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RESEARCH

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Influence of career awareness on STEM career interests: examining the roles of self-efficacy, outcome expectations, and gender

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Abstract

Background The studies of science, technology, engineering, and mathematics (STEM) career interests have progressed substantially over the recent years. However, the influence of career awareness on STEM career interests is an area that requires further discussion. Evidently, Chinese adolescents have limited awareness and interest in STEM careers in the context of the Chinese cultural milieu, which can potentially constrain their future career trajectories. This study explored the influence of career awareness on the STEM career interests of Chinese high school students, examining the mediating roles of self-efficacy and outcome expectations for STEM courses in this relationship. Additionally, it analyzes the impact of gender on the average levels and interrelations of these variables. A sample of high school students from both eastern and western regions of China ($N=2542$) was selected, and data was analyzed using a structural equation modeling approach.

Results The findings indicate that while STEM career awareness impacts various types of STEM career interests, minor differences exist in these effects. Specifically, the influence of STEM career awareness on analytical STEM career interests is entirely mediated by self-efficacy and outcome expectations in STEM courses. However, for life-survival and life-healthy STEM career interests, this mediation is only partial, with respective effects accounting for 39% and 45%. Notably, significant mean-level differences exist between male and female students in STEM career interests and self-efficacy in STEM courses, yet the relationships among these variables remain consistent across genders.

Conclusions This study underscores the pivotal influence of career awareness in molding STEM career interests, shedding light on the mediating functions of self-efficacy and outcome expectations within STEM courses. Through a gender-based analysis, it offers valuable insights into the differing inclinations of male and female high school students in the STEM realm, while also revealing consistent patterns in the relationships among these variables across genders. These findings underscore the necessity for heightened efforts to bolster STEM career awareness and fortify self-efficacy and outcome expectations within STEM courses, particularly in domains characterized by notable gender disparities, aiming to foster equitable advancement within the STEM disciplines.

Keywords STEM, Career interests, Career awareness, Gender differences

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Introduction

With the rapid global advancement of science and technology, highly skilled and innovative workforces in Science, Technology, Engineering, and Mathematics (STEM) are crucial for a nation's competitiveness

(Chinese National Institute of Education Sciences, 2018). Notably, the interest in STEM careers during secondary school is a pivotal predictor of subsequent involvement in STEM-related activities and professions (Jiang et al., 2023; Liong et al., 2023; Maltese & Tai, 2011; Tai et al., 2006). However, a phenomenon referred to as the "leakage pipeline" is observed in the STEM field—as students age, their interests in STEM courses and associated careers tend to wane, with this trend being particularly prominent among females (DeWitt et al., 2014; Nitzan-Tamar & Kohen, 2022; Sevilla et al., 2023). Data from Organization for Economic Co-operation and Development (OECD) countries further substantiates this observation, revealing that female students constitute a mere 33% of tertiary graduates in the STEM domain (OECD, 2023).

This challenge is particularly pronounced within the Chinese cultural context. Despite China's notable production of a vast pool of STEM talents and its students' exceptional academic performance in STEM subjects (Zwetsloot et al., 2021), a stark disparity persists between these achievements and adolescents' actual interest in pursuing STEM careers (OECD, 2019). For instance, while the 2018 Programme for International Student Assessment (PISA) ranks Chinese students at the top in academic accomplishments, their aspirations for STEM careers rank significantly lower, placing 71st out of 79 countries and regions. Alarmingly, a considerable portion of Chinese youth seems to lack clear career awareness, with nearly 30% unable to articulate definitive occupational goals in the PISA survey (OECD, 2019). Additionally, China's position in the *Global Gender Gap Report 2023* is concerning, as it ranks 107th out of 146 countries in terms of gender disparities (World Economic Forum, 2023). Chinese students demonstrate distinctive trends concerning their interests in STEM careers and gender disparities; however, research focusing on these aspects within the context of Chinese culture remains conspicuously limited (Chan, 2022; Lv et al., 2022; Wang et al., 2023).

From a career development perspective, career awareness emerges as a crucial determinant in predicting students' career choices (Playton et al., 2024; Watson & McMahon, 2016). Despite previous studies have highlighted a certain correlation between STEM career awareness and career interests (Kang et al., 2023; McMaster et al., 2023; Spyropoulou et al., 2020), the precise nature of this relationship and its underlying mechanisms remain to be further explored. On one hand, there are inconsistent views regarding the relationship between STEM career awareness and career interests. For instance, Kang et al (2023) found that enhancing students' career awareness contributes to improving their interest in science careers, while Vela et al. (2020) found that although career interventions increase students' awareness of STEM careers, they might not necessarily augment students' interests. On the other hand, there may be some underlying mechanisms between STEM career awareness and career interests. Mohtar et al. (2019) found that the influence of career awareness on career interests varies depending on the type of STEM careers. Luo et al. (2021) found that students' self-efficacy and outcome expectations in STEM fields play mediating roles between negative perceptions of STEM careers (stereotypes) and career interests.

To address the limitations of prior research, this study aimed to explore how career awareness influences students' interests in different types of STEM careers. Additionally, it integrated the Chinese cultural context to assess the mediating impacts of self-efficacy and outcome expectations within STEM courses, as well as the role of gender. This study adds evidence to the existing literature on the underlying mechanisms of how these factors (career awareness, self-efficacy, outcome expectations, gender) might jointly influence students' STEM career interests. Knowledge of possible effects is important for developing STEM experiences to foster students' career interests in diverse STEM fields.

Literature review and research hypotheses

Students' interests in STEM careers

STEM career interests are defined as individuals' general interests in choosing STEM-related careers (such as scientists, engineers, or technologists) in the future (Luo et al., 2021). Previous studies have concluded that STEM career interest is a significant predictor of students' STEM choices (Maltese & Tai, 2011; Tai et al., 2006). However, variations in students' interests may exist in different STEM career areas. For instance, findings from the *China STEM Education Research Report* (Chinese National Institute of Education Sciences, 2019) indicated that Chinese students exhibit a notably high interest in computer-related fields while showing a comparatively lower interest in veterinary-related careers. Moreover, it is crucial to acknowledge that the factors influencing students' interests in distinct STEM careers may diverge. For example, Matusovich et al. (2017) discovered a relationship between students' interests in engineering and their preference for math and science courses, but a similar correlation was not observed for fields related to healthcare.

Although some researchers have recently turned their attention to students' interests in various types of STEM careers (e.g., Rosenzweig & Chen, 2023), given the heterogeneity of STEM careers, few studies have addressed the factors behind the variation. In response to this gap, a handful of studies have attempted to categorize STEM careers. For instance, Cheng et al. (2021) employed cluster analysis to categorize STEM careers into analytical and empathic subcategories, with the former emphasizing strong analytical skills and the latter requiring more empathy. Additionally, Xu and Lastrapes (2022) categorized STEM careers into two broad areas: coreSTEM and biol/Med, while Mohtar et al. (2019) distinguished between physical science and life science. However, we found that even within life science STEM careers, there are distinctions in focus, such as medicine primarily addressing life-healthy issues and environmental science focusing more on life-survival issues. Consequently, there may be various classification schemes for STEM careers. Considering the restricted breadth of previous research on the influencing factors of diverse STEM career types, this study sought to offer empirical insights in this area. To achieve this, we undertook a categorization of STEM careers into subcategories through data analysis, followed by an investigation into the impact of specific potential factors on each category.

Career awareness and STEM career interests

Career awareness is regarded as a foundational construct in career development (Watson & McMahon, 2016), with Nasir and Lin (2013) emphasizing its pivotal role in the early stages of career development, aligning with Super's lifelong career development model (Super, 1980). Eliason and Patrick (2008) define career awareness as an individual's understanding of existing job opportunities, education and skill requirements, work environment, and the specific regulations and expectations of an industry. It is essential to note that there exists another closely related concept known as career perception, both of which pertain to the prospects and skills associated with a career (Mohtar et al., 2019; Spyropoulou et al., 2020). However, it is imperative to distinguish their subtle differences to maintain conceptual clarity. Following a comprehensive literature review, we concluded that career awareness primarily focuses on an individual's level of comprehension and knowledge regarding career-related information (Kang et al., 2023; Spyropoulou et al., 2020). This understanding can vary from "uninformed" to "informed," emphasizing "what do you know, and how well-informed are you?". Conversely, career perception centers on personal opinions regarding a career (Chen et al., 2024; Mohtar et al., 2019; Wang et al., 2023), which can be either "positive" or "negative," concentrating on "what do you believe, and how do you think?". Mohtar et al. (2019) noted that students' basic knowledge of career requirements, such as necessary skills and job prospects, can significantly impact their perception of a STEM profession. From this perspective, we posit that career perception might be shaped based on career awareness, thereby serving as an outcome of it. Previous research has demonstrated that both concepts are intricately linked to career decision-making (Wang et al., 2021; Watson & McMahon, 2016). Considering their malleability, numerous career-related interventions aim to bolster students' career awareness or perceptions (Drymiotou et al., 2021; Keumala et al., 2018; McMaster et al., 2023; Salonen et al., 2018).

