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STEM learning opportunities and career aspirations: the interactive effect of students' self-concept and perceptions of STEM professionals

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Abstract

Background Students' positive perceptions of scientists or engineers have been reported to be positively related to their science, technology, engineering, and mathematics (STEM) career aspirations. However, other research indicates that positive perceptions of experts in these fields might not necessarily lead to students' pursuit of STEM careers. Self-concept, defined as one's perceived abilities in specific academic domains, likely plays a moderating role in the relationship between perceptions and career aspirations according to the motivational theory of role modelling. Moreover, students' perceptions of STEM professionals might be sourced from STEM-related media and school experiences. Therefore, through running a moderated mediation model, this study examined whether and how the influences of media consumption and school STEM learning opportunities on career aspirations would be mediated by perceptions of STEM professionals, and whether the mediation effect would be conditional on students' self-concept.

Methods Data were collected through an online survey of 608 primary and secondary school students from Hong Kong, and were analysed using structural equation modelling.

Results Results revealed that the students' positive perceptions of STEM professionals were positively associated with their career aspirations, and mediated the links from media consumption and school opportunities to career aspirations. In addition, this mediated pathway depended on STEM self-concept, such that perceptions of STEM professionals were only linked with STEM career aspirations for adolescents with average or high levels of self-concept.

Conclusions The findings of this study suggest the need to pay attention to the STEM perceptions and self-concept interaction while designing and implementing learning activities to connect a diversity of students with STEM careers. It is not only important to foster students' self-concept, but also to enrich their knowledge of diverse occupations, so as to help diversify their perceptions that being professionals in these fields is desirable and attainable, and to eventually inspire more student engagement and participation in STEM.

Keywords Media consumption, Positive perceptions of STEM professionals, School STEM opportunities, Self-concept, STEM career aspirations

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Introduction

The critical role of science, technology, engineering, and mathematics (STEM) education in developing global competitiveness and prosperity has been emphasized in many regions across the world over the years. Yet, research indicates that despite multiple educational reforms and substantial resources, there are still low college enrolment rates in STEM fields and a lack interest in STEM careers (Kayan-Fadlelmula et al., 2022; Sahin et al., 2020; Vooren et al., 2022). A similar situation can be observed in Hong Kong. While the government and stakeholders have been stepping up efforts to promote STEM education in primary and secondary schools, there is no evidence that students have developed aspirations for STEM-related careers.

Students' positive perceptions of STEM professionals are considered to have positive impacts on their career aspirations in the STEM fields (e.g.Chan et al., 2019; Scholes & Stahl, 2020). When students consider STEM professionals as intelligent, competent, innovative, or successful, they show respect and interest in STEM-related jobs and are likely to pursue these jobs (Chan et al., 2019). However, other studies have revealed that positive perceptions (e.g., scientists as smart people) may not necessarily contribute to some students' STEM interests or aspirations (e.g.DeWitt et al., 2013; Jones & Hite, 2020; Kang et al., 2019). Evidence of the link between perceptions of STEM professionals and career aspirations remains inconclusive. Hence, research into the potential moderators of students' perceptions of STEM professionals is still warranted (Gladstone & Cimpian, 2021).

Students' self-concept may be one of the crucial moderators of the relationship between perceptions of STEM professionals and career aspirations. Researchers have defined self-concept as one's beliefs about one's personal abilities in specific academic domains (such as science or mathematics) (Bong & Skaalvik, 2003; Rüschenpöhler & Markic, 2019). The motivational theory of role modelling (Morgenroth et al., 2015), which was developed based on the expectancy-value theories of motivation, highlights the distinct functions of individuals' perceptions of STEM professionals and self-concept in influencing students' role modelling for career motivations. Specifically, students might be more inclined to pursue or select STEM careers if they perceive themselves as being capable in STEM-related subjects and able to achieve success in STEM fields like their STEM role models (match between self-concept and perceptions of STEM professionals) (Gladstone & Cimpian, 2021; Morgenroth et al., 2015; Starr & Leaper, 2019). By contrast, a mismatch between self-concept and perceptions of STEM professionals' STEM abilities and success may lead students to perceive STEM professionals as unreachable or unattainable role models, resulting in decreased intentions or aspirations to pursue STEM careers. In other words, there may be an interaction between students' perceptions of STEM professionals and STEM self-concept, or more specifically, STEM self-concept is likely to moderate the association between students' perceptions of STEM professionals and their career choices or aspirations (Morgenroth et al., 2015). Not many studies have been conducted to examine this, except for one previous study by Starr and Leaper (2019). However, their study was limited to investigating the moderating role of self-concept in the association between STEM stereotypes and confidence and interest in STEM learning through using regression analyses, and only involved high school students in the United States. Our study extended their research by directly examining whether self-concept would play a moderating role in the relationship between positive perceptions and career aspirations with a sample of Hong Kong primary and secondary school students.

Moreover, while positive links from media consumption and school STEM experiences to career aspirations were found in several past studies (e.g.Archer et al., 2014, 2015; Bottia et al., 2015; Dou et al., 2019; Gossen & Ivey, 2023; Halim et al., 2021; Reinhold et al., 2018; Tzu-Ling, 2019), other studies have indicated that increased STEM exposure failed to contribute to some students' STEM interests or aspirations (e.g.Kang et al., 2019; Rezayat, 2020; Wieselmann et al., 2020). Hence, research is needed to include the examination of interactive effects (e.g., in this study, the interaction effect of perceptions of STEM professionals and self-concept on career aspirations) that can help reveal how and why these STEM experiences affected students differently (Cohen et al., 2021). Given the positive links between media consumption and school experiences with students' perceptions of STEM professionals (Archer et al., 2014; Davis-Hall et al., 2023; Martin & Fisher-Ari, 2021; Halim et al., 2021; Martin & Moote et al., 2020; Starr, 2018), and the potential interaction of perceptions and self-concept as described above, it was hypothesized that self-concept could possibly moderate the mediating role of perceptions in the links from media consumption and school opportunities to STEM career aspirations (a moderated mediation model). To the best of our knowledge, the possible influence of the interaction between perceptions and self-concept on the relations between media consumption, school STEM opportunity, and career aspirations remains underexplored in the literature.

To address this gap, this study aimed to examine the interactive effects of perceptions of STEM professionals and self-concept on the relationships between media consumption, school opportunities, and STEM career aspirations among Hong Kong students. This study adds evidence to the existing literature on the underlying mechanisms of how these factors (media consumption, school opportunities, perceptions of STEM professionals, and self-concept) might jointly influence students' STEM career aspirations. Knowledge of possible mediating or moderating effects is important for developing STEM experiences to foster students' career aspirations with different characteristics (e.g., students with different levels of self-concept). Overall, there were two major research questions addressed in this study.

RQ1. Do students' positive perceptions of STEM professionals mediate the relationships between media consumption, school opportunities, and their career aspirations in STEM?

RQ2. Does students' STEM self-concept moderate such mediated relations?

Literature review

STEM career aspirations

STEM career aspirations can be considered as a subset of career aspirations, defined as 'an individual's expressed career-related goals or choices' (Rojewski, 2005, p. 132), which contribute to future STEM-related career paths (Mau & Li, 2018). Hou and Leung (2011) explained that STEM career aspirations refer to the evolving goals, ideals, and intentions of individuals to aspire to careers in the STEM fields in the future. Aspirations for STEM careers can be understood as expressions of people's hopes or ambitions regarding further STEM studies and careers (Archer et al., 2020).

