VTE VOCATION, TECHNOLOGY & EDUCATION

ORIGINAL ARTICLE

An analysis of science, technology, engineering, and mathematics career interests and influencing factors among Tanzanian University students: Evidence from a survey of 1497 science and engineering students

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) education represents a critical avenue for cultivating talent in scientific and technological innovation, playing a pivotal role in national economic development and social advancement. Enhancing university students' interest in STEM careers can strengthen the foundation of STEM education and bridge individual educational experiences with national development imperatives. This study, based on a survey of 1497 science and engineering students at the University of Dar es Salaam in Tanzania, examines the factors influencing students' interests in STEM careers from both individual and environmental perspectives. The analysis reveals six key challenges confronting STEM development in Tanzania: occupational gender bias, dual imbalances between STEM academic disciplines and the needs of the industrial sector, lack of vocational guidance within families, disparities in educational access between urban and rural areas, high barriers to entry into STEM specializations, and academic burnout. To overcome these challenges, a coordinated approach involving family engagement, institutional support, and broader social collaboration is necessary to promote the development of STEM talent and support Tanzania's industrialization efforts.

Key words: Tanzania, science, technology, engineering, and mathematics career interests, science and engineering students

INTRODUCTION

The ongoing technological revolution is rapidly accelerating the advancement of productive forces, thereby amplifying the critical role of science, technology, engineering, and mathematics (STEM) education. In domains ranging from global competition and international scientific collaboration to data-intensive fields such as artificial intelligence and quantum computing, as well as knowledge-driven industries such as materials science and biotechnology, progress is fundamentally reliant on robust STEM talent ecosystems and the integration of cross-disciplinary knowledge (Chen & Yang, 2024). STEM professionals constitute a strategic resource essential for driving technological innovation and societal advancement, drawing sustained attention from governments and institutions worldwide. Universities, as primary centers

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Received: 4 May 2025; Revised: 6 June 2025; Accepted: 20 June 2025
https://doi.org/10.54844/vte.2025.0988

for cultivating such talent, must fulfill their essential role in preparing the next generation of innovators. For developing countries like Tanzania, fostering university students' interest in STEM careers and nurturing a technically skilled workforce is vital for building the strategic human capital necessary to support national industrialization and long-term development goals.

RESEARCH CONTEXT

The concept of "interest" has its roots in psychology, where it is understood as an individual's psychological inclination toward specific activities or knowledge domains. Career interest reflects this inclination as applied to occupational choices (Dai *et al*., 2013). Acting as a preferential behavior toward particular activities, career interest both activates and sustains goal-directed behavior, serving as a strong predictor of students' future professional trajectories (Wang *et al*., 2020). STEM education adopts a distinctive approach by integrating STEM through inquiry-based learning and project-oriented activities to cultivate innovative, practically skilled individuals (Yang, 2024). As STEM education has grown in prominence, scholarly attention to STEM career interests has also increased. Early research in this area primarily drew upon social cognitive career theory (SCCT), while Holland's hexagonal model of vocational interests, which includes the realistic, investigative, social, artistic, enterprising, and conventional types, has been particularly influential in measuring the factors affecting career interests and in informing educational and career guidance practices (Zhao & Liu, 2017).

Research approaches to STEM career interests have varied based on different scholarly emphases. Some researchers have examined the topic through single-discipline studies. For example, Lindahl (2007) characterized scientific career interest as a vocational orientation shaped by positive early experiences with science and participation in scientific activities. Du and Wong (2019), analyzing Program for International Student Assessment (PISA) 2015 data, identified the crucial roles of scientific self-efficacy and career aspirations in shaping students' interest in science-related careers. Other scholars have adopted a broader approach by investigating multiple factors influencing STEM career interests, including gender, academic level, learning motivation, and 21st-century skills. Among individual factors, gender plays a significant role: males tend to exhibit higher self-efficacy and greater interest in STEM learning than females (Jiang *et al*., 2024;Wang *et al*., 2023). Regarding the academic level, findings are mixed. Some studies suggest that college student's interest in STEM careers declines with age (Wu & Zhang, 2008), while others report that senior students demonstrate a higher interest in STEM careers compared to their junior counterparts (Balta *et al*., 2023). Learning motivation and efficiency also contribute significantly; students with stronger motivation and greater learning efficiency tend to show higher levels of interest in STEM careers (Liang *et al*., 2020). Environmental factors also play important roles. For example, parental educational background is positively correlated with students' STEM career interests (Sáinz & Müller, 2018). Geographic factors—such as urban versus rural upbringing—also appear to influence the development of interest in STEM fields. Beyond these personal and environmental factors, proficiency in 21st-century skills—encompassing critical thinking, collaborative creativity, communication competence, and various life, career, and technological capabilities (Kelley *et al*., 2019) —has been shown to influence STEM learning outcomes and, consequently, STEM career interests (Han *et al*., 2021).