This study focused on career awareness within STEM fields, defined as an individual's comprehension and knowledge of job profiles, employment prospects, and necessary skills in STEM-related professions (Spyropoulou et al., 2020). Given the subtle distinctions and close relationship between this concept and career perception, we also integrated relevant research on career perception as required. Previous studies have suggested that STEM career awareness could significantly differ depending on the quality and emphasis of a school's STEM career guidance (Blotnicky et al., 2018; Karahan et al., 2021; Playton et al., 2024). Such discrepancies may lead to variations in how students make decisions about pursuing STEM careers. The OECD (2019) has emphasized that a lack of accurate information regarding employment prospects and qualifications required for various positions might cause students to form educational and vocational expectations inconsistent with their academic achievements, potentially impeding their success in future job markets. Despite the promising employment prospects and rewards typically associated with STEM careers, students often lack a comprehensive understanding of these career paths (Blotnicky et al., 2018; McMaster et al., 2023; Mohtar et al., 2019). This information gap may deter many students from considering STEM careers as viable options (Blotnicky et al., 2018; Ferguson et al., 2023).

While existing research highlights the significance of STEM career awareness, the precise mechanisms through which it shapes students' STEM career interests remain inadequately elucidated, and there is a scarcity of research examining the impact of STEM career awareness on various types of STEM career interests. Only a limited number of studies have delved into the effects of STEM career awareness and its related concept, career perception, on students' career interests (Blotnicky et al., 2018; Kang et al., 2023; Mohtar et al., 2019). However, these studies have not converged on a consensus. For instance, Blotnicky et al. (2018) discovered that students with greater STEM career knowledge were more inclined to choose a STEM career. Kang et al. (2023) argued that awareness of science careers might moderate the relationship between interest and career aspirations. Mohtar et al. (2019) found that the impact of STEM career perception on different types of STEM career interest is different. It can directly influence students' interests in life sciences-based STEM careers but not physical sciences. Notably, while studies on the relationship between STEM career awareness and career interests exist in Western cultural contexts, relevant research in China remains relatively scarce. Considering the significant differences between China's educational system and cultural background and those of the West, it becomes imperative to further investigate the relationship between STEM career awareness and career interests among Chinese adolescents. Hence, one of the primary objectives of this study is to explore the mechanisms and intensity of the influence of STEM career awareness on career interests among Chinese students, aiming to bridge the gaps in current research. Based on the existing literature, the following hypothesis is proposed:

H1: STEM career awareness would directly influence high school students' STEM career interests.

Mediating roles of self-efficacy and outcome expectations between career awareness and interests

Researchers have approached the subject students' motivations for choosing STEM careers from various perspectives to gain a profound understanding of these choices (Nugent et al., 2015; Rachmatullah & Wiebe, 2023; Rosenzweig et al., 2024). One commonly used theoretical framework for explaining adolescents' educational and vocational choices is the Social Cognitive Career Theory (SCCT) (Lent et al., 1994, 2008). SCCT originates from Bandura's Social Cognitive Theory (Bandura, 1989, 1993) and provides a theoretical foundation for understanding individual career choices and performance in specific domains. Within SCCT, learning experiences, self-efficacy, and outcome expectations elucidate the development process of career interests. Self-efficacy pertains to an individual's confidence in their ability to succeed in a specific domain (e.g., STEM), while outcome expectations refer to an individual's anticipations of the consequences of particular actions. Both are considered key driving factors for career interests, and self-efficacy might further influence outcome expectations. Learning experiences, including past personal experiences, verbal preconceptions from others, and vicarious learning, are considered significant sources of self-efficacy and outcome expectations (Lent et al., 1994, 2008). The framework posits that learning experiences can influence career interests by affecting self-efficacy and outcome expectations. However, SCCT does not explicitly explain how career-related outcomes acquired through learning experiences (such as career awareness) can strengthen, weaken, or shape adolescents' self-efficacy and outcome expectations, ultimately influencing their career choices.

On the contrary, certain studies in the realm of career development have centered on how individuals accumulate career awareness through diverse learning experiences over their developmental trajectory, subsequently shaping their career decision-making processes (Keumala et al., 2018; Nasir & Lin, 2013; Salonen et al., 2018). For example, Keumala et al. (2018) discovered that career guidance programs could enhance elementary school students' career awareness, thereby influencing their career aspirations. A limited body of research has underscored the impact of career awareness on individual self-efficacy and outcome expectations, which, in turn, influence career choices and decision-making processes (Hashish, 2019; McMaster et al., 2023; Nasir & Lin, 2013). For instance, Hashish (2019) found that bolstering career awareness among nursing students positively affected their career self-efficacy, enabling them to effectively navigate potential career barriers. However, previous studies have not extensively explored the intricate relationships among career awareness, self-efficacy, outcome expectations, and career interests within the STEM domain. Therefore, this study endeavors to apply the SCCT alongside existing evidence related to career awareness in the STEM field to delve into the specific manifestations of these factors within this domain. We aim to investigate whether STEM career awareness, stemming from learning experiences, can influence individuals' self-efficacy and outcome expectations for STEM courses, subsequently impacting their interest in STEM careers.

Self-efficacy, outcome expectations, and STEM career interests

In accordance with the SCCT framework, prior studies have highlighted that self-efficacy and outcome expectations pertaining to STEM activities can positively predict students' interests in STEM careers (Jiang et al., 2020; Turner et al., 2019; Tzu-Ling, 2019; Zhao et al., 2024). Tzu-Ling (2019) corroborated the positive predictive role of self-efficacy on STEM career interests. Turner et al. (2019) further elucidated that adolescents' self-efficacy in STEM can influence their interests in STEM careers through their outcome expectations. However, it is noteworthy that existing studies present varying perspectives on STEM course self-efficacy and outcome expectations. Some studies adopt a holistic view regarding STEM (Lv et al., 2022; Tzu-Ling, 2019), while others treat STEM as distinct subjects, such as science and mathematics (Jiang et al., 2020; Wang et al., 2023). The present study aligns with the latter perspective, consistent with how STEM courses are typically taught in Chinese high schools. We aim to understand how high school students' self-efficacy and outcome expectations for school STEM courses influence their interests in various STEM careers.

While studies in Western contexts have established the connection between STEM self-efficacy, outcome expectations, and career interests (Inda-Caro et al., 2016; Kang et al., 2017; Turner et al., 2019), such a relationship within the Chinese cultural context remains largely unexplored. A well-known Chinese adage, which suggests that "those with a brilliant command of math and sciences will be professionally successful with great ease"(学好数理化，走遍天下都不怕) not only epitomizes the self-efficacy and outcome expectations of STEM courses but also implies their interrelation. Theoretically, STEM self-efficacy and outcome expectations should influence students' career interests. However, this theoretical assumption is yet to be fully validated in the Chinese cultural context. Thus, one of the primary objectives of this study is to investigate this relationship to bridge the existing research gap on the subject. Therefore, we propose the following hypothesis:

H2a: Self-efficacy and outcome expectations for STEM courses would directly influence STEM career interests, with self-efficacy further influencing outcome expectations.

STEM career awareness and self-efficacy, outcome expectations

Previous research has demonstrated that students' awareness of STEM careers often arises from specific learning experiences or educational processes, such as classroom instruction, school career guidance, participation in activities, or online resources (Crawford et al., 2021; Drymiotou et al., 2021; Ferguson et al., 2023; Han et al., 2021; Yoel & Dori, 2022). As students engage in these experiences, their awareness of STEM careers is heightened (Karahan et al., 2021). This enhanced career awareness, in turn, positively influences their self-efficacy and outcome expectations (Morris et al., 2020; Thevenin & Elliott, 2015). For example, Morris et al. (2020) corroborated that students' positive awareness of engineering can bolster their self-efficacy and career expectations in the field, aligning with our perspective.

While the SCCT and the current evidence provide a theoretical foundation for the influence of career awareness on self-efficacy and outcome expectations, applying this relationship within the STEM domain has not been extensively explored. One of our research objectives is to provide empirical support for this hypothesis. With this aim in mind, we propose the following hypothesis:

H2b: STEM career awareness is expected to positively impact students' self-efficacy and outcome expectations for STEM courses.

Mediating roles of self-efficacy and outcome expectations

The SCCT explicitly posits how learning experiences shape an individual's self-efficacy and outcome expectations, which in turn influences their career interests (Lent et al., 1994). Drawing on the current evidence (Crawford et al., 2021; Drymiotou et al., 2021; Han et al., 2021; Yoel & Dori, 2022), this study posits STEM career awareness as a pivotal outcome of learning experiences related to STEM career pathways. Within the SCCT framework and considering the existing evidence, we propose that STEM career awareness, acquired through learning experiences, might influence career interests via the mediating effects of self-efficacy and outcome expectations related to STEM courses. Luo et al. (2021) is the only study to express similar perspective by demonstrating that elementary students' STEM stereotypes can influence career interests by predicting self-efficacy and outcome expectations. Unlike Luo et al. (2021), who focused on the stereotypes of STEM careers (e.g., people in STEM-related jobs tend to engage in physical labor), our study takes a different approach. We emphasize students' comprehensive cognition and understanding of STEM careers, exploring a broader perspective beyond stereotypes.

While previous studies have established a theoretical framework linking STEM career awareness with STEM self-efficacy, outcome expectations, and career interests, there remains a dearth of empirical evidence validating these connections. The main objective of this study is to empirically investigate the potential mediating role of STEM course self-efficacy and outcome expectations. Therefore, we propose the following hypothesis:

H2c: STEM course self-efficacy and outcome expectations may mediate the relationship between STEM career awareness and career interests.