However, it has been a long-standing issue that our students lack interest in or aspirations to pursue careers in STEM (DeWitt et al., 2014; Du &Wong, 2019; Martin & Fisher-Ari, 2021). Students were found to hold persistent, low aspirations in science during the secondary school stage (Archer et al., 2020). Chinese students reported relatively low science career aspirations as well (Du & Wong, 2019). A number of factors such as learning experiences, perceptions of STEM professionals, motivational beliefs, gender, or parental educational levels and occupations have been identified as significant predictors of students' career aspirations (Ketenci et al., 2020; Mau & Li, 2018; Mau et al., 2020; Rosenzweig & Chen, 2023; Tyler-Wood et al., 2018; Wang & Degol, 2017). For instance, students who did not show strong science ability beliefs, that is, did not strongly believe that they could do science and that they valued science, tended not to aspire to STEM careers (Aschbacher et al., 2014). Girls were found to be less likely to pursue an STEM-related career than boys (Ketenci et al., 2020; Tandrayen-Ragoobur & Gokulsing, 2021; Wang et al., 2023), and the attrition rates in STEM subjects were found to be higher for girls than for boys (Edwin et al., 2019), resulting in low participation of females in STEM professions. After controlling variables such as socio-economic status, school type, or school urbanicity, female students were two times less likely than male students to choose a career in the STEM fields. Particularly, girls were found to be heavily under-represented in careers in physical science, computer science, and engineering (Rosenzweig & Chen, 2023). Conlon et al. (2023) asked primary school students what job in the future they wanted, and reported similar results that boys showed higher aspirations to STEM careers than girls. Besides, students with non-college-educated parents were found to be significantly more likely to change from STEM to non-STEM career expectations by 11th grade (Starr et al., 2022). Hence, still more studies are needed to explore how to bolster or maintain students' STEM career aspirations.

Students' positive perceptions of STEM professionals and career aspirations

A number of studies have been conducted to investigate how students perceive STEM professionals (e.g., scientists, technicians, or engineers) and their work (Bian et al., 2017; Ferguson & Lezotte, 2020; Liu & Chiang, 2019; Luo & So, 2022; Martin & Fisher-Ari, 2021; So et al., 2020; Starr, 2018). Results have shown that students tend to see STEM professionals positively in terms of intelligence, competence, accuracy, or success (Chan et al., 2019; DeWitt et al., 2013), yet regard their appearance, personality, or sociability negatively (Garriott et al., 2017; Jones & Hite, 2020; Starr, 2018).

Students' perceptions of scientists or engineers might be highly influential in the formation and actualization of their aspirations for STEM careers (So et al., 2020). Students' positive views of innovation and entrepreneurship competencies might have positive and direct impacts on their STEM-related aptitudes, and their views of engineers' career prestige could have positive and direct impacts on their career interest in engineering (Chan et al., 2019). However, negative stereotypes might decrease students' confidence, interest, and goals regarding STEM (Garriott et al., 2017; Scholes & Stahl, 2020). A narrow understanding of scientists might exacerbate students' inability to imagine themselves as scientists, considering science as something that is not 'for

me', resulting in decreased desires for those careers in the future (Bøe et al., 2011). For instance, the perceived masculine nature and dangers of such work might increase students' reluctance to become scientists (Scholes & Stahl, 2020). Through interviews with STEM undergraduates, it was found that for those who decided to leave the STEM pipeline, the reasons they mostly gave were that they perceived non-STEM jobs, especially those in finance and business, as more secure and accessible and having greater economic returns as compared to jobs in the STEM sector (Wong et al., 2022). Thus, promoting positive conceptions of STEM is important for increasing participation and diversity in STEM (Martin & Fisher-Ari, 2021).

While positive perceptions (or images) of scientists or engineers were often found to have positive impacts on STEM career aspirations, other studies have reported that there might be no relationship between the two (Kang et al., 2019; Mohtar et al., 2019), or sometimes a contrast effect might occur (DeWitt et al., 2013; Jones & Hite, 2020). For instance, students' interest in physical sciences-based careers was found to not be influenced by their perceptions of those careers (Mohtar et al., 2019). It was also revealed that students' perceptions of scientists' work did not predict their interest in careers in biology science and physical science (Kang et al., 2019). Sometimes positive perceptions can be demotivating. Popular perceptions of scientists, such as 'specialist' and 'clever' might feed into students' feelings that science is not for them, resulting in their negative science identity and low aspirations (DeWitt et al., 2013). When students saw high levels of STEM professionals' competence might also be less attainable. Perceived high levels of STEM professionals' competence or success (e.g., very competent, extremely successful) might decrease students' motivation to pursue STEM careers, because students might feel that success is unattainable and therefore be demotivated (e.g., they can, but I cannot) (Gladstone & Cimpian, 2021). Jones and Hite (2020) analysed Korean students' drawings of scientists in terms of science behaviours, science subjects, setting and appearance, skills and abilities, job satisfaction, scientist attributes, and job attributes. Their findings suggested that students might view scientists in a positive light, but as role models, students considered their jobs as being unattainable or undesirable, resulting in their rejection of the possibility of choosing science-related careers. Hence, research is still needed to address questions about why and for whom positive perceptions of STEM professionals as intelligent, and/or competent motivate their career aspiration development (Gladstone & Cimpian, 2021).

Interaction between self-concept and perceptions of STEM professionals

Self-concept is one of the important constructs of the expectancy-value theory (Wigfield & Eccles, 2000). It represents a key predictor of individuals' motivation, emotion, and performance, and may directly influence achievement or career choices (Wigfield & Eccles, 2000). Self-concept is often defined as one's perceived ability in a specific domain (e.g., science or mathematics) that is necessary to successfully perform a particular behaviour in that domain (Bong & Skaalvik, 2003). Thus, applied to STEM-related domains, if students believe that they can do well in learning mathematics, science, or information technology (IT), they are referred to as having a higher self-concept in those domains.

Self-concept in STEM-related domains has been shown to be related to students' aspirations in those fields (e.g.Kang et al., 2021; Rosenzweig & Chen, 2023; Rüschenpöhler & Markic, 2019; Sax et al., 2015; Wang et al., 2017). For instance, students with a high science self-concept were likely to show a stronger intention to pursue science-related careers than those with a low science self-concept (Kang et al., 2021). In addition, students were more likely to pursue an STEM-related career if they perceived them as having high abilities in learning mathematics (Ketenci et al., 2020). Having a greater ability self-concept in math helped increase the likelihood of future STEM employment among students (Wang et al., 2017). By contrast, inadequate self-concept might lead students to consider not entering the STEM fields. For instance, there might be a link between female students' stereotypes that women do not have natural STEM abilities and women's under-representation in STEM careers (Clark et al., 2021). For some students who considered computer science or engineering as their least preferred careers, they frequently chose competence-related beliefs (e.g., by not thinking that they would do well at the career) as one main category of their reasons (Rosenzweig & Chen, 2023).

Self-concept was likely to moderate the association between perceptions of STEM professionals and aspirations. According to the motivation theory of role modelling, this is because students tend to evaluate how well their self-concept matches the attributes of the possible role models when they are deciding whether to pursue a particular career (Morgenroth et al., 2015). When students perceive a mismatch between their own abilities and those of role models (e.g., scientists or engineers), they may be demotivated to follow their role models (Morgenroth et al., 2015). As a result, perceptions of STEM professionals may not positively impact

the development or maintenance of career aspirations for students with relatively low levels of self-concept. Starr and Leaper (2019) found that the negative relation between students' endorsing stereotypes and motivation was only significant among those with low genius self-concept, suggesting the moderating role of self-concept. However, their study was limited to investigate the relationships between self-concept and stereotypes with students' STEM learning. The potential moderating role of self-concept in the relationship between positive perceptions of STEM professionals and career aspirations remained unknown, which was tested in this study.