Despite the growing body of research on STEM career interests, most studies have focused on primary and secondary school populations, predominantly in developed countries. In contrast, limited attention has been given to university students in African contexts. Empirical investigations specifically examining university students' STEM career interests remain particularly scarce. This study seeks to address that gap through field research involving 1497 science and engineering students at the University of Dar es Salaam. It examines how factors such as gender, academic level, geographical origin, and parental education influence STEM career interests among Tanzanian university students. By identifying the key determinants of STEM career interest in this context, the study aims to inform practical strategies for enhancing STEM career engagement among Tanzanian university students. Ultimately, the findings contribute to supporting Tanzania's industrial development goals and strengthening Sino-Tanzanian collaboration in STEM education.

RESEARCH METHODOLOGY AND PROCESS

Research subjects

The study primarily focused on students from STEM-related majors at the University of Dar es Salaam. Participants were selected using random sampling. The final sample consisted of 1497 students, comprising 957 males (63.9%) and 540 females (36.1%). In terms of academic level, 618 participants (41.3%) were first-year students, 460 (30.7%) were second-year students, and 419 (27.9%) were third-year students.

Research methodology

The study employed a questionnaire survey approach. A

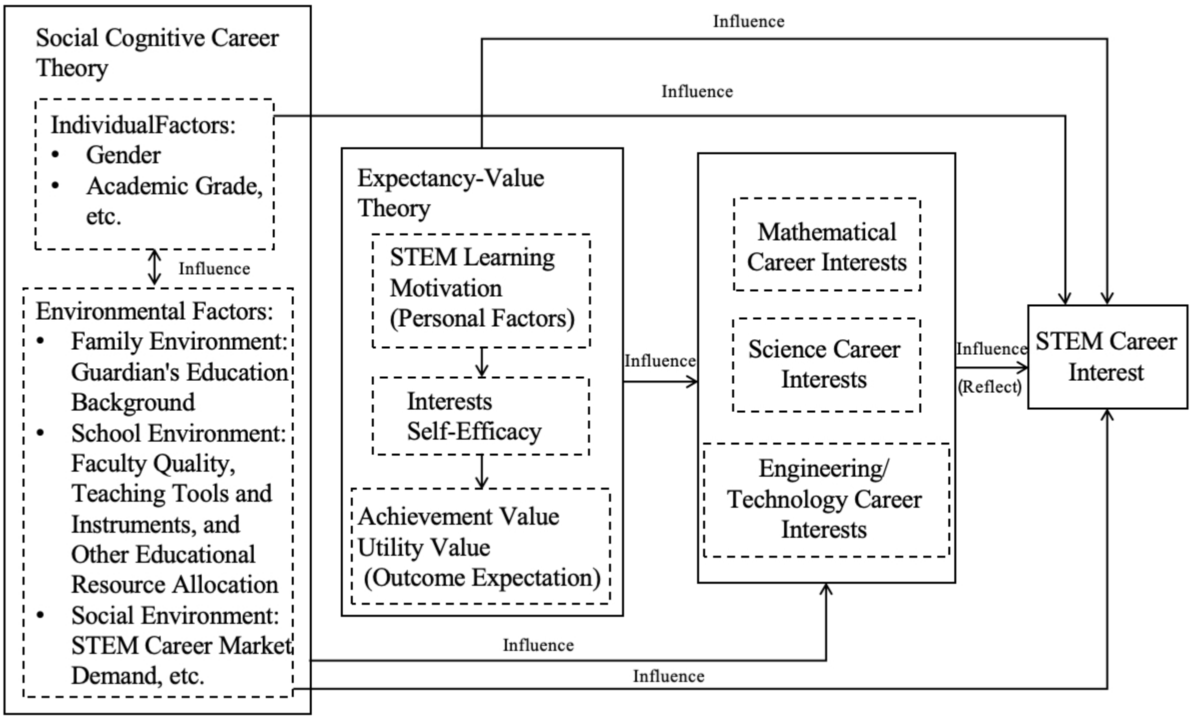

Figure 1. Theoretical analysis framework. STEM, Science, technology, engineering, and mathematics.

total of 1671 paper questionnaires were distributed. Invalid questionnaires were excluded based on the following criteria: incomplete responses, pattern answering, contradictory answers within the same dimension, and excessively short or long completion times. Ultimately, 1497 valid questionnaires were collected, yielding an effective response rate of 89.6%. After completing the data collection, SPSS 22.0 and Amos 24.0 software were used for data analysis.