Gender-related disparities in STEM

Gender disparities in STEM fields have been a focal point of research (Dost, 2024; Eidlin-Levy et al., 2023; Hermans et al., 2022; Myint & Robnett, 2024; Wang et al., 2023). According to the SCCT, an individual's interest in specific occupational fields may be influenced by background factors, socialization behaviors, and the broader cultural context of the individual, potentially resulting in gender-related disparities (Lent et al., 1994, 2008). Within the context of Chinese culture, gender disparities in STEM fields manifest unique characteristics (Ma et al., 2016; Yang et al., 2024). While China has made strides towards gender equality, resulting in an increased number of women pursuing higher education, a significant gender gap persists in the selection of STEM majors, with males disproportionately choosing engineering fields

(Ma et al., 2016). This trend may be linked to traditional Chinese cultural norms, such as the Confucian ideals of "men work outside, women stay inside" (男主外，女主内), where women are expected to embody the role of "a virtuous wife and good mother" (贤妻良母) (Liu, 2014). The competitive nature of many STEM fields may deter women from pursuing careers in these areas, despite their potential (Cheng et al., 2021). Differences in socialization processes and backgrounds can result in gender disparities at both the mean level, such as females showing lower interest in STEM careers than males (Balta et al., 2023), or at the process level, where the predictive role of STEM self-efficacy for female career interests might be more pronounced than that for males (Lv et al., 2022; Watt et al., 2012). Set within the specific cultural context of China, this study aims to explore both the mean level differences and relational differences between males and females in STEM career awareness, self-efficacy, outcome expectations, and career interests.

At the mean level, while the majority of studies suggest that females tend to exhibit lower mathematical and scientific abilities and self-efficacy compared to males (Eidlin-Levy et al., 2023; Shin et al., 2018), some studies offer contrasting perspectives. For instance, Tzu-Ling (2019) proposed that male and female students exhibit similar performance and motivational behaviors in the STEM domain. Moreover, recent PISA results have indicated a narrowing gender gap in science and mathematics, with girls even slightly outperforming boys in science (OECD, 2019). Concerning career interests, male and female students may gravitate towards different STEM career paths. For instance, female students may be more inclined to pursue STEM careers involving social relations, such as medicine, while male students may prefer STEM careers involving interaction with inanimate objects, such as physics (Cheng et al., 2021; Yang et al., 2024). Given these divergent research findings, further investigation into gender differences among high school students in the STEM domain is essential. Therefore, in this study, we hypothesize that:

H3a: There should be a significant difference between male and female students on the mean levels of STEM career awareness, self-efficacy, outcome expectations, and career interests.

At the process level, the research findings regarding whether gender moderates the relationship between process variables such as self-efficacy and students' STEM career interests are inconsistent (Jiang et al., 2020; Lv et al., 2022; Tzu-Ling, 2019; Watt et al., 2012). For example, Lv et al. (2022) found that, compared to female students, self-efficacy has a more robust predictive effect on male students' STEM career expectations. However, Jiang et al. (2020) discovered that self-efficacy plays a similar role in predicting STEM major choices for both. Currently, there is a lack of comprehensive research on whether there are gender differences in the relationship between career awareness, self-efficacy, outcome expectations, and career interests. Therefore, this study seeks to address this research gap by examining whether or not the gender factor can moderate these associations. It is, therefore, hypothesized that:

H3b: The role of gender should have a moderating effect on the relationship between STEM career awareness, self-efficacy, outcome expectations, and career interests.

The current study

To expand upon the understanding of the influence of STEM career awareness on career interests and elucidate the phenomenon of Chinese adolescents' involvement in STEM, we constructed a conceptual model grounded in the literature review and the SCCT framework (Fig. 1). This framework, underpinned by research hypotheses, endeavors to enrich the existing body of knowledge in this domain. The alignment between the depicted paths in Fig. 1 and the research hypotheses (H1 to H2c), as well as the research objectives, is as follows:

H1: Examining the direct effect of STEM career awareness on career interests, delineated by path ①; H2a: Examining the relationship between self-efficacy, outcome expectations and career interests, illustrated by paths ④, ⑤, ⑥; H2b: Investigating the impact of STEM career awareness on self-efficacy and outcome expectations, involving paths ② and ③; H2c: Examining the multiple mediating roles of self-efficacy and outcome expectations between STEM career awareness and career interests, with three paths: ②→⑤; ③→⑥; ②→④→⑥.

Additionally, we further examined the effect of gender on the means and interrelationships of these variables. H3a aims to test the differences in gender at the mean level of each variable, H3b aims to test the potential moderating effect of gender on the relationship between the variables in Fig. 1.

Methods

Participants and data collection

In China, public high schools constitute the vast majority of educational institutions. Currently, approximately 81.66% of the total enrollment in regular high schools nationwide originates from public high schools, while only 18.34% attend private high schools (Ministry of Education of the People's Republic of China, 2023). The high school stage comprises grades 10 through 12, with students taking the National College Entrance Examination (commonly known as "Gaokao") in grade 12 to determine

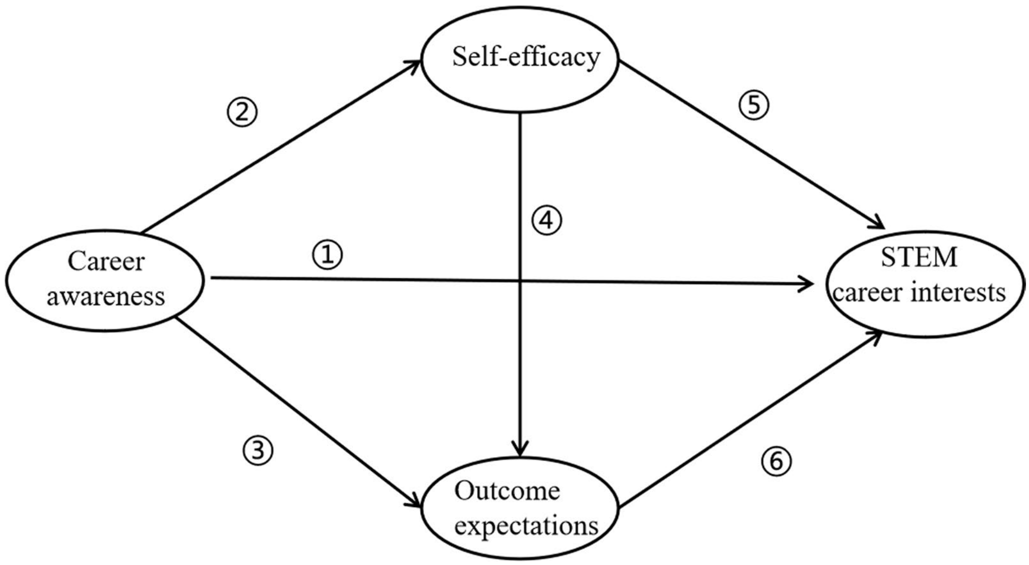

Fig. 1 Conceptual model

their eligibility for admission to different universities. High schools are categorized into demonstration and ordinary high schools based on the comprehensive quality of performance.

The current research was conducted in Anhui Province in the eastern region and Guizhou Province in the western region of China. We selected one demonstration high school and one general high school from each of the two provinces, all of which are public institutions located in urban areas, drawing students from both urban and surrounding rural areas. The target participants for recruitment were students in grades 10 and 11. The sample selection is primarily guided by the following considerations: First, Guizhou, located in the western region, experiences a relatively lower level of economic development, while Anhui, situated in the eastern region, falls within the moderate level of economic development. This geographical and economic contrast enhances the diversity of the research context. Second, in the preliminary stages of recruitment, teachers in the two provinces agreed to assist with our investigation, facilitating the progress of the research. Third, to accommodate variations in school types and student diversity, we selected both demonstration and general high schools that draw students from urban and rural backgrounds. Fourth, given the intensive preparation for the National College Entrance Examination in grade 12, the study targeted students in grades 10 and 11 to ensure their sufficient availability for participation in the research.

We selected 8 classes each from the 10th and 11th grades in four schools for on-site questionnaire surveys. Prior to data collection, informed consent was obtained from both the students and their respective classroom teachers, ensuring ethical research practices. It was explicitly communicated to the students that they retained the option to withdraw from the study at any point. Following this, participants filled out the paper-based questionnaires within a 30-min period under their teachers' supervision. The study enrolled 2,542 high school students with an average age of 15.81 years. Among the participants, approximately 44.8% ($n = 1138$) were male, while 55.2% ($n = 1404$) were female. Regarding grade level, 52.4% ($n = 1332$) were from the 10th grade, and 47.6% ($n = 1210$) were from the 11th grade. Regarding ethnicity, the majority were Han Chinese, constituting 68% ($n = 1729$), while 32% ($n = 813$) belonged to various ethnic minorities. In terms of family residence, 48.7% ($n = 1238$) of the students reported living in rural areas, while 51.3% ($n = 1304$) indicated urban residences. The distribution of participants across the four schools was 27.9% ($n = 708$), 26.2% ($n = 666$), 23.5% ($n = 598$), and 22.4% ($n = 570$), respectively. A detailed summary of student demographics can be found in Table 1.