Roles of perceptions and self-concept in the relations between media consumption, school STEM experiences, and career aspirations

Increasing students' STEM opportunities and experiences may foster their STEM interest and engagement, and contribute to increased STEM demands (Bottia et al., 2015; Cohen et al., 2021; Dou et al., 2019; Gossen & Ivey, 2023; Halim et al., 2021; Reinhold et al., 2018; Tzu-Ling, 2019). In addition to school experiences, Hong Kong students were found to have more media-related experiences (e.g., reading books/magazines) than other out-of-school experiences (e.g., visiting museums) (Chen et al., 2022). By considering the context of Hong Kong, this study placed a specific focus on investigating the links from media consumption and school experiences to career aspirations, and the potential role of perceptions of STEM professionals and self-concepts in mediating or moderating these links.

Prior research has revealed positive connections between students' career aspirations and the instructional quantity and quality of school science education (Wang & Staver, 2001). Science-related classroom experiences might largely affect students' views of their career path (Gossen & Ivey, 2023) and their decisions regarding whether or not to pursue STEM careers (Banerjee et al., 2018; Šorgo et al., 2018). More specifically, students' primary school science experiences seem to be a significant positive predictor of their career pursuits, indicating the importance of schooling (Cohen et al., 2021). Experiences of STEM extracurricular activities seem to boost students' confidence and benefit their STEM career intentions and actions (Gossen & Ivey, 2023). STEM-related media consumption, as an important form of capital, is also considered to play an essential role in strengthening students' STEM trajectories (Archer et al., 2014; Moote et al., 2020). The extent to which students consume STEM-related media, such as via TV programs, books/magazines, and online, appears to largely affect their STEM aspirations (Archer et al., 2015; Halim et al., 2021). There might be influences on career choice from popular science television channels and programmes (Cerinsek et al., 2013). After controlling for home environment, gender, and other relevant factors, consuming science and science-fiction media (e.g., books and television) was found to still be predictive of students' STEM identity, which might show strong influences on their future career choice and persistence (Dou et al., 2019).

However, other research found that students' experiences with science in the classroom did not directly predict their choices of STEM majors (Steenbergen-Hu & Olszewski-Kubilius, 2017), or their identification with STEM-related careers (Kang et al., 2019). Rather, early experiences might have negative impacts on career choices when students encounter some difficulties in learning science (Rezayat, 2020). School-based instruction may sometimes decrease students' STEM interest and career choices due to constraints, such as time, standardized test pressures, or lack of teaching and learning resources (Rezayat, 2020; Wieselmann et al., 2020). Likewise, media influences might not guarantee students' choice of STEM careers (e.g.Mohtar et al., 2019; Steinke et al., 2021). STEM media (e.g., STEM TV; STEM videos) were found to not directly impact students' interest in STEM careers (Chen et al., 2023). Students' preferences for STEM professionals featured in media might affect the influence of media on their career decisions to some extent by affecting their self-identification with STEM (Steinke et al., 2021). The findings of these studies imply that not all students seem to benefit from STEM-related media consumption or school opportunities.

In other studies, school and media were found to play important roles in shaping how students perceive STEM professionals (Davis-Hall et al., 2023; Jones & Hite, 2020). For instance, many STEM educational programmes or interventions were purposefully designed to feature experts in various STEM fields to give students a more accurate understanding of the attributes of scientists or engineers, and to improve their intentions to aspire to STEM careers (Davis-Hall et al., 2023; Emembolu et al., 2020; Farland-Smith, 2010; Gladstone & Cimpian, 2021; Shimwell et al., 2023; Wyss et al., 2012). Researchers have found that involving STEM-speaking adults who introduced their jobs and the use of STEM during robotics-based interventions had a positive impact on primary school students' interest in learning STEM and their positive attitudes toward STEM careers (Hudson et al., 2020). As for media influences, televised scientist characters might affect young learners' views of science (Whitelegg et al., 2013). Students who were exposed to

accurate images of scientists through school (e.g., textbooks) or media resources (e.g., magazines, museums, and TV) were found to be more likely to have non-stereotyped images of scientists (Tan et al., 2017). Media images of STEM professionals may be used as important information for students when they consider future personal and professional identities during their adolescence (Steinke, 2017).

Hence, students' perceptions of STEM professionals might potentially mediate the influence of school and media-related experiences on their career aspirations. School or media experiences might be more or less effective in partially increasing students' career aspirations, depending on whether these experiences help develop students' positive perceptions. Moreover, given the potential interplay between perceptions and self-concept, it is possible that the impacts of school or media experiences on career aspirations might vary among students with differing levels of STEM self-concept. When students are presented with successful, competent images of STEM professionals in diverse STEM activities, those with higher self-concept might be able to perceive the possibility of STEM careers as attainable, whereas those with lower self-concept might be demotivated by seeing STEM careers as too difficult to achieve. In short, it was hypothesized that these experiences might be more motivating for students with higher self-concept, but less motivating for those with lower self-concept to develop or maintain aspirations to STEM careers. How the interactions between perceptions and self-concept might contribute to the varying relations between school and media experiences and career aspirations was directly examined in this study.

The hypothesized model of this study

This study drew upon the motivational theory of role modelling (Morgenroth et al., 2015), with the aim of investigating the complex relationships among media consumption, school STEM opportunities, positive perceptions of STEM professionals, self-concept and students' STEM career aspiration development. Previous findings have indicated that career aspirations might be significantly influenced by factors, such as gender, grade level, and parents' occupation and education level (e.g.Domenico & Jones, 2006; Reinhold et al., 2018; Sáinz & Müller, 2018; Starr et al., 2022; Wang et al., 2023). Given these findings, gender, school level,