Research instruments and reliability/validity

The study adopted the STEM Interest and Choice Scale developed by Sarah A. Roller and colleagues, with modifications based on guidance from subject-matter experts and frontline STEM instructors to ensure its applicability. The resulting "Tanzanian University Students' STEM Career Interest Scale" consists of three dimensions: mathematics career interest, science career interest, and engineering/technology career interest. The scale comprises 45 items, all scored on a five-point Likert scale with a positive score.

Upon verification, the Cronbach's alpha coefficients for each dimension ranged between 0.85 and 0.87. All items demonstrated correlation values of at least 0.3, and the removal of any item did not increase the scale's Cronbach's alpha coefficient, indicating good reliability. Confirmatory factor analysis of the sample showed standardized loadings ranging from 0.67 to 0.89 across dimensions, with composite reliability (CR) exceeding 0.8 and average variance extracted values greater than 0.5, demonstrating sound convergent validity and CR. The model fit indices met the standard goodness-of-fit criteria, confirming that the measurement model aligned well with the empirical data.

Theoretical analytical framework

The investigation of Tanzanian university students' STEM career interests was primarily grounded in SCCT and expectancy-value theory. The SCCT framework explores four interconnected models of career development: the interest model, choice model, performance model, and satisfaction model. These models integrate psychological, social, and economic factors through three core concepts—self-efficacy, outcome expectations, and goal selection—dynamically illuminating the complete process of career choice and development (Long *et al.*, 2002). The expectancy-value theory model emphasizes that achievement behavior is determined by achievement motivation, expectations of success, and incentive value. Both success expectations and incentive value are perceptions based on specific task situations. The greater the perceived likelihood of achieving a goal and the higher the incentive value derived from that goal, the stronger an individual's motivation to complete the task. The study organically combines these two theoretical models to construct a career orientation model using interest (M01, S01, E01), self-efficacy (M02, S02, E02), outcome expectations (M03, S03, E03), behavioral choices (M04, S04, E04), and goal selection (M05, S05, E05) as key measurement indicators. This framework explores how individual factors (gender, academic level) and environmental factors (place of origin, guardians' educational background) influence mathematics career interest, science career interest, and engineering/technology career interest—each reflecting dimensions of overall STEM career interest (Figure 1).

RESEARCH FINDINGS

This study examined the key factors influencing STEM career interest among Tanzanian university students majoring in science and engineering. The analysis considered both individual-level factors (such as gender, academic year, and the number of years studying physics and chemistry in secondary school) and environmental factors (including place of origin and guardians' educational background).

Tanzanian science and engineering students generally exhibit high levels of STEM career interest

The effective sample size was 1497, with item scores ranging from 1 to 5. The mean scores across dimensions and the overall scale ranged between 3.64 and 4.27, indicating that Tanzanian science and engineering university students generally demonstrate high levels of STEM career interest. The highest score (4.27) was observed in E04 (goal selection) within the engineering/technology career interest dimension, while the lowest score (3.64) was found in M04 (goal selection) within the mathematics career interest dimension.

Gender and duration of physics and chemistry study in secondary school significantly influence STEM career interest

Male students demonstrate significantly higher STEM career interest than female students

Gender has a significant impact on mathematics career interest, science career interest, and engineering/technology career interest scores among science and engineering university students ($P < 0.001$). Male students consistently scored higher than female students across all three career interest dimensions, indicating that male students exhibit higher STEM career interest overall (Table 1).

Longer duration of physics and chemistry study in secondary school has a more significant impact on STEM career interest

As shown in Tables 2 and 3 (not included in the excerpt), the duration of physics and chemistry study during secondary school significantly impacts mathematics career interest, science career interest, and engineering/technology career interest scores among Tanzanian science and engineering university students ($P < 0.001$). The longer students studied physics and chemistry in secondary school, the more significant the influence on their STEM career interest, and the greater their tendency to choose STEM-related careers.

Academic grade and place of origin significantly influence science career interest

Academic grade aignificantly impacts science career interest

As shown in Table 4, the academic grade does not significantly affect mathematics career interest or engineering/technology career interest among Tanzanian science and engineering university students, but it does significantly impact science career interest ($P < 0.001$). Additionally, as the academic grade increases, the mean scores for science career interest gradually decrease. This indicates that science and engineering university students show a weakening persistence and motivation regarding science-related career choices as they progress through their studies.