Measures

We developed, translated, and revised several measurement instruments. The STEM career awareness tool was first jointly developed by a team of three STEM teachers based on Chinese cultural background. Tools for assessing STEM self-efficacy and outcome expectations were adapted from Roller et al. (2020), while the tool for measuring STEM career interests was adapted from Unfried et al. (2015). These tools have been used in the Chinese context (e.g., Chinese National Institute

Table 1 Student demographics

Demographics	Student *n* (%)
Age	Mean: 15.81 (*SD* = 0.90)
Gender	Male: *n* = 1138 (44.8%); Female: *n* = 1404 (55.2%)
Grade	Grade 10: *n* = 1332 (52.4%); Grade 11: *n* = 1210 (47.6%)
Ethnicity	Han: *n* = 1729 (68%); Minorities: *n* = 813 (32%)
Residence	Rural: *n* = 1238 (48.7%); Urban: *n* = 1304 (51.3%)
School	Guizhou: Ordinary: *n* = 708 (27.9%), Demonstration: *n* = 666 (26.2%); Anhui: Ordinary: *n* = 598 (23.5%), Demonstration: *n* = 570 (22.4%)

of Education Sciences, 2019). In this study, to ensure their suitability for Chinese high school students, we first conducted a re-translation and thorough proofreading of the instruments. Subsequently, two experts and three STEM teachers extensively discussed each item, refining them to align with the content of Chinese STEM courses and career classifications. After the development or adaptation of the instrument set, we initially invited 28 high school students to participate in a pre-test, soliciting their feedback. Based on their responses, further modifications were made to the instruments. Following this iterative process, a formal survey was conducted using the refined tools. Finally, the validity of the formal research instrument was established using the dataset comprising 2542 responses.

To evaluate the quality formal instruments, we employed exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). For instruments without a predefined internal structure (i.e., career awareness and career interests), we conducted EFA followed by CFA. For those with a known structure (i.e., STEM self-efficacy and outcome expectations), we solely used CFA for construct validity confirmation. Following Hair et al. (2006), we conducted EFA and CFA on separate, randomly divided subsamples: Sample I ($n = 1255$) for EFA in SPSS 22.0 and Sample II ($n = 1287$) for CFA in AMOS 24.0. CFA evaluation utilized standard goodness-of-fit criteria: RMSEA < 0.08, SRMR < 0.05, and CFI/TLI > 0.9 (Brown, 2015; Kline, 2015). Construct validity was assessed through composite reliability (CR > 0.7) and average variance extracted (AVE > 0.5), following Hair et al. (2006), and maintained validity with AVE < 0.5 if CR > 0.6, per Fornell and Larcker (1981). Discriminant validity was confirmed when construct correlations were below the square root of the AVE for each construct. Following a series of procedures, the final versions of the instruments in English and Chinese are presented in Additional file 1: Supplementary Material S1. A detailed description of each measurement tool and its corresponding quality indicators is provided below.

Key predictor: STEM career awareness

The final version of STEM career awareness instrument consists of 5 items. Responses were captured using a 5-point Likert scale, ranging from 1 = "very uninformed" to 5 = "very informed." EFA results indicated that STEM career awareness is a unidimensional construct, explaining 65.72% of the variance. CFA further supported the instrument's validity with the following fit indices: $\chi^2 = 31.09$ ($df = 5$), CFI = 0.99, TLI = 0.99, RMSEA = 0.06, and SRMR = 0.02. All five items had factor loadings above 0.7, and Cronbach's alpha was a robust 0.88.

Mediators: self-efficacy and outcome expectations for STEM courses

The final version of STEM self-efficacy and outcome expectations tool comprises a total of 18 items. In the original tool (Roller et al., 2020), they belong to three subscales of mathematics, science, and engineering technology, and the Cronbach's alpha values for these three subscales as 0.89, 0.84, and 0.87, respectively. In this study, we selected 18 items related to self-efficacy and outcome expectations in STEM from the three subscales. These items were then translated into Chinese and adapted to suit the specific context of STEM education in China. Specifically, STEM self-efficacy was categorized into self-efficacy for science, technology engineering, and mathematics, while STEM outcome expectations covered expectations for science, technology engineering, and mathematics. Each domain included three items. All items were rated using a 5-point Likert scale, with 1 indicating "strongly disagree" and 5 indicating "strongly agree."

The results of the CFA for STEM self-efficacy indicated a second-order factor model with the following fit indices: $\chi^2 = 53.84$ ($df = 24$), CFI = 0.99, TLI = 0.99, RMSEA = 0.03, and SRMR = 0.02. This model comprised three first-order factors: science, engineering technology, and math self-efficacy, all of which loaded onto a higher-order STEM self-efficacy factor. The factor loadings for individual items ranged from 0.64 to 0.93, and the overall Cronbach's alpha was a robust 0.88. Similarly, the CFA results for STEM outcome expectations also supported a second-order factor model, comprising three first-order factors: science, engineering technology, and math outcome expectations. The fit indices for this model were: $\chi^2 = 204.88$ ($df = 24$), CFI = 0.96, TLI = 0.93, RMSEA = 0.08, and SRMR = 0.03. All these first-order factors were loaded onto a higher-order STEM outcome expectations factor. The factor loadings for individual items varied from 0.56 to 0.84, and the model demonstrated good reliability with a Cronbach's alpha of 0.83. These results collectively demonstrate that our measurement items for STEM self-efficacy and outcome expectations, which are based on the three sub-domains of science, engineering technology, and mathematics, possess high validity and reliability. Additional evidence supporting these findings can be found in Additional file 1: Supplementary Material S2.

Outcome variable: STEM career interests

The final version of STEM career interests instrument consists of 12 items. The original tool was developed by Unfried et al. (2015) based on the U.S. Bureau of Labor Statistics' (2011) *Occupational Outlook Handbook* and underwent rigorous validation. This scale encompassed 12 career domains: physics, environmental science, biology, veterinary medicine, mathematics, general medicine, earth science, computer science, medical science, chemistry, energy, and engineering. Unfried et al. (2015) noted that these 12 career domains might not form a single construct; therefore, they conducted no additional psychometric tests on the career-interest section. To align with the Chinese context, we adjusted it based on the *Chinese Occupational Classification Dictionary* (National Occupational Classification Revision Working Committee, 2015). "Veterinary medicine," typically a subset of "agricultural science" in China, was thus replaced by "agricultural science." To enhance students' comprehension of each career domain, we listed four typical occupations under each, all generally requiring a university degree in China. The survey began with the question, "How interested are you in pursuing the following careers in the future?" and then presented the 12 STEM career fields along with representative occupations. Students' interest in each career field was rated on a 5-point Likert scale, with 1 indicating "not interested at all" and 5 indicating "highly interested."

We initially conducted an EFA to identify the possible subcategories of STEM careers. The EFA yielded a three-factor solution, explaining 60.82% of the variance. Based on the discussion of the classification of STEM careers in the literature review section, these factors were labeled as follows: (a) Analytical STEM careers, including physics, mathematics, computer science, chemistry, energy, and engineering. (b) Life-survival STEM careers, including environmental science, biology, agricultural science, and earth science. (c) Life-healthy STEM careers, including general medicine and medical science. CFA analysis showed a good model fit for the three-factor model: $\chi^2=283.47$ ($df=40$), CFI = 0.96, TLI = 0.93, RMSEA = 0.07, and SRMR = 0.05. Additionally, Cronbach's alpha values for the three factors were 0.83, 0.77, and 0.78, respectively. Table 2 presents detailed structural information regarding STEM career interests.

Table 2 The construct of STEM career interests

Factors	Career pathways	Cronbach's α
Analytical STEM careers	Physics, math, computer science, chemistry, energy, engineering	0.83
Life-survival STEM careers	Environmental science, earth science, biology, agricultural science	0.77
Life-healthy STEM careers	General medicine, medical science	0.78

Convergent validity and discriminant validity of each construct

We conducted further analysis to assess the convergent and discriminant validity of all constructs, as shown in Table 3. The CR for all constructs was above 0.7. With the exception of analytical STEM career interests, the AVE for all other constructs met or exceeded the 0.5 threshold. Although the AVE for analytical STEM career interests was 0.45, nearing the 0.5 threshold, its CR was 0.83, meeting the acceptable criteria established by Fornell and Larcker (1981). Therefore, all constructs demonstrated satisfactory convergent validity. The square roots of the AVE values, ranging from 0.67 to 0.81, were greater than the correlations among the constructs, indicating effective discriminant validity. These results suggested that all measurement tools possessed adequate reliability and validity.

Data analysis

The analysis of data was conducted in four stages utilizing SPSS 22.0 and AMOS 24.0.

Descriptive statistics

Initial analysis involved generating descriptive statistics for STEM career awareness, self-efficacy, outcome expectations, and career interests, which included mean calculations, kurtosis and skewness assessments, and correlation examinations.

Structural equation modeling (SEM)

We applied SEM to discern relationships among the variables and the effects were examined using bootstrap 5000 with 95% confidence intervals (CI). Given the numerous items in self-efficacy and outcome expectations for STEM courses, we employed item parceling based on the CFA results suggested by Little et al. (2002). Using the internal consistency approach, we parceled STEM self-efficacy and outcome expectations into three distinct measures each.