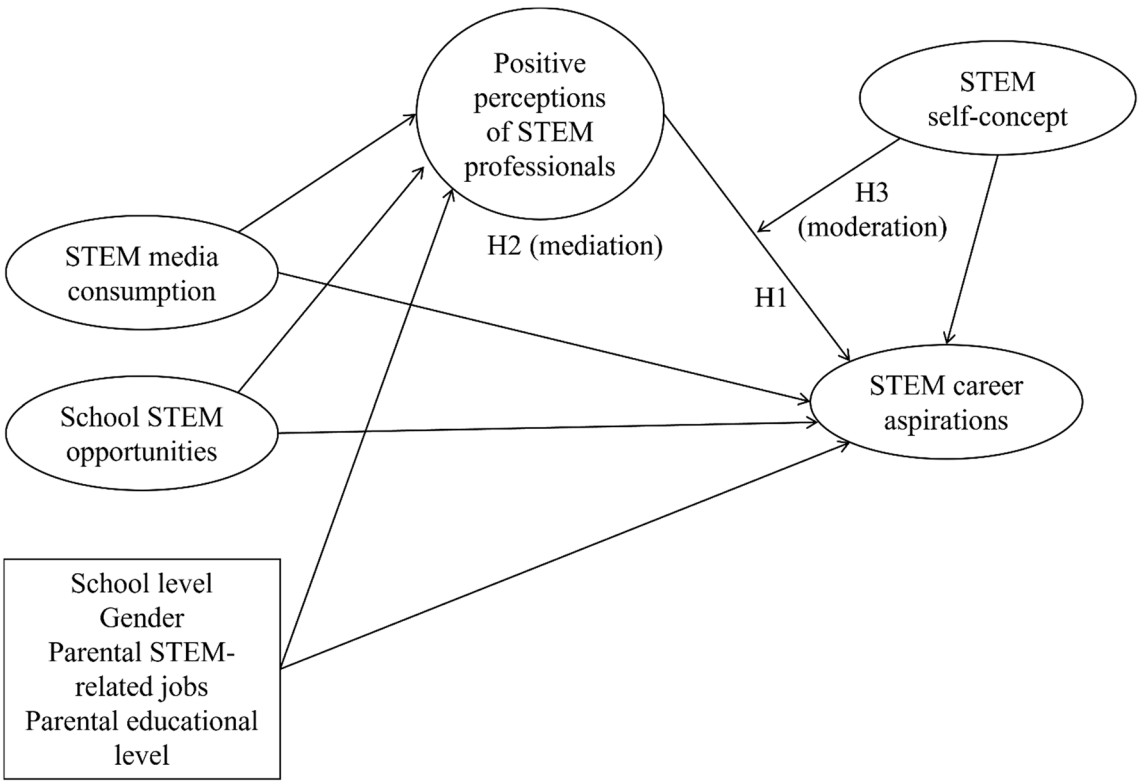

Fig. 1 Hypothesized moderated mediation model

parental educational level, and parental STEM-related jobs were also included. The hypothesized moderated mediation model is presented in Fig. 1. Specifically, the study was mainly concerned with the following three hypotheses:

H1. Positive perceptions of STEM professionals are positively and significantly associated with STEM career aspirations. (To address RQ1).

H2. STEM-related media consumption and school opportunities are positively associated with positive perceptions of STEM professionals, and subsequently with career aspirations. (To address RQ1).

H3. STEM self-concept significantly moderates the direct effect of positive perceptions of STEM professionals, and the indirect effects of media consumption and school opportunities on career aspirations. (To address RQ2).

Methods

Participants

A total of 608 students from three primary schools, two junior secondary schools, and one senior secondary school in Hong Kong were involved in this study, of whom 353 were girls and 255 were boys. As for school levels, 56.6% ($n=344$) were upper primary students from Grade 4 to Grade 6, with ages ranging from 11 to 13 (years), and an average age of 11.63 (0.78); 31.9% ($n=194$) were junior secondary students from Grade 7 to Grade 9, with ages ranging from 15 to 17 and an average age of 15.25 (0.53); and 11.5% ($n=70$) were senior secondary students from Grade 10 to Grade 12, with ages ranging from 17 to 19, and an average age of 17.10 (1.024). They were all ethnic Chinese, and around 95% of the students were born in Hong Kong. Student participation was on a voluntary basis. Before participating in this study, consent forms were sent to the students, their teachers, and schools to obtain their permission. Questionnaires were anonymous and confidential.

Data collection

Data were collected through an online survey with the help of teachers in participating schools. A questionnaire was created for this online survey, and consisted of five main scales subjected to statistical analysis, namely, (1) STEM career aspirations, (2) STEM self-concept, (3) positive perceptions of STEM professionals, (4) STEM-related media consumption, and (5) school STEM-related opportunity. Overall, there were 27 items for the five scales (see Table 3). These items were mostly adopted and modified from the instrument developed and validated by Archer and colleagues (Archer & DeWitt, 2016; DeWitt & Archer, 2015; DeWitt et al., 2011) to investigate young learners' science aspirations. The validated instruments of Chan et al. (2019) and Starr (2018) which measured students' perceptions of engineers and scientists, respectively, were also taken into consideration when selecting items for understanding students' positive perceptions of STEM professionals. Demographic information such as gender (girls coded as 0 and boys coded as 1), school level (primary school as 0, junior secondary as 1, senior secondary as 2; dummy coded with primary school as the reference group in the analysis), parental STEM-related jobs (parents having STEM jobs as 1 and the others as 0), and parental educational level (bachelor or above as 1 and the others as 0) was also collected. Questions were presented to students in plain Chinese language to help them understand the meaning. More details of the five scales are presented below.

Scale 1: STEM career aspirations (career aspirations)

In this scale, students were asked about their intentions to engage in STEM careers in the future. There was one item used by Archer and Dewitt (2016) to measure students' science career aspirations. This study adopted this item and added additional items to assess students' career aspirations for a wide range of STEM areas, not merely the science area. Overall, there were four items using a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*). Each item measured students' career aspirations for one STEM field. Some common job examples of each STEM area were provided to facilitate students' responses. Sample items are: 'When I grow up, I would like to work in mathematics (e.g., actuarial, accounting, insurance)' and 'When I grow up, I would like to work in engineering (e.g., civil engineering, automotive engineering, or architectural design)'. The reliability and validity of these items had been confirmed in a previous study by Chen et al. (2022) with another group of Hong Kong students. Higher scores refer to stronger STEM career aspirations among the students.

Scale 2: positive perceptions of STEM professionals (perceptions)

Different instruments have been developed for assessing students' perceptions of scientists (Archer & Dewitt, 2016), engineers (Chan et al., 2019) or more generally, people who work in STEM (Starr, 2018). For instance, Archer and Dewitt (2016) used items such as 'can make a difference in the world', 'make a lot of money', 'smart',

or 'are respected by others' to measure students' views of scientists. The study by Starr (2018) used items, such as 'gifted in math', 'naturally very intelligent', or 'geniuses' to understand students' perceptions of STEM people. In the study by Chan et al. (2019), students' perceptions of engineers in terms of STEM-related aptitude and career prestige were measured with items, such as 'good at maths and science', 'enjoys their job', 'well paid', or 'well-respected'. It could be found that there were some overlaps in the use of items for understanding students' views of scientists or engineers.

Items that assessed positive views of STEM professionals and were more commonly included in these instruments (Archer & Dewitt, 2016; Chan et al., 2019; Starr, 2018) were adopted, because this study intended to measure students' positive perceptions of a diversity of STEM people at a more general level. Overall, eight 4-point Likert items (1 = *strongly disagree* to 4 = *strongly agree*) were selected and utilized to understand how students perceived STEM professionals, particularly their STEM-related abilities, and the contribution and success of their work. Sample items are: good at math, good at science, have an exciting job, make a difference in the world, high income, or respected by others. Higher scores refer to more positive perceptions of STEM professionals expressed by the students.

Scale 3: STEM self-concept (self-concept)

The students' STEM self-concept was measured with six items using a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*). The students were asked to self-evaluate whether they were confident in their personal abilities to learn science, mathematics, and technology at school. Because engineering-related subjects are not included in most Hong Kong schools (Zhang et al., 2022), measures of students' self-concept in learning engineering-related subjects were not included in this study. Sample items are 'I do well in Math subjects' and 'I understand most of the things in my Science subjects'. Higher scores refer to stronger STEM self-concept among the students.

Scale 4: STEM-related media consumption (media consumption)

Past studies (e.g., Jones & Hite, 2021; Tan et al., 2017) have identified books or magazines, televisions, and/or websites as the main media sources of students' perceptions of scientists or career aspirations. Hence, in this scale, students were asked to report how often they obtained STEM information from these media resources (e.g., books, magazines, TV, or websites). This scale included one guiding question 'How often do you obtain STEM information via the following media?' and the four items indicated the four media resources of Books, Magazines, TV, and Websites (e.g., Google). All four items were designed on a 5-point Likert scale from 0 (never), 1 (*about once a year*), 2 (*about once a half year*), 3 (*about once a month*), and 4 (*about once a week*).