Different places of origin significantly influence science career interest

As shown in Table 5, place of origin has no significant impact on mathematics career interest ($P = 0.649$) or engineering/technology career interest ($P = 0.592$) among Tanzanian science and engineering university students, but it does significantly influence science career interest ($P = 0.002$). Students from urban areas demonstrate a greater inclination toward science-related careers compared to those from rural areas.

Guardians' educational background does not significantly influence STEM career interest

In this study, guardians' educational backgrounds were categorized into three groups: primary education or below, secondary education, and higher education. As shown in Table 6, guardians' different educational backgrounds do not significantly affect mathematics career interests, science career interests, or engineering/technology career interest among science and engineering university students ($P > 0.05$).

RESEARCH CONCLUSIONS AND ANALYSIS OF CAUSES

The main factors influencing STEM career interest among Tanzanian science and engineering university students include gender, academic grade, place of origin, and the duration of physics and chemistry study during secondary school. Additionally, the research found that guardians' educational background does not significantly influence STEM career interests. The following analysis and discussion focus on the factors identified as having a meaningful influence.

Gender role bias in the labor market

While science and engineering university students represent a vital driving force in Tanzania's industrialization process, female students demonstrate lower STEM career interest than their male counterparts. This disparity does not imply that women are inherently less inclined toward STEM careers; rather, it reflects the constraints imposed by Tanzania's current social environment and women's survival status in the labor market (Zhang, 2005). According to the 2022 statistical yearbook published by the Tanzania Commission for Universities, the proportion of female university graduates in STEM fields is significantly lower than that of males (Tanzania Commission for University, 2023). First, this disparity is largely attributable to gender discrimination and bias that foster social gender differences, which gradually evolve into social symbols used for conscious discrimination and differential treatment. Traditional Tanzanian social norms dictate that men should bear the responsibility of supporting their families, while women should accept unpaid domestic labor and supervision from men (OECD, 2022). Such enduring perceptions contribute to a gender gap that is difficult for women to overcome. Additionally, demand-side bias in the labor market exacerbates this issue. Under traditional social norms, women have been increasingly marginalized in their roles throughout the evolution of social productivity. The labor market unconsciously favors males in job supply and demand, talent selection, and skills training, creating survival challenges for women in the workplace. To break this impasse, it is necessary to dismantle the occupational segregation resulting from traditional social norms and enable more women to return to and participate in the industrial development labor market.

Dual imbalances between STEM program structure and industrial structure

Industrial development depends heavily on a skilled workforce in infrastructure-related fields. As the primary platforms for talent cultivation, universities play a critical role in the design and structure of their academic programs. The rationality of this program structure directly influences the quality and relevance of professional talent development (Wang, 2023). On the one hand, in Tanzania, STEM-related programs are overly generalized, and the irrational program structure creates an internal imbalance. For example, at the University of Dar es Salaam, four out of seven faculties primarily focus on science programs, with comparatively less emphasis on mathematics and engineering/technology. On the other hand, there is an external imbalance due to the mismatch between the program structure and industrial development. As one of the fastest-growing economies in East Africa and sub-Saharan Africa, Tanzania's industrial development remains in its early stages. The domestic industrial landscape is predominantly agricultural, with most existing industrial developments relying on foreign investment. While systematic foreign industrial investment can rapidly stimulate domestic industrial development, foreign companies offer very few positions for local science and technology talent, and these positions tend to favor well-educated and affluent groups (Ministry of Commerce of the People's Republic of China, 2020). When the program structure is misaligned with the social industrial structure, industrial infrastructure development becomes difficult to sustain, the growth of scarce talent slows, and the extreme scarcity of job opportunities fails to provide science and engineering university students with opportunities to apply their professional skills. Over time, neither the specifications nor the quality of localized talent can be effectively guaranteed.