Table 3 Convergent validity and discriminant validity of the constructs

Constructs	CR	AVE	1	2	3	4	5	6
1. Awareness	0.89	0.61	**0.78**					
2. Self-efficacy	0.82	0.62	0.40	**0.79**				
3. Outcome expectations	0.78	0.55	0.36	0.63	**0.74**			
4. Analytical career interests	0.83	0.45	0.29	0.64	0.53	**0.67**		
5. Life-survival career interests	0.80	0.50	0.28	0.36	0.38	0.65	**0.71**	
6. Life-healthy career interests	0.79	0.66	0.22	0.31	0.30	0.52	0.61	**0.81**

The bold number refers to the square root of AVE in each construct

Multivariate analysis of covariance (MANCOVA)

To determine the average level differences between male and female students in STEM career interests, career awareness, self-efficacy, and outcome expectations, this study employed MANCOVA. Previous research has indicated that background factors such as ethnicity, parental education level, and family residence might influence students' performance in STEM fields (Jiang et al., 2020; Myint & Robnett, 2024; Smith et al., 2023). Given that the focus of our study is on exploring gender differences, we controlled for these variables, including ethnicity (Han or minorities), parents' highest level of education (scaled from 1 = elementary school and below to 6 = master's degree and above), and family residence (rural or urban). Effect sizes were quantified using partial η^2, with thresholds of 0.01, 0.06, and 0.14 indicating small, medium, and large effects, respectively, in line with Cohen (1988).

Multi-group structural equation modeling (MGSEM)

MGSEM was applied to explore potential differences in variable relationships between genders. Initially, we conducted a free estimation for the models of male and female students separately, resulting in an unconstrained model. Subsequently, we incrementally imposed constraints on the model, successively obtaining the measurement weights model and the structural weights model. Next, we compared these constrained models with the unconstrained model. Competing models were generally compared using the chi-square difference ($\Delta\chi^2$): a significant probability ($p < 0.05$) associated to $\Delta\chi^2$ means a disparity between the models. However, like χ^2, $\Delta\chi^2$ is sensitive to sample size. With large sample sizes in each group, $\Delta\chi^2$ can easily reach significance, erroneously rejecting the null hypothesis and suggesting significant differences where there may be none (Wu, 2020). Consequently, some researchers recommend using sample size-insensitive indices like CFI and TLI for assessing measurement equivalence. For instance, Cheung and Rensvold (2002) noted that a $\Delta CFI \le 0.01$ indicates model equivalence, while Little (1997) suggested that a $\Delta TLI \le 0.05$ signifies acceptable measurement equivalence. Considering that male and female sample sizes both exceed 1000 in the current study, we used a combination of χ^2, TLI, and CFI to evaluate measurement invariance. Additionally, to ensure robustness of statistical results, the critical ratio index, representing the parameter's critical difference ratio, was used to compare the significance of path effects between male and female student models. A critical ratio index with an absolute value greater than 1.96 indicates significant differences between the two parameters.

Results

Descriptive statistics

Table 4 presents a summary of the means, standard deviation (SD), correlations, kurtosis, and skewness of the main variables. The average level of STEM career interests was observed to be near the midpoint, with the mean scores for the subcategories as follows: analytical (*mean* = 2.92), life-survival (*mean* = 2.84), and life-healthy (*mean* = 3.07). The predictor variable, STEM career awareness, exhibited a slightly lower mean of 2.63. Students demonstrated relatively modest self-efficacy in STEM courses (*mean* = 2.85), while their outcome expectations in STEM displayed notably optimistic values (*mean* = 3.84). Upon examining the correlations, we found that career awareness displayed weak to moderate associations with other variables ($r = 0.18–0.31$). The three dimensions of STEM career interests, analytical, life-survival, and life-healthy, demonstrated more pronounced correlations ($r = 0.36–0.53$). Furthermore, the correlations between the mediator variables (including STEM self-efficacy and outcome expectations) and the outcome variable ranged from 0.17 to 0.52. Importantly, all variables exhibited kurtosis and skewness values within the − 1 to 1 range, indicating adherence to a normal distribution (Kline, 2015). These statistical findings lay the groundwork for subsequent analytical procedures.

The relationship between STEM career awareness, self-efficacy, outcome expectations, and career interests

We employed a latent variable structural equation model to validate hypotheses (H1 to H2c). Given the sample includes four schools from various regions across China,

Table 4 Mean, SD, Skewness, Kurtosis, and correlation between key variables

Variables	1	2	3	4	5	6
1. Awareness						
2. Self-efficacy	0.31**					
3. Outcome expectations	0.29**	0.41**				
4. Analytical career interests	0.23**	0.52**	0.36**			
5. Life-survival career interests	0.25**	0.23**	0.24**	0.53**		
6. Life-healthy career interests	0.18**	0.17**	0.21**	0.36**	0.45**	
Mean	2.63	2.85	3.84	2.92	2.84	3.07
SD	0.02	0.01	0.01	0.02	0.02	0.02
Skewness	− 0.20	− 0.08	− 0.43	− 0.23	− 0.20	− 0.08
Kurtosis	− 0.14	0.13	0.99	− 0.15	− 0.11	− 0.28

All variables take values in the range of 1–5. The factor analysis results indicate that STEM careers can be divided into three subcategories: analytical, life-survival, and life-healthy, so we show the career interests of each subcategory separately

**$p < 0.01$

there may be potential differences between schools. To determine the necessity of multilevel modeling (MLM) as suggested by Peugh (2010), we first examined the Intraclass Correlation Coefficients (ICCs) of each latent variable. The results showed that the ICCs are all below 1%: STEM career awareness (0.08%), STEM self-efficacy (0.12%), STEM outcome expectations (0.08%), Analytical STEM career interests (0.12%), Life-survival STEM career interests (0.04%), and Life-healthy STEM interests (0.03%). Furthermore, the design effects for all variables were less than 2. According to Cohen (1988), an ICC below 0.059 indicates a weak degree of intra-group correlation, suggesting that most variance is attributed to within-school differences. Also, Peugh (2010) states that design effect estimates below 2 indicate MLM may not be necessary. Consequently, we opted not to conduct MLM.

During the instrument validation process, STEM career interests were identified as a three-dimensional construct, encompassing analytical, life-survival, and life-healthy facets (see Table 2). Consequently, in the model fitting phase, we decomposed the STEM career interests from our conceptual model (Fig. 1) into these three interrelated sub-constructs for comprehensive modeling. The overall fit indices of the model met acceptable standards: $\chi^2 = 2267.81$ ($df = 213$), CFI = 0.91, TLI = 0.90, RMSEA = 0.06, SRMR = 0.04. The standardized path coefficients between the key latent variables are illustrated in Fig. 2. In the following sections, we present the findings in alignment with each research hypotheses.

Direct effects of STEM career awareness on career interests

The results revealed that the direct influence of STEM career awareness on the three different types of STEM career interests is inconsistent. Specifically, STEM career awareness did not have a significant direct effect on analytical STEM career interests ($\beta = 0.00$, $p > 0.05$). However, it had significant direct effects on both life-survival ($\beta = 0.18$, $p < 0.001$) and life-healthy ($\beta = 0.11$, $p < 0.001$) STEM career interests. These findings partially support H1.

The mediating roles of self-efficacy and outcome expectations between career awareness and career interests

STEM self-efficacy significantly and directly predicted all three dimensions of career interests: analytical ($\beta = 0.57$, $p < 0.001$), life-survival ($\beta = 0.13$, $p < 0.001$), and life-healthy ($\beta = 0.11$, $p < 0.01$). Similarly, STEM outcome expectations also significantly and directly predicted all three dimensions: analytical ($\beta = 0.16$, $p < 0.001$), life-survival ($\beta = 0.19$, $p < 0.001$), and life-healthy ($\beta = 0.14$, $p < 0.001$). Additionally, STEM self-efficacy significantly predicted STEM outcome expectations ($\beta = 0.63$, $p < 0.001$). These results fully support H2a. Moreover, STEM career awareness had a direct positive predictive effect on both self-efficacy ($\beta = 0.39$, $p < 0.001$) and outcome expectations ($\beta = 0.10$, $p < 0.001$). The findings support H2b.

We conducted further analysis to examine the indirect effects of STEM career awareness on STEM career interests (H2c) and the relative proportions of these effects within the total effects. Recognizing that STEM career interests are categorized into three distinct dimensions: analytical, life-survival, and life-healthy, we systematically explored the indirect influences for each dimension. The breakdown of effects is presented in Table 5.

Analytical STEM career interests: STEM career awareness significantly influenced analytical STEM career interests through both self-efficacy ($\beta = 0.22$, $p < 0.001$, 95% CI [0.18, 0.26], path ①) and outcome expectations ($\beta = 0.02$, $p < 0.01$, 95% CI [0.01, 0.03], path ②).