Scale 5: school STEM opportunities (school opportunities)

In Hong Kong, STEM education emphasizes the integration and application of the four fields, and aims at preparing students to face the needs of the rapid technological and scientific developments in society (Educational Bureau [EDB], 2016). STEM education was recommended to be integrated into regular Science, Mathematics, Information Technology (IT), or other school subjects (EDB, 2016). In addition, many schools organize STEM activities as short-term and extracurricular activities during out-of-class time (Tam et al., 2020; Zhang et al., 2022).

Hence, in this scale, students were asked to report whether they had opportunities for integrated STEM activities in regular Science, Mathematics, IT or other subjects, and/or out-of-class time inside school. There were five items using a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*). Sample items are 'My school provides STEM opportunities in Science lessons', 'My school provides STEM opportunities in IT lessons', and 'My school provides STEM opportunities out of class time'. Higher scores refer to more adequate school STEM opportunities as reported by the students.

Data analysis

A confirmatory factor analysis (CFA) was used to test and confirm the fit of the measurement model for our own data set using the Mplus 8.0 software. Goodness-of-fit was evaluated with the following indices: χ^2, Root Mean Square Error of Approximation (RMSEA) (cutoff value of the fit < 0.08), Comparative Fit Index (CFI) (adequate value > 0.90), Tucker–Lewis index (TLI) (adequate value > 0.90), and Standardized Root Mean Square Residual (SRMR) (cutoff value of the fit < 0.08) (Cangur & Ercan, 2015; Hu & Bentler, 1999). Reliability was tested via SPSS as well to ensure the internal consistency of these scales. After that, descriptive statistics (i.e., means and standard deviations) and correlations among the variables, including school STEM opportunity, media consumption, perceptions of STEM professionals, self-concept, and career aspirations, were computed. In addition, *t* tests and one-way ANOVAs were run to detect whether there were significant differences in these variables due to gender or school level, respectively.

To test the hypothesized moderated mediation model (see Fig. 1), structural equation modelling (SEM) via Mplus 8.0 was employed. Through the SEM analysis (Stride et al., 2015), the mediating role of students' perceptions of STEM professionals and the moderating role of STEM self-concept in the associations between school opportunity, media consumption, and career aspirations were tested. To ensure that the hypothesized model in this study was acceptable and meaningful, three models (as shown in Appendix A) were tested.

First, a reference model (Model A) and the hypothesized model (Model B) were tested to ensure the model fit of the hypothesized model. In the reference model (Model A), there were five latent variables (STEM opportunity, media consumption, perceptions of STEM professionals, self-concept, and career aspirations) and four categorical variables (gender, school level, parental educational level, and parental STEM-related jobs). In the hypothesized SEM model (Model B), one latent interaction term (perceptions of professionals × self-concept) was added on the basis of the reference model. Self-concept was specified as the moderator. A latent variable interaction approach was used to create the latent interaction term (perceptions of professionals × self-concept) to examine the interaction between perceptions of professionals and self-concept, which were latent variables.

In Mplus, to test latent interactions, random estimation and numerical integration are needed through the use of 'type = random' and 'algorithm = integration' commands (Wang & Wang, 2012). When numerical integration is carried out, Mplus does not provide model fit indices, such as CFI or TLI, but provides Akaike (AIC) and Bayesian (BIC) only. Hence, a comparison of the indices of AIC and BIC between the reference model (Model A) and the hypothesized model (Model B) was conducted. The model with the smaller AIC or BIC indicates a better model fit. Before running these models, all measured items were standardized. Hence, unstandardized results are reported in this study. Non-significant paths were excluded from the finalized model. For instance, parental educational level was found to have non-significant paths to perceptions and career aspirations, and thus was excluded. For a more specific test of the interactive effect between perceptions of STEM professionals and self-concept, simple slope analyses were performed.

According to the *t* test and ANOVA results shown below (Table 3 and 4), significant differences by gender and school level were found in school STEM opportunities and/or media consumption. Gladstone and Cimpian (2021) also indicated that the impacts of students' perceptions of STEM professionals might vary due to gender or age. It was considered that gender or school level might affect the hypothesized model. In view of this, one additional model (Model C) with gender and school level effects controlled was tested to further test the correctness of the hypothesized model. In Model C, four paths from school level to school STEM opportunity and media consumption, and one path from gender to media consumption were added on the basis of the hypothesized model. Three additional interactive latent variables (gender_x_perceptions of professionals, and school level (junior secondary)_x_perceptions of professionals, and school level (senior secondary)_x_perceptions of professionals) were also added to examine whether the moderating effects of self-concept would change with gender or school level moderation taken into consideration.

Results

Preliminary analyses

A confirmatory factor analysis was performed to evaluate the structural validity of the scales used in this study. The CFA model included five latent variables (school opportunities, media consumption, self-concept, perceptions of professionals, and career aspirations). Results showed that the factor loadings of most items were greater than 0.5 (see Table 1). Model fit indices were: $\chi^2 = 758.485$, $df = 307$, RMSEA = 0.049, CFI = 0.936, TLI = 0.927, SRMR = 0.049. Cronbach's alpha was greater than 0.8. Thus, these scales demonstrated good structural validity and inter-consistency reliability.

The means, standard deviations, and correlation coefficients are presented in Table 2. The participating students' average STEM self-concept was 2.86 out of 4, and their average aspiration for STEM careers was 2.33 out of 4, indicating that a considerable percentage of these students might lack adequate self-concept in learning mathematics, science, or IT, and might not show strong aspirations for careers in those STEM fields. Regarding students' perceptions of STEM professionals, the average score was 3.06 out of 4, suggesting that the students tended to perceive experts in those fields as having adequate STEM capabilities, enjoying their jobs, having high incomes, and/or being respected by others. As for STEM media consumption and school opportunities, the mean scores were 2.41 and 3.09 out of 4, respectively. The results suggested that the students sometimes obtained information about science, technology, engineering, and mathematics via mass media, and most had STEM learning opportunities in school. All variables were positively associated with each other (see Table 2).

Table 1 Standardized factor loadings and reliability coefficients of the latent variables

Variables	Items	Factor loading	Reliability
STEM career aspirations	A1. To work in science	0.704	0.832
	A2. To work in engineering	0.746	
	A3. To work in mathematics	0.797	
	A4. To work in a field using technology	0.730	
STEM self-concept	B1. I do well in Math	0.532	0.832
	B2. I understand most of the things in my Math subjects	0.649	
	B3. I do well in Science subjects	0.653	
	B4. I understand most of the things in my Science subjects	0.773	
	B5. I do well in IT-related subjects	0.606	
	B6. I understand most of the things in my IT-related subjects	0.647	
Perceptions of STEM professionals	C1. are good at science	0.692	0.839
	C2. are good at math	0.657	
	C3. are naturally very intelligent	0.694	
	C4. have many interests	0.748	
	C5. can make a difference in the world	0.524	
	C6. have an exciting job	0.534	
	C7. have a high income	0.428	
	C8. are respected by people	0.543	
STEM media consumption	D1 Access STEM information via books	0.762	0.824
	D2 Access STEM information via magazines	0.746	
	D3 Access STEM information via TV programmes	0.772	
	D4 Access STEM information via websites (e.g., Google)	0.733	
School STEM opportunities	E1 My school provides STEM opportunities in Math lessons	0.840	0.897
	E2 My school provides STEM opportunities in Science-related lessons	0.840	
	E3 My school provides STEM opportunities in IT-related lessons	0.819	
	E4 My school provides STEM opportunities in other lessons (e.g., Arts, Music, Sports and language studies)	0.707	
	E5 My school provides STEM opportunities out of class time	0.730	

