *Maintaining career aspirations in science, technology, engineering, and mathematics (STEM) among college students*. University of California. http://www.heri.ucla.edu/nih/downloads/ASHE2011HerreraSTEMCareers.pdf

Halim, L., Rahman, N. A., Ramli, N. A. M., & Mohtar, L. E. (2018, June 6–8). *Influence of students' STEM self-efficacy on STEM and physics career choice*. In AIP Conference Proceedings (Vol. 1923, No. 1). AIP Publishing. https://doi.org/10.1063/1.5019490

Hurtado, S., Eagan, K., & Hughes, B. (2012, June). *Priming the pump or sieve: Institutional contexts and URM STEM degree attainments. Paper presented at the Association for Institutional Research annual forum*, New Orleans, LA. https://www.heri.ucla.edu/nih/downloads/AIR2012HurtadoPrimingthePump.pdf

Kang, H., Calabrese Barton, A., Tan, E., Simpkins, S., Rhee, H. y., & Turner, C. (2018). How do middle school girls of color develop STEM identities? Middle school girls' participation in science activities and identification with STEM careers. *Science Education, 103*(2), 418–439. https://doi.org/10.1002/sce.21492

Kyvik, S. (2002). The merger of non-university colleges in Norway. *Higher Education, 44*(1), 53–72.

Kyvik, S. (2004). Structural changes in higher education systems in Western Europe. *Higher Education in Europe, 29*(3), 393–409.

Larson, L. M., Pesch, K. M., Surapaneni, S., Bonitz, V. S., Wu, T. F., & Werbel, J. D. (2015). Predicting graduation: The role of mathematics/science self-efficacy. *Journal of Career Assessment, 23*(3), 399–409. https://doi.org/10.1177/1069072714547322

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice and performance. *Journal of Vocational Behavior, 45*(1), 79–122.

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. https://doi.org/10.1037/cou0000243

Lowell, B. L., & Regets, M. (2006). *A half-century snapshot of the STEM workforce, 1950 to 2000*. Commission on Professionals in Science and Technology.

Luzzo, D. A., Hasper, P., Albert, K. A., Bibby, M., A., & Martinelli, E. A. (1999). Effects of self-efficacy-enhancing interventions on the math/science self-efficacy and career interests, goals, and actions of career undecided college students. *Journal of Counseling Psychology, 46*(2), 233–243. https://doi.org/10.1037/0022-0167.46.2.233

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669–685. https://doi.org/10.1080/09500690902792385

Ministry of Education (1990). *Suomen koulutusjärjestelmä, koulutuksen taso ja kehittämislinjat.* Valtion painatuskeskus. Helsinki. (Selonteko 1990).

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

National Research Council. (2000). *How people learn: Brain, mind, experience, and school: Expanded edition*. National Academies Press. https://doi.org/10.17226/9853

https://doi.org/10.33225/jbse/24.23.979

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

OECD (2003). *Polytechnic Education in Finland*. OECD.
Petersen, A. M. (2014). *Females and STEM: Determining the K–12 experiences that influenced women to pursue STEM fields* [Doctoral dissertation, William & Mary]. https://dx.doi.org/doi:10.25774/w4-n1x9-2c86
Pratt, J. (1997). *The Polytechnic Experiment: 1965-1992*. Society for Research into Higher Education and Open University Press.
Sasson, I. (2020). Becoming a scientist-Career choice characteristics. *International Journal of Science and Mathematics Education, 19*(3), 483–497. https://doi.org/10.1007/s10763-020-10059-9
Scott, A. B., & Mallinckrodt, B. (2005). Parental emotional support, science self-efficacy, and choice of science major in undergraduate women. *The Career Development Quarterly, 53*(3), 263–273.
Steenbergen-Hu, S., & Olszewski-Kubilius, P. (2017). Factors that contributed to gifted students' success on STEM pathways: The role of race, personal interests, and aspects of high school experience. *Journal for the Education of the Gifted, 40*(2), 99-134. https://doi.org/10.1177/0162353217701022
Thiry, H. (2019). Issues with high school preparation and transition to college. In E. Seymour & A.B. Hunter (Eds.), *Talking about leaving revisited* (pp. 137-147). Springer. https://doi.org/10.1007/978-3-030-25304-2
Wang, X. (2009). Baccalaureate attainment and college persistence of community college transfer students at four-year institutions. *Research in Higher Education, 50*(6), 570–588.
World Economic Forum. (2017). *The global gender gap report*. https://www.weforum.org/reports/the-global-gender-gap-report-2017
U.S. Bureau of Labor Statistics. (2020). *Employment in STEM occupations*. Employment Projections. https://www.bls.gov/emp/tables/stem-employment.htm
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
Xu, S., & Zhou, S. (2022). The effect of students' attitude towards science, technology, engineering, and mathematics on 21st century learning skills: A structural equation model. *Journal of Baltic Science Education*, *21*(4), 706-719. https://doi.org/10.33225/jbse/22.21.706
Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82-91. https://doi.org/10.1006/ceps.1999.1016
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
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

Received: *June 07, 2024* Revised: *August 26, 2024* Accepted: *September 10, 2024*

Cite as: Xu, S.-R., & Zhou, S.-N. (2024). STEM attitude disparity: The impact of learning experiences in vocationally-oriented polytechnic and university on students' self-efficacy, expectancy-value, and career interest. *Journal of Baltic Science Education*, *23*(5), 979–989. https://doi.org/10.33225/jbse/24.23.979

Shao-Rui Xu MSc, Lecturer, School of Electronics and Communication, Guangdong Mechanical & Electrical Polytechnic, Guangzhou 510550, China.
E-mail: 2020010027@gdmec.edu.cn

Shao-Na Zhou
(Corresponding author) PhD, Professor, Guangdong Basic Research Center of Excellence for Structure and Fundamental Interactions of Matter, School of Physics, South China Normal University, Guangzhou 510006, China.
E-mail: zhou.shaona@m.scnu.edu.cn
ORCID: https://orcid.org/0000-0003-1455-5122