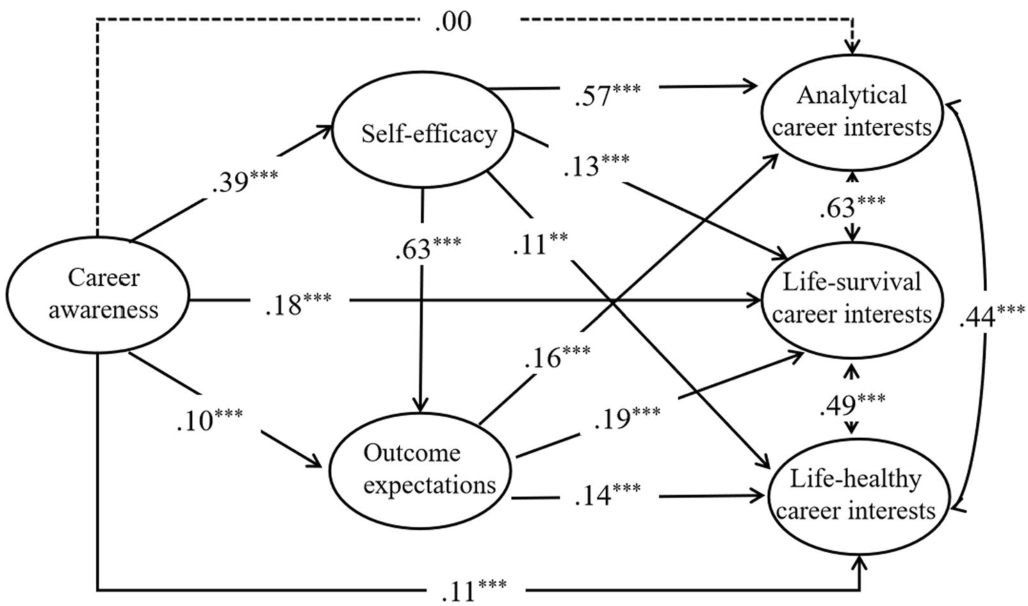

Fig. 2 Standardized coefficients of the paths in the model. $N=2542$ $^{**}p<0.01$ $^{***}p<0.001$

Table 5 The effects of the model

Effects	Path labels	β	95% CI		Sig	Percents
			Lower	Upper		
Analytical career interests						
Indirect effects						
Awareness → Self-efficacy → Analytical	①	0.22	0.18	0.26	***	
Awareness → Outcome → Analytical	②	0.02	0.01	0.03	**	
Awareness → Self-efficacy → Outcome → Analytical	③	0.04	0.02	0.06	***	
Total indirect effects		0.28	0.23	0.31	***	100%
Direct effect: Awareness → Analytical		0.00	−0.05	0.04		0%
Total effects		0.28	0.22	0.31	***	
Life-survival career interests						
Indirect effects						
Awareness → Self-efficacy → Life-survival	④	0.05	0.02	0.08	**	
Awareness → Outcome → Life-survival	⑤	0.02	0.01	0.03	***	
Awareness → Self-efficacy → Outcome → Life-survival	⑥	0.05	0.03	0.07	***	
Total indirect effects		0.12	0.08	0.13	***	39%
Direct effect: Awareness → Life-survival		0.18	0.11	0.21	***	61%
Total effects		0.30	0.22	0.31	***	
Life-healthy career interests						
Indirect effects						
Awareness → Self-efficacy → Life-healthy	⑦	0.04	0.01	0.07	**	
Awareness → Outcome → Life-healthy	⑧	0.01	0.01	0.03	**	
Awareness → Self-efficacy → Outcome → Life-healthy	⑨	0.03	0.02	0.06	**	
Total indirect effects		0.09	0.06	0.11	***	45%
Direct effect: Awareness → Life-healthy		0.11	0.05	0.15	***	55%
Total effects		0.20	0.14	0.24	***	

Due to each indirect path containing multiple relationships, for easier understanding, we have added a label to each indirect path to correspond one-to-one with Fig. 2 and the description in the text. $^{**}p<0.01$ $^{***}p<0.001$

Moreover, the impact of STEM career awareness on analytical STEM career interests was sequentially mediated by both self-efficacy and outcome expectations ($\beta = 0.04$, $p < 0.001$, 95% CI [0.02, 0.06], path ③). The total indirect effect of STEM career awareness on analytical interests was 0.28 ($p < 0.001$, 95% CI [0.23, 0.31]), suggesting a complete mediation, accounting for 100% of the effects ($\beta = 0.28$, $p < 0.001$, 95% CI [0.22, 0.31]).

Life-survival STEM career interests: STEM career awareness significantly influenced life-survival STEM career interests through both self-efficacy ($\beta = 0.05$, $p < 0.01$, 95% CI [0.02, 0.08], path ④) and outcome expectations ($\beta = 0.02$, $p < 0.001$, 95% CI [0.01, 0.03], path ⑤). Additionally, the effect of STEM career awareness on life-survival interests was sequentially mediated by both self-efficacy and outcome expectations ($\beta = 0.05$, $p < 0.001$, 95% CI [0.03, 0.07], path ⑥). The total indirect effect was 0.12 ($p < 0.001$, 95% CI [0.08, 0.13]), indicating a partial mediation, constituting 39% of the total effects ($\beta = 0.30$, $p < 0.001$, 95% CI [0.22, 0.31]).

Life-healthy STEM career interests: STEM career awareness significantly influenced life-healthy STEM career interests through both self-efficacy ($\beta = 0.04$, $p < 0.01$, 95% CI [0.01, 0.07], path ⑦) and outcome expectations ($\beta = 0.01$, $p < 0.01$, 95% CI [0.01, 0.03], path ⑧). Furthermore, the effect of STEM career awareness on life-healthy interests was sequentially mediated by both self-efficacy and outcome expectations ($\beta = 0.03$, $p < 0.01$, 95% CI [0.02, 0.06], path ⑨). The total indirect effect was 0.09 ($p < 0.001$, 95% CI [0.06, 0.11]), suggesting a partial mediation, accounting for 45% of the total effects ($\beta = 0.20$, $p < 0.001$, 95% CI [0.14, 0.24]).

In summary, our findings support H2c. STEM career awareness influences STEM career interests through the multiple mediating roles of self-efficacy and outcome expectations. This mediation is evident across all three subcategories of STEM career interests, with a complete mediation for the analytical dimension and partial mediation for both the life-survival and life-healthy dimensions.

Gender differences

To test Hypotheses 3a and 3b, we first employed MANCOVA to control for potential confounding effects of background factors and to compare the average differences between male and female students. Subsequently, we utilized MGSEM to determine if gender moderated the relationships among the variables.

Gender differences in the mean level

The results of the MANCOVA indicated that covariates had a modest impact on the study population. Specifically, parents' highest level of education ($F = 6.71$, $p < 0.001$, $\eta_p^2 = 0.016$), family residence ($F = 3.75$, $p = 0.001$, $\eta_p^2 = 0.009$), ethnicity ($F = 1.85$, $p = 0.07$, $\eta_p^2 = 0.004$) were found to have slight effects on the outcomes. The gender showed a strong main effect ($F = 112.11$, $p < 0.001$, $\eta_p^2 = 0.21$), indicating that gender is a significant distinguishing factor among the variables examined. Follow-up univariate ANOVAs indicated that, although there were no significant differences between male and female students in terms of STEM career awareness and outcome expectations, notable disparities were observed in several key areas (as detailed in Table 6). Specifically, compared to males, females demonstrated significantly lower self-efficacy in STEM courses ($F = 243.14$, $p < 0.001$, $\eta_p^2 = 0.087$). Regarding STEM career interests, gender differences manifested in domain-specific patterns: females expressed significantly lower interests in analytical STEM careers compared to males ($F = 335.63$, $p < 0.001$, $\eta_p^2 = 0.117$), and their interest in life-survival STEM careers was slightly lower but still close to that of males ($F = 4.23$, $p < 0.05$, $\eta_p^2 = 0.002$); however, females showed slightly higher interests in life-healthy STEM careers than males ($F = 14.64$, $p < 0.001$, $\eta_p^2 = 0.006$). These findings partially support H3a,

Table 6 Mean, standard deviation, and tests of the differences across gender

Variables	Female		Male		Mean difference	F	η_p^2
	Mean	SD	Mean	SD			
1. Awareness	2.65	0.75	2.61	0.83	0.04	2.82	0.001
2. Self-efficacy	2.67	0.64	3.07	0.65	−0.40	243.14***	0.087
3. Outcome expectations	3.82	0.56	3.86	0.54	−0.04	3.17	0.001
4. Analytical career interests	2.67	0.78	3.23	0.74	−0.56	335.63***	0.117
5. Life-survival career interests	2.81	0.83	2.87	0.77	−0.06	4.23*	0.002
6. Life-healthy career interests	3.14	0.98	2.99	1.00	0.15	14.64***	0.006

η_p^2 represents Partial Eta Squared (η^2), a measure of effect size that indicates the unique contribution of a specific independent variable to the dependent variable, after controlling for other variables. The effect size classifications for η_p^2 are consistent with those for η^2, values of 0.01, 0.06, and 0.14 indicate small, medium, and large effects, respectively (Cohen, 1988). *$p < 0.05$ ***$p < 0.001$

indicating gender differences in mean levels exist only for STEM self-efficacy, STEM career interests.