The collision between absent family career guidance and independent career choice

Family education is a crucial component in students' development, with modern society emphasizing the collaborative educational mechanism integrating family, school, and society (Gao *et al.*, 2024). For students, a positive family educational environment provides important guidance for social participation. However, it is evident that Tanzanian science and engineering university students' family education lacks an effective balance between career guidance and autonomous career decision-making. On the one hand, due to cultural and historical factors, Tanzanians have learned to seek self-fulfillment amid hardship and enjoy life during prosperity. This optimistic philosophy is embedded in every Tanzanian's heart like a life creed, forming an educational consensus—"let the tree grow as a tree". Neither affluent nor limited family human capital becomes a decisive factor influencing STEM career interests among science and engineering university students. Tanzania's unique educational approach involves utilizing limited resources to provide students with moderate attention without interfering with their career choices, allowing them to find self-worth through existing life experiences. University students also build effective psychological capital by accumulating self-efficacy, optimism, and resilience based on realistic factors, which internalize as intrinsic career motivation for external exploration and internal self-improvement (Chen *et al.*, 2021). On the other hand, while parents grant students freedom in career choices, they often neglect the importance of career guidance education due to excessive permissiveness. University students are still in a stage of limited life and social experience. In such a "loosely engaged" environment, they can only navigate with limited experience. Consequently, the tripartite educational mechanisms of school, family, and society fail to form an effective closed loop to some degree.

Table 1: Independent samples *t*-test of gender differences in STEM career interest among science and engineering university students

Dependent variable	Gender	Number of cases	Mean ± SD	*t*	*P*
Mathematics career interest	Female	540	3.70 ± 0.77	-5.417	< 0.001
	Male	957	3.91 ± 0.70		
Scientific career interests	Female	540	4.04 ± 0.75	-4.682	< 0.001
	Male	957	4.21 ± 0.64		
Engineering and technology career interests	Female	540	3.96 ± 0.63	-7.179	< 0.001
	Male	957	4.20 ± 0.58		

SD, standard deviation; STEM, Science, technology, engineering, and mathematics.

Table 2: One-way ANOVA of the impact of physics study duration in secondary school on STEM career interest

Dependent variable	1-2 years	2-4 years	4-6 years	*F*	*P*	Post. hoc
Mathematical career interests	3.26 ± 0.90	3.63 ± 0.71	4.11 ± 0.56	140.082	0.000	3 > 2 > 1*
Science career interests	3.50 ± 0.93	4.05 ± 0.70	4.26 ± 0.55	71.433	0.000	3 > 2 > 1*
Engineering/technology career interests	3.68 ± 0.67	3.97 ± 0.60	4.21 ± 0.51	58.929	0.000	3 > 2 > 1*

Data are presented as mean ± SD. *, The significance level for mean differences is 0.05. 1, 1-2 years of physics study in secondary school; 2, 2-4 years of physics study in secondary school; 3, 4-6 years of physics study in secondary school. SD, standard deviation; STEM, Science, technology, engineering, and mathematics.

Table 3: One-way ANOVA of the impact of chemistry study duration in secondary school on STEM career interest

Dependent variable	1-2 years	2-4 years	4-6 years	*F*	*P*	Post. hoc
Mathematical career interests	3.27 ± 0.91	3.67 ± 0.70	4.03 ± 0.63	76.356	0.000	3 > 2 > 1*
Science career interests	3.32 ± 0.93	3.89 ± 0.67	4.30 ± 0.54	137.854	0.000	3 > 2 > 1*
Engineering/technology career interests	3.66 ± 0.70	3.98 ± 0.60	4.18 ± 0.53	42.585	0.000	3 > 2 > 1*

Data are presented as mean ± SD. *, The significance level for mean differences is 0.05. 1, 1-2 years of chemistry study in secondary school; 2, 2-4 years of chemistry study in secondary school; 3, 4-6 years of chemistry study in secondary school. SD, standard deviation; STEM, Science, technology, engineering, and mathematics.

Table 4: One-way ANOVA of the impact of academic grade on STEM career interest

Dependent variable	First year	Second year	Third year	*F*	*P*	Post. hoc
Mathematical career interests	3.88 ± 0.71	3.88 ± 0.69	3.89 ± 0.70	0.007	0.993	-
Science career interests	4.23 ± 0.70	4.08 ± 0.67	4.04 ± 0.67	10.308	< 0.001	1 > 2 > 3*
Engineering/technology career interests	4.11 ± 0.59	4.10 ± 0.56	4.06 ± 0.58	1.162	0.313	-

Data are presented as mean ± SD. *, The significance level for mean differences is 0.05. 1, First year; 2, Second year; 3, Third year. SD, standard deviation; STEM, Science, technology, engineering, and mathematics.