Table 2 Correlations among variables

Variables	1	2	3	4	5
1. STEM career aspirations	1				
2. STEM self-concept	0.253**	1			
3. Positive perceptions of STEM professionals	0.285**	0.185**	1		
4. STEM media consumption	0.238**	0.355**	0.175**	1	
5. School STEM opportunities	0.175**	0.329**	0.216**	0.313**	1
Mean (*SD*)	2.33 (0.77)	2.86 (0.60)	3.03 (0.58)	2.41 (1.16)	3.09 (0.63)

** $p < 0.01$; The score range for STEM media consumption and school opportunity is 0 to 4, and the score range of the other variables is 1–4

In addition, *t* tests were performed to examine whether there were significant gender differences in these variables. As shown in Table 3, significant gender differences were found in self-concept, career aspirations, and media consumption. Boys were likely to show significantly stronger self-concept and career aspirations and to obtain more media resources related to STEM than girls. For perceptions of STEM professionals and school experiences, no significant gender differences were found. This means that boys and girls did not differ in their views about people in those areas in terms of their science or mathematics abilities or career prestige. Nor did they differ in their views about the opportunities provided in their schools.

Table 3 Differences in these variables by gender

Variables	Gender		*t* value	Effect size
	Girls	Boys		
STEM career aspirations	2.20 (0.69)	2.50 (0.84)	− 4.71***	0.038
Self-concept	2.71 (0.57)	3.07 (0.55)	− 7.76***	0.091
Positive perceptions of STEM professionals	3.03 (0.54)	3.02 (0.62)	0.123	
Media consumption	2.27 (1.15)	2.61 (1.15)	− 3.646***	0.021
School opportunities	3.06 (0.58)	3.12 (0.68)	− 1.19	

*** $p < 0.001$

ANOVAs were performed to test differences by school level (senior primary vs. junior secondary vs. senior secondary) on these variables (see Table 4). Significant differences by school level were found in self-concept, media consumption, and school opportunities. For multiple comparisons, it was found that secondary school students' self-concept was significantly lower than that of primary school students. In addition, they reported significantly less media consumption or school opportunities compared to their younger peers. No statistically significant differences by school level were found in career aspirations or perceptions of STEM professionals.

The moderated mediation model of STEM career aspirations

In this study, three models (the reference model, the hypothesized model, and the model with gender and grade level further controlled) were performed and compared to ensure that the hypothesized model (Fig. 1) had a good model fit and so was more acceptable. Model fit indices of each model and the unstandardized coefficients of the paths included in each model are listed in Appendix A.

The reference model (Model A) and the hypothesized model (Model B) were first tested and compared to ensure the model fit of the hypothesized model. After excluding non-significant paths, it was found that the reference model fitted the data well (RMSEA = 0.042, CFI = 0.927, TLI = 0.919, SRMR = 0.060). There were no big differences found in AIC or BIC between these two models, indicating that the hypothesized model was likely to have a good model fit as well. After that, an additional model (Model C) with gender and grade level effects further controlled based on the hypothesized model (Model B) was performed. It was found that Model C had larger AIC and BIC. There were no significant moderating effects of gender or school level on the relation between perceptions and career aspirations. While significant paths from school level to media consumption or school opportunities were found, the inclusion of these paths seemed not to strongly affect those paths which were also shown in the hypothesized model (Model B). Looking at the variance explained, the hypothesized model (Model B) accounted for 20.3% of the variance in STEM career aspirations, whereas the other two models explained relatively less, with 18.0% and 18.4%, respectively. In other words, the hypothesized model (Model B) showed an acceptable model fit and helped explain relatively more variance in STEM career aspirations than Model A and Model C. Hence, the hypothesized model with unstandardized coefficients (see Fig. 2) was finally accepted in this study.

The mediating role of students' positive perceptions of STEM professionals

According to Fig. 2, students' perceptions of STEM professionals were significantly and positively associated with career aspirations ($\beta = 0.305$, $p = 0.000 < 0.001$). H1 was supported. STEM media consumption was significantly and positively associated with career aspirations as well ($\beta = 0.120$, $p = 0.012 < 0.05$). In addition,

Table 4 Differences in these variables by school level

Variables	School level			*F* value	Multiple comparisons	Effect size
	1. SP (*n* = 344)	2. JS (*n* = 194)	3. SS (*n* = 70)			
Career aspirations	2.32 (0.85)	2.36 (0.69)	2.23 (0.49)	0.77		
Self-concept	3.08 (0.53)	2.64 (0.54)	2.38 (0.54)	71.803***	1 > 2 > 3	0.193
Positive perceptions of STEM professionals	3.07 (0.59)	2.95 (0.58)	3.02 (0.47)	2.774		
Media consumption	2.66 (1.11)	2.19 (1.14)	1.83 (1.15)	21.285***	1 > 2,3	0.066
School opportunities	3.18 (0.64)	2.97 (0.40)	3.09 (0.63)	8.984***	1 > 2,3	0.030

SP refers to senior primary level; JS refers to junior secondary level, and SS refers to senior secondary level

*** $p < 0.001$

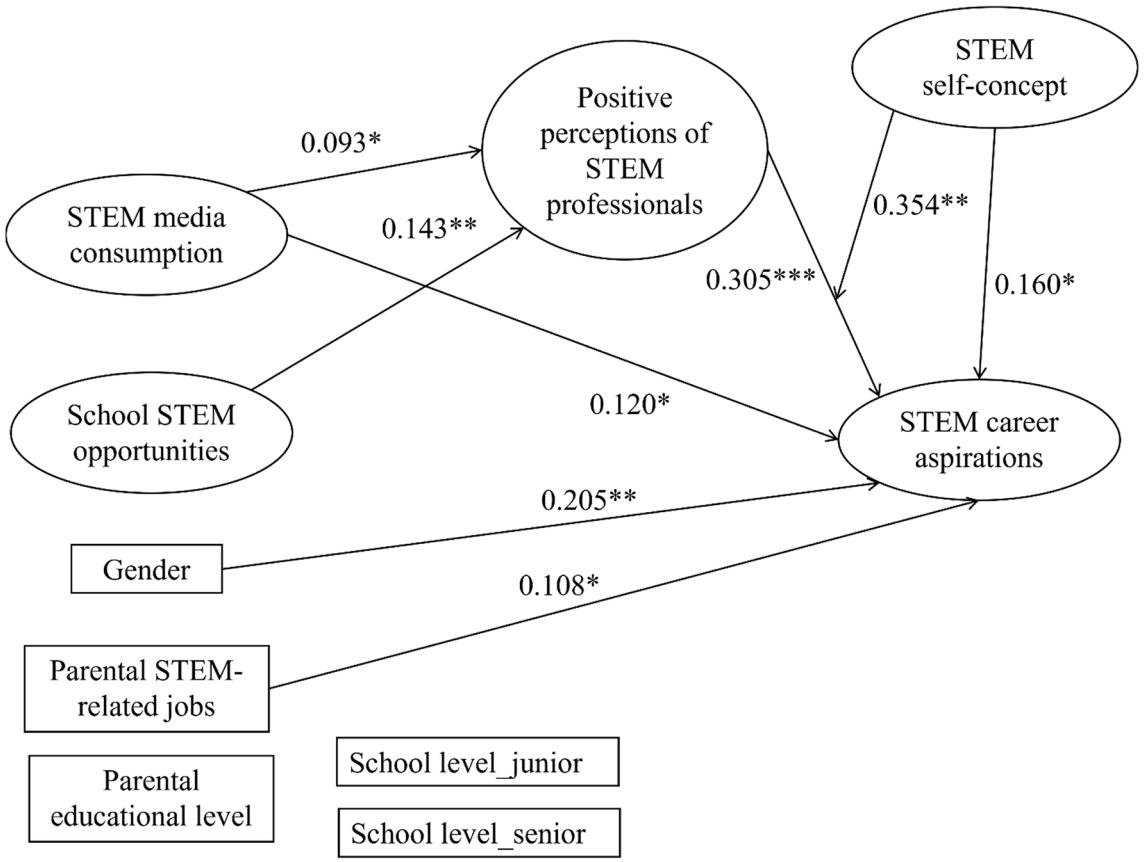

Fig. 2 Unstandardized model of media consumption, school STEM opportunities, positive perceptions of STEM professionals, self-concept and career aspirations in STEM. Non-significant paths were excluded from the finalized model