Moderating effects of gender

In examining the pathways and strength of relationships among the variables, our MGSEM comparisons between male and female groups (refer to Table 7) indicated that $\Delta\chi^2$ reached significance ($p < 0.05$). However, the ΔTLI values ranged from 0.001 to 0.003, and ΔCFI values varied between −0.003 and −0.002, both far below the recommended thresholds of 0.05 and 0.01 (Cheung & Rensvold, 2002; Little, 1997), respectively. Given for large sample sizes, the χ^2 statistic provides a highly sensitive statistical test, but not a practical test, while ΔCFI and ΔTLI, being unaffected by sample size, provide more robust results (Cheung & Rensvold, 2002; Little, 1997). Therefore, we consider the models for males and females to be equivalent. Further examination of the paths revealed that all differences in path coefficients between the male and female models were non-significant, as all paths had critical ratio index absolute values less than 1.96 (details provided in Additional file 1: Supplementary Material S3). This further demonstrates the robustness of the equivalence between the male and female models. The results mean that the influences of STEM career awareness, self-efficacy, and outcome expectations on the three facets of STEM career interests are consistent across genders. Consequently, gender does not serve as a significant moderator for the relationships among these variables, leading to the rejection of H3b.

Discussion

This study aims to examine the influence of high school students' awareness of STEM careers on their interests in different types of STEM careers, with a specific focus on the mediating roles of self-efficacy and outcome expectations in STEM courses. Additionally, we examine how gender may impact the average levels of these variables and their interconnections. Our findings suggest that the effect of STEM career awareness on analytical STEM career interests is fully mediated by self-efficacy and outcome expectations. Conversely, the influence on life-survival and life-healthy STEM career interests is only partially mediated, with mediation effects accounting for 39% and 45%, respectively. While significant disparities exist between male and female students in terms of self-efficacy in STEM courses and interests in STEM careers, gender does not appear to significantly moderate the relationships among variables. Given the limited exploration of the impact of career awareness on different types of STEM career interests within the SCCT framework and the insufficient discussion on these variables and their gender differences in the Chinese context (Liu, 2018; Lv et al., 2022; Yang & Gao, 2021; Yang et al., 2024), this study offers fresh evidence on their relationship. It provides a new theoretical perspective for comprehending high school students' STEM career interests and offers valuable insights for future research and practical interventions.

Relationship between STEM career awareness, self-efficacy, outcome expectations, and career interests

Our research hypotheses regarding the relationships between STEM career awareness, self-efficacy, outcome expectations, and interest in STEM careers (including H1 to H2c) were largely supported. We now discuss these results in detail.

Relationship between STEM career awareness and career interests

STEM disciplines include a wide range of career paths, and students' interests in distinct STEM careers can differ (Rosenzweig & Chen, 2023). This study contributes to the existing literature by addressing the gap in understanding how STEM career awareness influences interests in different STEM career paths. Our findings support the hypothesis that STEM career awareness can directly impact interests in specific types of STEM careers (H1) and can also indirectly shape these interests through the mediating effects of self-efficacy and outcome expectations (H2c). Specifically, we found that the influence of STEM career awareness on analytical STEM careers is fully mediated by self-efficacy and outcome expectations, while its impact on life-survival and life-healthy STEM careers is only partially mediated. To our knowledge, this is the first study to demonstrate how career awareness impacts different types of STEM career interests. Two studies related to the perception of STEM

Table 7 The results of the measurement invariance analysis by gender

Model	χ^2	*df*	TLI	CFI	RMSEA	$\Delta\chi^2$	Δdf	ΔTLI	ΔCFI
Unconstrained	2440.412	426	0.897	0.913	0.043				
Measurement weights	2503.447	443	0.898	0.911	0.043	63.035*	17	0.001	−0.002
Structural weights	2533.368	455	0.900	0.910	0.042	92.956*	29	0.003	−0.003

*$p < 0.05$

careers have provided evidence supporting our findings. For example, Chen et al. (2024) demonstrated that the correlation between students' positive perceptions of STEM professionals and their aspirations towards STEM careers is contingent upon their levels of self-concept. Similarly, Mohtar et al. (2019) observed that while career perception directly influences interests in life science-related STEM careers but not in physical sciences. Our study extends these findings by suggesting that career perception may indirectly affect interests in physics-related STEM careers through self-efficacy and outcome expectations. The differences in work environments and required skills among STEM professions likely contribute to these findings. Analytical STEM careers such as mathematics and physics emphasize skills like logical reasoning and data analysis, which may be perceived as more challenging and reliant on intellectual problem-solving (Chen et al., 2023; Cheng et al., 2021). Therefore, students' career awareness may only transform into interests in these careers when they have strong self-efficacy and positive outcome expectations regarding STEM courses. In contrast, life-survival and life-healthy STEM careers, have people-oriented work environments, emphasizing interpersonal communication and emotional expression (Su & Rounds, 2015). Students' career awareness might directly translate into interests or be further enhanced through self-efficacy and outcome expectations. Our study highlights the complex mechanisms linking STEM career awareness with interests and provides valuable insights for future research and educational practices.

Relationship between self-efficacy, outcome expectations, and career interests

This study provides empirical evidence supporting the relationship between Chinese students' self-efficacy and outcome expectations in STEM courses and their interests in various STEM career paths. Specifically, we found that higher levels of self-efficacy and outcome expectations in STEM courses positively predict interests in analytical, life-survival, and medically related STEM careers, with self-efficacy also indirectly predicting career interests through outcome expectations (H2a). These findings are consistent with the theoretical framework of SCCT, which emphasizes the interplay between self-efficacy, outcome expectations, and career interests (Lent et al., 1994; Turner et al., 2019; Zhao et al., 2024). The results of this study further substantiate the pivotal role of self-efficacy in cultivating the STEM career interests of Chinese students, corroborating the results of Wang et al. (2023) and Chan (2022). In the Chinese cultural context, there is a strong emphasis on academic achievements in mathematics and science (Yang & Gao, 2021), with the belief that proficiency in these subjects leads to professional success, as encapsulated by the adage "those with a brilliant command of math and sciences will be professionally successful with great ease." Therefore, when students exhibit higher levels of self-efficacy and outcome expectations in STEM courses, they are more likely to express interests in pursuing STEM careers. This study bridges Chinese academic value perceptions with the SCCT framework, demonstrating the applicability of SCCT in the Chinese cultural context. By providing empirical support for the relationship between self-efficacy, outcome expectations, and STEM career interests among Chinese students, this study offers valuable insights for educators and policymakers in guiding Chinese students in their STEM career planning endeavors.

Relationship between career awareness and self-efficacy, outcome expectations

This study confirms that STEM career awareness positively predicts self-efficacy and outcome expectations in STEM courses (H2b). The findings suggest that by exposing students to more learning experiences related to STEM careers and enhancing their understanding of the prospects and requirements of STEM professions, we can strengthen their self-efficacy in STEM courses and elevate their outcome expectations. This result aligns with previous research by Han et al. (2021), which claimed that experiences of STEM practice increase students' career awareness and enhance their self-efficacy. Similarly, research by Friedman et al. (2017) demonstrated that participation in a summer program significantly boosts secondary school students' interest in STEM, career awareness, and self-efficacy. Our findings contribute to the understanding of the SCCT by highlighting the role of STEM career awareness as an outcome of STEM-related learning experiences and its subsequent impact on self-efficacy and outcome expectations. This provides a fresh perspective for understanding the SCCT.

Gender differences in STEM

We conducted further investigation to determine whether male and female high school students exhibited differences in their average levels of STEM career awareness, self-efficacy, outcome expectations, and career interests, as well as in the relationships among these variables (H3a and H3b). Our findings indicated variances in the average levels of certain variables between genders, thus partially supporting H3a. However, there were no significant gender differences observed in how these variables were interconnected, leading to the rejection of H3b. We will discuss the findings from the following three aspects.

First, the results indicated no significant differences between male and female students regarding STEM career awareness and STEM course outcome expectations. Both groups scored lower in STEM career awareness but higher in their outcome expectations for STEM courses. This phenomenon may stem from China's high school system which emphasizes science and mathematics, while often neglecting career education in STEM. During the high school years, although mathematics and science are compulsory subjects, career education is not. This leads to a lack of comprehensive career education programs in many schools. As Fan and Qiao (2017) have highlighted, this disparity creates a gap between academic teaching and career guidance, adversely impacting students' overall career awareness. Notably, compared to males, females exhibit significantly lower self-efficacy in STEM courses, consistent with previous research findings (Hur et al., 2017; Mau et al., 2020; Wang et al., 2023). In the context of Chinese culture, traditional views, such as the belief that "girls are unsuited for science and engineering," may contribute to this gap (Yang et al., 2024; Zhang & Zhen, 2011). A survey focusing on female engineering college students found that, despite their academic superiority over their male counterparts, they still lack confidence due to these prevailing cultural norms (Zhang & Zhen, 2011). These findings support the need for future educational strategies to focus on popularizing STEM career education, especially enhancing female students' self-efficacy in STEM.