Passive choices behind geographic differences

As a predominantly agricultural country, Tanzania faces significant socioeconomic disparities that have exacerbated the already unbalanced urban-rural education divide. These disparities manifest in concrete ways, particularly in family nurturing practices and the quality of school education, both of which shape the academic and career trajectories of science and engineering university students. Students from different regions often exhibit cognitive differences and selection biases in their career planning, largely influenced by their contrasting educational environments. Regarding family nurturing behaviors, urban families tend to adopt a "normative" approach to student upbringing. Enhanced by affluent family capital, these students have more opportunities and conditions to access modern facilities, making it easier to form clear career perceptions. In contrast, students in rural educational settings often have vague future career plans due to their families' free-range nurturing approach. Moreover, rural students frequently encounter significant challenges in the school environment. Not only do they lack support from family or social capital, but they are often burdened with

Table 5: Independent samples *t*-Test of the impact of place of origin on STEM career interest

Dependent variable	Place of origin	Number of students	Mean ± SD	*t*	*P*
Mathematical career interests	Rural	887	3.84 ± 0.72	0.455	0.649
	Urban	610	3.82 ± 0.76		
Science career interests	Rural	887	4.10 ± 0.68	-3.077	0.002
	Urban	610	4.21 ± 0.69		
Engineering/technology career interests	Rural	887	4.12 ± 0.60	0.536	0.592
	urban	610	4.10 ± 0.62		

SD, standard deviation; STEM, Science, technology, engineering, and mathematics.

Table 6: One-way ANOVA of the impact of guardians' educational background on STEM career interest

Dependent variable	Primary Education and below	Secondary education	Higher education	*F*	*P*
Mathematical career interests	3.85 ± 0.73	3.87 ± 0.69	3.94 ± 0.65	1.313	0.269
Science career interests	4.19 ± 0.70	4.11 ± 0.62	4.10 ± 0.64	2.351	0.071
Engineering/technology career interests	4.10 ± 0.61	4.05 ± 0.55	4.18 ± 0.57	1.066	0.362

Data are presented as mean ± SD. SD, standard deviation; STEM, Science, technology, engineering, and mathematics.

domestic labor responsibilities such as herding and farming. These responsibilities compete with their academic obligations, further impeding educational progress. Additionally, rural schools face severe shortages of qualified teachers, inconsistency in teaching quality, and a critical lack of teaching materials and technological tools. These persistent structural inequities become external forces that influence students' academic performance and long-term development. Over time, students internalize these disparities through social signals from teachers, parents, and peers, gradually forming a psychological schema of "this is how it should be". This schema shapes habitual patterns related to lifestyle, social perception, and cultural norms, which in turn influence future career expectations and practical choices.

Excessively high thresholds for STEM program selection

The STEM academic performance of Tanzanian science and engineering university students during secondary school directly determines whether they can continue studying STEM programs in higher education. However, there exists a persistent contradiction between the reality of inconsistent STEM educational resource allocation standards, varying teaching standards, unrealistic professional admission standards, and excessively high requirements for studying STEM programs. Field research reveals that insufficient STEM educational resources in schools have become normalized due to inconvenient transportation and inadequate funding. Problems with nonstandardized faculty instructional behaviors and inconsistent student learning standards are also widespread. As the primary person in teaching activities, faculty members frequently arrive late and leave early, lack sufficient teaching skills, and engage in serious corporal punishment. For students, inconsistent evaluation standards and nonstandardized experimental operations make it difficult to develop sound disciplinary literacy. Objectively speaking, inadequate faculty training systems, management structures, and scarce teaching resources are the root causes of these issues. Unrealistic professional admission standards create a bottleneck for Tanzania's future STEM talent pipeline. While university students can continue studying STEM majors if they achieve a grade D (passing) or above in entrance examinations, only those with grades of B (good) or above are recommended to choose STEM majors, with different institutions imposing varying requirements and standards. This creates a logical paradox: on the one hand, students have extremely limited access to educational resources, and the country faces a severe shortage of scientific and technological talent, both currently and for decades to come; on the other hand, the National Examinations Council sets unrealistically high standards for passing examinations. As a result, the nation lacks usable talent to develop its industries, and potential talent lacks opportunities to contribute to national strength.