media consumption was found to be significantly and positively linked to students' perceptions ($\gamma = 0.093$, $p = 0.037 < 0.05$), which were subsequently linked to career aspirations. That is, media consumption was likely to influence students' career aspirations in STEM careers positively and directly, but also positively and indirectly through enriching students' perceptions of scientists or engineers.

School STEM opportunities were found to have no significant direct path to career aspirations ($\beta = 0.034$, $p = 0.432$). However, the indirect path from school opportunities to career aspirations via perceptions of professionals was found to be statistically significant (0.042, $p = 0.013 < 0.05$). That is, perceptions of STEM professionals significantly mediated the relation between school opportunities and career aspirations. In other words, school opportunities might be more beneficial for students' career aspiration development if these opportunities concurrently helped develop students' positive views of STEM professionals. Besides, self-concept was found to be significantly and positively associated with career aspirations ($\beta = 0.160$, $p = 0.033 < 0.05$). Hence, H2 was partially supported. Regarding parent-related factors, only the association between parental STEM-related jobs and career aspirations was found to be significant ($\beta = 0.108$, $p = 0.043 < 0.05$).

The moderating role of STEM self-concept

In terms of the moderation effect, the results showed that the interaction (perceptions of professionals × self-concept) was significantly related to aspirations ($\beta = 0.354$, $p = 0.004 < 0.01$). STEM self-concept positively moderated the impacts of perceptions of STEM professionals on career aspirations. The link between perceptions and career aspirations was much stronger for students with high STEM self-concept ($\beta = 0.659$, $p = 0.000 < 0.001$), than for students with mid ($\gamma = 0.305$, $p = 0.000 < 0.001$) or low ($\beta = -0.049$, $p = 0.707$) self-concept (see Fig. 3).

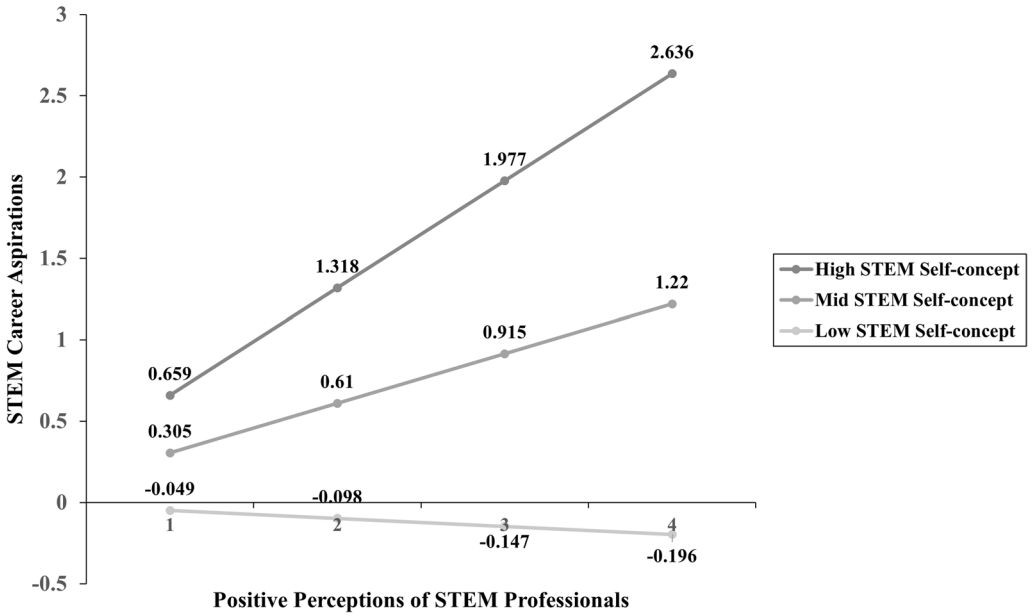

Fig. 3 Moderated impacts of positive perceptions of STEM professionals on career aspirations by self-concept

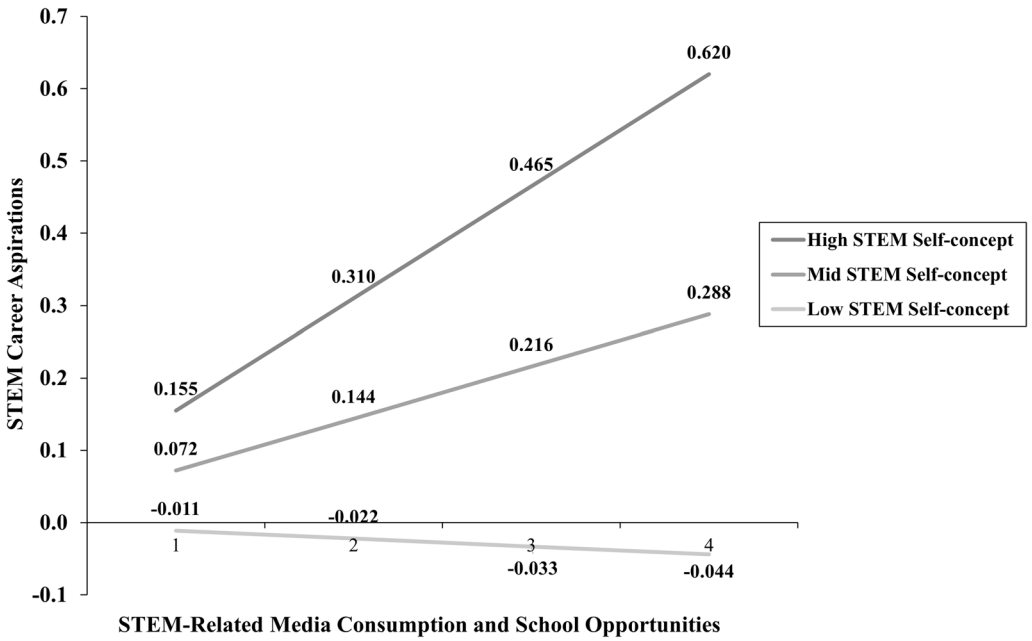

Fig. 4 Moderated indirect effects of school opportunities, and media consumption on STEM career aspirations via positive perceptions of STEM professionals by self-concept

The SEM model also demonstrated that the indirect effect of school opportunities and media consumption on aspirations via perceptions of STEM professionals was conditional, depending on self-concept. The conditional indirect effect of school opportunities and media consumption on aspirations via perceptions through adjustment of self-concept is indicated by this formula: (a1 + a2) (b1 + b2 self-concept) (Stride et al., 2015). Specifically, the effect of school opportunities and media consumption on perceptions was a1 and a2, the effect

of perceptions on aspirations was b1, and the effect of interaction item (perceptions × self-concept) on aspirations was b2. When self-concept took the value of -1SD, 0, and 1SD, the overall conditional indirect effect of school opportunities and media consumption was -0.011 ($p = 0.721$), 0.072 ($p = 0.003 < 0.01$), and 0.155 ($p = 0.001 < 0.01$), respectively. That is, the impacts of school opportunities and media consumption on aspirations through perceptions of STEM professionals was likely to increase as students' self-concept increased (see Fig. 4). Yet, if students had low self-concept, even though they were provided with more STEM opportunities inside school or more STEM-related media resources to develop understandings of scientists or engineers, their STEM career aspirations might not be effectively enhanced. Hence, H3 was supported.