Second, although previous studies suggested that male students had a greater interest in STEM careers than female students (Balta et al., 2023; Chan, 2022; Lv et al., 2022; Wang et al., 2023), this study, after controlling for background factors such as ethnicity, parental education level, and family residence, found that this trend was primarily evident in analytical STEM careers ($\eta_p{}^2 = 0.117$). In life-survival STEM careers, females' interest was only marginally lower than males', with a very small effect size ($\eta_p{}^2 = 0.002$). Interestingly, female students even showed slightly higher interests in life-healthy STEM careers ($\eta_p{}^2 = 0.006$). This was consistent with the findings of prior studies, which also identified differences in the STEM career fields of interests between male and female students (Babarović, 2022; Cheng et al., 2021; Rosenzweig & Chen, 2023; Watt et al., 2017). National Science Library of the Chinese Academy of Sciences (2022) reported that, while gender disparities exist among Chinese scientific researchers, the ratio of males to females in the life sciences and medicine is becoming more balanced; however, in fields such as material science, computer science, and engineering technology, the academic influence of females remains lower than that of males. Such gender differences may be related to the values and career preferences of male and female students. Males often gravitate towards fields that involve interaction with objects and require analytical skills, such as engineering, whereas females typically prefer sectors emphasizing social services and human interactions, such as healthcare (Cheng et al., 2021; Quigley et al., 2024; Rosenzweig & Chen, 2023; Wang et al., 2023). This inclination leads to notable differences in male and female interests in analytical and life-healthy STEM career categories. Fields such as biology and earth science, falling under life-survival STEM careers, balance social service with analytical skills, resulting in similar preferences across genders. Additionally, within the Chinese context, females are often expected to pursue stable careers. Life-healthy STEM careers (e.g., doctor), perceived as stable "iron rice bowl" jobs (铁饭碗), align with societal expectations for females, possibly explaining their slightly stronger interest in these areas compared to males. This study categorized STEM career interests into three dimensions to analyze gender differences, providing a new perspective for understanding the differences in STEM field interests between male and female students. Future strategies for fostering STEM career interests should be tailored based on gender and field differences.

Third, this study found that gender did not significantly moderate the relationships between STEM career awareness, self-efficacy, outcome expectations, and STEM career interests. This finding aligns with parts of the studies conducted by Jiang et al. (2020) and Wang et al. (2023). Jiang et al. (2020) determined that in most cases, gender does not moderate the relationship between self-efficacy beliefs in science and math courses and students' STEM learning outcomes or their choice of university STEM majors. Similarly, the study by Wang et al. (2023) indicated that while the indirect effects of STEM self-efficacy on the STEM career interests of male and female students vary, the direct predictive effects show no significant differences. One possible explanation is that in Chinese society, STEM is generally perceived as a pathway to success and achievement for individuals of all genders. Students, regardless of gender, are inclined to pursue STEM careers when they possess higher levels of career awareness, self-efficacy, and outcome expectations in STEM, driven by aspirations for economic success and upward social mobility (Chan, 2022). Consequently, the pattern of influence among these variables appears to be similar for both male and female students. Additionally, China's highly standardized secondary education system and rigorous national curriculum ensure universal standards and exposure to STEM subjects for males and females (Liu, 2020). This educational system may have similar effects on both male and female students. Our findings suggest that intervention strategies aimed at enhancing STEM career interests by improving STEM career awareness, self-efficacy in STEM courses, and outcome expectations may be equally effective for both male and female students in most scenarios.

Implications

This study integrates the concept of career awareness with the SCCT framework, contributing the first empirical evidence for the relationship between STEM career awareness and various types of STEM career interests, with self-efficacy and outcome expectations in STEM courses serving as mediating factors between them. Furthermore, it sheds light on the gender differences and similarities in the average and procedural levels of these variables. Additionally, these findings contribute to elucidating the unique phenomena observed among Chinese students in the STEM field. In summary, this study offers both theoretical and practical insights.

From a theoretical perspective, our study contributes significantly by elucidating the impact of STEM career awareness on career interests within the SCCT framework. Career awareness, often overlooked in previous research within this framework, is fundamentally influenced by individuals' vocational learning experiences, which crucially in turn shape their career decisions. By integrating career awareness into the SCCT framework and examining its relationship with self-efficacy and outcome expectations, our research enhances our understanding of the mechanisms influencing career interests. Moreover, our study breaks new ground by categorizing STEM careers into distinct analytical, life-survival, and life-healthy categories. This classification allows for a nuanced exploration of how career awareness influences each category and provides insights into the individual variations in interest across different types of STEM careers. Understanding these variations is essential for tailoring interventions to promote interest in STEM fields effectively. Additionally, our research sheds light on the factors contributing to the relatively low interest in STEM careers among Chinese adolescents. Limited understanding of STEM careers and low self-efficacy in STEM courses emerge as potential explanations. Furthermore, our analysis of gender disparities in STEM career interests highlights the role of self-efficacy and gender biases in shaping career preferences among Chinese. The lower self-efficacy of female students and gender biases toward different types of STEM careers could be significant contributors to this result.

From a practical perspective, educators and policymakers can adopt the following strategies to address these challenges. First, providing experiential learning opportunities related to STEM career education to enhance students' awareness of STEM careers. For instance, utilizing multimedia and online resources to showcase STEM careers and periodically inviting experts from diverse STEM fields to schools or providing for online interactions with students can inspire interest and motivation among students (Chen et al., 2023; Gladstone & Cimpian, 2021; Ju & Zhu, 2023). Second, designing hands-on STEM projects that encourage real-world problem-solving can effectively boost students' self-efficacy and outcome expectations. For example, courses or competitions based on real-world problem-solving, where students apply their knowledge and skills to tangible challenges, can bolster their confidence in the STEM domain (Beier et al., 2019; Jiang et al., 2022; Verma & Ali, 2023; Yazıcı et al., 2023). Lastly, creating an equitable and inclusive learning environment is essential for promoting interest in STEM careers among all students, regardless of gender. For example, showcasing successful female role models in analytical STEM careers (such as female engineers or computer experts) and male success stories in medical fields (such as male cardiothoracic surgeons or pharmaceutical researchers), can motivate students to discard gender biases related to STEM careers and increase female students' confidence in their potential success in STEM (Freedman et al., 2023; González-Pérez et al., 2020; Sperling et al., 2024).

Limitations

Our research contributes important insights into the factors influencing students' interests in STEM careers, yet it is imperative to acknowledge certain limitations. First, the cross-sectional design captures relationships at a singular point in time, without tracking their evolution. Given that students' STEM career interests and self-efficacy can vary due to learning experiences, societal contexts, and personal growth (Han et al., 2021; Sadler et al., 2012), future studies employing a longitudinal approach would provide a more nuanced understanding of these dynamics. Second, our reliance on self-reported data might introduce potential biases, as responses could be influenced by societal norms or personal biases. Future research should consider incorporating diverse data sources, such as teacher feedback or direct observations, to bolster the robustness of findings. Third, despite a large sample size, our study's samples were limited to Anhui and Guizhou provinces in China, areas with moderate and lower economic development, respectively. Therefore, the generalizability of our study's conclusions may require further validation. Future research should aim to include student samples from economically more developed regions for a more comprehensive understanding. Lastly, our study focused mainly on individual-level determinants, overlooking broader contextual influences. The formation of STEM career interests is likely influenced by a combination of macro-level factors (e.g., socio-cultural norms policies), meso-level factors (e.g., familial and educational environments), and micro-level factors (e.g., individual characteristics and motivations). A more comprehensive exploration, integrating these layers, would provide a fuller picture of what drives students towards STEM fields.

Conclusions

In summary, our study underscores the pivotal role of STEM career awareness in shaping students' career interests, with varying degrees of mediation by self-efficacy and outcome expectations in STEM courses. While the influence of STEM career awareness on analytical STEM career interests is fully mediated by these factors, it is only partially mediated for life-survival and life-healthy STEM career interests. Moreover, our findings reveal notable gender differences, with female students exhibiting lower self-efficacy in STEM courses and less interest in analytical STEM careers compared to male students. Despite this, female students show comparable interest in life-survival STEM careers and even slightly higher interest in life-healthy STEM careers than their male counterparts. Importantly, our analysis using MGSEM indicates that gender does not significantly moderate the relationships among these variables. Overall, this study offers valuable insights for policymakers and practitioners in the STEM field, emphasizing the importance of promoting equity and inclusivity in STEM education. By understanding the mechanisms underlying students' STEM career interests, it provides direction on how to foster these interests effectively.

Abbreviations

STEM	Science, Technology, Engineering, and Mathematics
SCCT	Social Cognitive Career Theory
PISA	Programme for International Student Assessment
OECD	The Organization for Economic Co-operation and Development
MANCOVA	Multivariate Analysis of Covariance
SEM	Structural Equation Modeling
MGSEM	Multi-group Structural Equation Model
ICC	Intraclass Correlation Coefficients
CR	Composite Reliability
AVE	Average Variance Extracted

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-024-00482-7.

Additional file 1: Supplementary material S1. The English and Chinese version of the instruments. **Supplementary material S2.** Measurement models for self-efficacy and outcome expectations in STEM courses. **Supplementary material S3.** Comparison of Multi-group Structural Equation Model between males and females.

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Author contributions

Heli Jiang was responsible for study conceptualization and design, data analysis, and manuscript writing. Lijin Zhang was responsible for directing the research design and manuscript revision. Wenlan Zhang contributed to the design of the study and revising the manuscript. All the authors read and approved the final manuscript.

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Availability of data and materials

The data from this project are available upon request; data are not publicly available at present due to other ongoing work with the broader project from which this data is drawn. All study questionnaires in the present paper are listed in the Additional file 1.

Declarations

Competing interests

The authors have no conflicts of interest related to this study.

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