Academic burnout resulting from low social support and unsatisfactory major satisfaction

As academic level increases, scores across all dimensions of STEM career interest among science and engineering university students show a declining trend. Students with shorter periods of physics and chemistry study during secondary school demonstrate decreased STEM career interest and show signs of academic burnout. Research confirms that prolonged academic burnout not only affects students' physical and psychological development but also hinders their future career development (Um & Seon, 2024). This phenomenon stems from two main causes. First, there is less social support. The scarcity of STEM career positions and extremely limited foreign-invested STEM job opportunities fail to provide effective social support for science and engineering university students. Second, there is less satisfaction with academic programs. Despite the Tanzanian government's efforts to create favorable educational environments for higher education institutions, such as increasing laboratory equipment and establishing vocational training bases (Ministry of Finance and Planning, 2021), these measures cannot effectively change existing hardware teaching conditions. Moreover, a shortage of qualified STEM faculty and the inadequate professional competence of some instructors hinder the delivery of effective, high-quality education. As a result, many students are unable to receive meaningful positive reinforcement from their academic experiences, leading to declining identification with and satisfaction in their chosen majors. Consequently, students face difficulties in knowledge transfer academically while struggling to find self-value fulfillment in job-seeking, subjecting them to dual pressures from both academic and employment concerns. Such practical challenges make it difficult to stimulate students' STEM career interests, and students tend to develop self-negation at the self-perception level. This sense of disconnection between future aspirations and current reality repeatedly overwhelms students' inner worlds, leading to a state of academic burnout.

COUNTERMEASURES AND RECOMMENDATIONS

Cultivating university students' interest in STEM careers is a gradual process that cannot be accomplished overnight. Based on the study's findings and the challenges identified —including occupational gender bias, dual imbalances between academic programs and industrial needs, absence of family-based career guidance, urban-rural educational disparities, excessively high entry barriers to STEM programs, and widespread academic burnout—this study proposes the following recommendations. These suggestions are tailored to Tanzania's current STEM education realities, fully leveraging existing local advantages to promote scientific progress through steady development and cultivating STEM strategic talent to support Tanzania's industrialization process.

Standardize market employment demands and break occupational gender segregation

The distorted development of market demand under traditional social cognition can be counterbalanced through "dual standardization". First is policy standardization: with the government as the responsible entity, relevant regulations and policies should be promulgated to clearly define women's legitimate rights in the labor market, effectively guaranteeing their rights to survival and development in the workplace. Second is economic standardization: with enterprises (employers) as the responsible entities, appropriate economic subsidies should be provided to employers who meet policy standardization requirements. Meanwhile, special funds should be established to both protect women's legitimate rights in their professional positions and provide special rewards for female employees with outstanding performance, creating a positive development trend characterized by government institutional guarantees, employer benefits, and active individual participation.

Optimize the professional program structure to match ecological industrial development

First, the STEM program structure should be optimized. Tanzania's national conditions feature agriculture-dominated production with weak infrastructure development, yet there is a severe imbalance in the proportion of mathematics and engineering technology programs in higher education institutions. Under these circumstances, the proportion of science programs should be optimized and adjusted to maximize the alignment of university program development with major national strategic development initiatives. Second, the STEM program structure should be balanced with the current national industrial structure to achieve ecological industrial development. Specifically, university talent cultivation should be based on the country's current development status, producing high-quality local technical talent. Policy guidance should use agricultural production as a starting point, gradually progressing toward industrialization and modernization in measured steps rather than blindly borrowing and introducing existing industrial models and modernization processes from other countries.

Emphasize family education and fully leverage family career guidance

In Tanzania, schools can raise parents' awareness of the importance of family education through regular family education seminars and public lectures. On this foundation, parents can actively cultivate students' career awareness based on their own social roles. For example, parents already working in STEM fields can provide targeted STEM career introductions to students. When conditions permit, they can lead students on field visits to understand STEM career development, helping them form their own unique professional judgment (Wu, 2016). For families without adequate resources, parents should appropriately adjust their fixed educational concepts, actively encouraging and supporting students to seek external opportunities, transitioning from traditional "endogenous" career education to "externally guided" career education. This approach moves beyond the "following in parents' footsteps" career selection model, enabling diversified development and varied choices through external exploration.

Accelerate digital education development to enable urban-rural sharing of quality educational resources

Digital education can narrow the urban-rural educational gap through three aspects: accessibility, appropriateness, and affordability. In terms of accessibility, it is essential to rapidly enhance information infrastructure across both urban and rural areas, establish reliable internet connectivity, create platforms for sharing educational resources, and systematically make high-quality educational content available to underserved regions. For appropriateness, educational resources should be tailored to the context of disadvantaged rural areas by ensuring the content is both acceptable and practical for local users. Regarding affordability, the cost of digital education must reflect the financial capacity of rural communities to avoid adding economic burdens. Overall, digital education is significant for improving Tanzanian education, but difficulties and challenges coexist. Effective solutions require ongoing collaborative efforts from the government and society.

REASONABLY LOWER STEM PROGRAM SELECTION THRESHOLDS AND APPROPRIATELY EXTEND PHYSICS AND CHEMISTRY LEARNING PERIODS

First, a "multiple examination" strategy should be implemented for student entrance assessments, whereby the highest scores from academic year evaluations are used to determine eligibility for STEM-related majors upon university admission. Students' personal interests and academic choices should be fully respected; faculty should be prohibited from interfering with students' program selections to ensure that students retain full autonomy in their academic trajectories. Second, the learning periods for physics and chemistry should be extended. As secondary school students are still in the process of cognitive and emotional development, they may not yet possess the capacity for deep understanding and integration of complex scientific knowledge. Prematurely guiding students toward specific academic tracks may hinder their long-term learning and decision-making. To address this, physics and chemistry should be made compulsory subjects in the third and fourth years of secondary education. This approach would prevent students from prematurely discontinuing these subjects due to poor performance in second-year examinations. Moreover, it would provide an opportunity for students to re-engage with and gain a deeper understanding of these disciplines, thereby fostering sustained interest in STEM careers.

Complete supporting teaching infrastructure and improve faculty training systems

The urgent priority for completing teaching support facilities is addressing the shortage of textbooks and essential laboratories. For textbooks, the government should establish reasonable textbook development plans and ensure funding for textbook production. School fiscal budgets should include textbook purchases as necessary expenditures. For remote educational locations, local governments and schools can establish dedicated printing facilities, creating employment opportunities for local residents and increasing local fiscal revenue, while effectively addressing textbook shortages at the source. For laboratories, universities can equip students with dedicated laboratories through government funding, self-raised construction funds, and support from international organizations and social enterprises. At the same time, faculty training systems should be improved by standardizing teaching behaviors and strengthening training in teaching skills and application abilities. Faculty members should emphasize diverse teaching methods to stimulate students' classroom learning interest and post-class desire for knowledge. Education departments should establish and improve a unified training system for pre-service, in-service, and post-service faculty development to ensure high-quality development of the teaching workforce.

Improve social employment supervision systems and construct school-enterprise collaborative development

First, the government should develop a comprehensive talent demand template based on actual labor market needs and major national development strategies. Universities should undertake talent cultivation responsibilities, allocating talent cultivation and establishing relevant courses for different types and regions of universities according to the talent demand template released by official government functional departments. Throughout this process, government departments at all levels must strengthen supervision and management, standardizing the linkage between markets and universities—being market demand-oriented without departing from educational realities. Second, school-enterprise collaboration should be strengthened through joint efforts in curriculum development and the enhancement of students' professional competencies. University curricula should be employment-oriented, structured around the specific needs of employers, and designed to align educational goals with enterprise standards for workforce readiness, while still ensuring the inclusion of essential disciplinary knowledge. Professional capacity development can be achieved through a "dual instructor" system and specialized training bases, integrating production, education, and research to help students rapidly master knowledge and skills in actual production processes, forming a school-enterprise co-construction and co-management teaching system and effective pathways for enhancing students' vocational abilities.

DECLARATIONS

Secondary publication declaration

This article was translated and adapted with permission from the Chinese language version first published by the *Journal of Shenzhen Polytechnic*. The original publication is detailed as: Bao, R. & Chen, W. (2025). [An Analysis of STEM Career Interests and Influencing Factors for Tanzanian University Students—Based on a Survey of 1497 Science and Engineering Students]. *Journal of Shenzhen Polytechnic*, *24*(2), 73-82. https://doi.org/10.13899/j.cnki.szpuxb.2025.02.010

Acknowledgement

None.

Author contributions

Chen W: Conceptuation, Data curation, Methodology, Sofeware, Validation, Investigation, Writing-Original draft. Bao R: Resources, Writing-Review and Editing, Funding acquisition. All authors have read and approved the final version.

Source of funding

This study was supported by the China Scholarship Council (2022) "International Regional Issues Research and Foreign Language High-level Talent Training" project (202207260011).

Ethical approval

Not applicable.

Informed consent

Prior to conducting this study, formal approval was obtained from Tanzania's Ministry of Education, Science and Technology. All participants were explicitly informed before data collection that the research data would be used exclusively for academic purposes. Respondents retain the right to decline answering any questions or to withdraw from the interview at any time. In all published results, data will undergo rigorous anonymization procedures to ensure complete protection of participants' privacy.

Conflict of interest

The authors have no conflicts of interest to declare.

Data availability statement

No additional data.

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