Discussion

This study contributes new insights to help understand the complex roles of perceptions of STEM professionals and self-concept in the connections of media and school experiences with STEM career aspirations among Hong Kong students. It was found that perceptions of STEM professionals were significantly and positively associated with students' career aspirations, and concurrently, it significantly mediated the relationships between media consumption and school STEM opportunities with career aspirations. Self-concept moderated the direct path from perceptions of STEM professionals to aspirations, and the indirect paths from media and school STEM experiences to career aspirations via perceptions. It is worth noting that the strength of the associations between STEM experiences, perceptions of STEM professionals, and career aspirations was more substantial among students with high (vs. mid or vs. low) STEM self-concept. Below, the implications of these findings are further discussed.

Media consumption, school opportunities and STEM career aspirations

The findings revealed that a considerable percentage of the students might lack adequate aspirations for STEM careers (Mean score = 2.33 out of 4). This may be related to the limited career prospects of STEM in Hong Kong (Legislative Council Secretariat, 2020; Tsui et al., 2019a). It was also demonstrated that there was a significant gender difference in career aspirations (see Table 3). Compared to girls, boys reported significantly higher career aspirations. For the impact of school level, no significant differences were found in aspirations, suggesting that Hong Kong students' aspirations in STEM seemed stable across school levels (see Table 4). This finding is consistent with those of previous studies (e.g.Archer et al., 2013, 2020; Sadler et al., 2012) which also found persistent and low aspirations among students during their secondary school years. One explanation for this would be that the proportion of young learners specifically aspiring to STEM careers might be established fairly early and then remain stable as they grow up (Archer et al., 2020). It is therefore important for students to form their career aspirations in the STEM fields by age 14, or before senior secondary school (Kang et al., 2021; Sadler et al., 2012). Aligned with these prior studies, this study emphasizes the need to cultivate Hong Kong students' science aspirations in their early learning stages.

STEM media consumption was found to be significantly and positively related to career aspirations. Students with more access to STEM media were likely to show higher aspirations for such careers. This result is consistent with those of previous studies (Chen et al., 2022; Dou et al., 2019; Halim et al., 2021) and supports Archer et al. and and's (2014, 2015) studies which emphasized the importance of media resources as one dimension of STEM capital for shaping students' career aspirations.

However, no positive link was found between school STEM opportunities and career aspirations. This result aligns with previous research (e.g.Kang et al., 2019; Rezayat, 2020; Steenbergen-Hu & Olszewski-Kubilius, 2017) that indicated the absence of a direct link between school experiences and students' attitudes toward STEM, but was inconsistent with others (Banerjee et al., 2018; Cohen et al., 2021). One reason may be that the scale used in this study mainly investigated students' STEM opportunities in their regular mathematics, science, technology, or other subject learning in school. Hence, the primary purpose of these STEM opportunities might be to enhance students' science, mathematics, or technology knowledge or skills that should be learned in these school subjects, rather than encouraging them to explore their possible directions for future careers. This might be due to the fact that in Hong Kong, academic performance is imperative in determining a promising future (Tsui et al. 2019b). Moreover, there was a concern about the limitations of instructional time and personal abilities of integrating STEM by teachers who are involved in STEM education (Chen & So, 2022). As a result, the integration of STEM into regular school subjects might still be relatively inadequate, and therefore its effectiveness is limited. Another explanation is that the variable of school STEM-related opportunities might lack variability across students at the individual level within a single school context, because the participating students were nested within schools in this study. However, due to the small

sample size at the school level (six schools involved), this study did not further examine the influence of school opportunities on students' career aspirations at the school level. Future studies may consider addressing this by including more schools.

Students' positive perceptions of STEM professionals and their impacts

Previous research has indicated that helping students develop positive views of scientists or engineers might effectively increase their likelihood of choosing STEM careers (e.g.Chan et al., 2019; DeWitt et al., 2014). In this study, a significant and positive link between perceptions of STEM professionals in terms of STEM abilities or career success and career aspirations was identified with the students who reported mid or high self-concept. That is, among students with mid or high self-concept, holding more positive perceptions of STEM professionals' competence and career prestige might better motivate them to aspire to careers in STEM. According to Tsui et al. (2019b), when Hong Kong students make choices about their future study and work, they place a high priority on personal public examination results, but also the stability and prospects that are offered by jobs. Therefore, for Hong Kong students with adequate self-concept in STEM, information on job satisfaction and prospects related to STEM should be disseminated to them so as to foster their positive understanding of STEM people, and so develop stronger career intentions. When they are able to perceive STEM professions as being attainable, enjoyable, and having prospects, they may be more motivated to choose STEM careers.

For most students, greater access to STEM-related media was likely to help them develop more positive perceptions of scientists or engineers. In this study, a positive path was found between media consumption and perceptions. This might be due to the fact that STEM information from media is an important source for students to develop images or perceptions of scientists or engineers (Jones & Hite, 2020; Steike, 2017; Tan et al., 2017). The portrayal of science, technology, or engineering in mass media as sometimes powerful, and generating hope for the future seems to promote a competitive schema related to the promise of science (Nisbet et al., 2002). On the other hand, school STEM opportunities were found to have a significant and positive path to perceptions. Comparing the two paths, school opportunities appeared to be potentially more relevant in shaping perceptions of STEM professionals than media experiences. There might be more direct and close exposure opportunities to STEM professionals provided in school, such as involving STEM experts to serve as role models and mentors, to arrange hands-on activities, to introduce students to career possibilities, and to boost students' STEM participation (Gamse et al., 2017). Moreover, with the support of school teachers, it might be easier for students to alter their negative or stereotypical views of scientists or engineers, and this may in turn contribute to their positive attitudes toward or perceptions of STEM careers. For instance, helping students to see the connections between their school learning and STEM-related jobs might enable them to develop more positive views on science, mathematics, or technology, and reduce their belief that these fields are difficult, dangerous, or masculine (Archer et al., 2010).

However, it was only for students who were confident in their STEM abilities that their enhanced perceptions of STEM professionals seemed to subsequently increase their desire to pursue STEM careers. In other words, perceptions of STEM professionals seemed to positively mediate the relationships from media and school experiences to career aspirations only for students with sufficient self-concept. Engaging these students in various STEM experiences in or outside school that help enhance their views of STEM professionals can be an effective method to inspire them to choose STEM careers (So et al., 2020). However, for students with lower levels of self-concept, the development of positive perceptions of STEM professionals might still be necessary, but seem insufficient. In the next section, the significant moderating role of self-concept is discussed in detail.

STEM self-concept as the moderator

While students in this study reported positive views regarding STEM professionals' abilities ($M = 3.04$ out of 4), the mean score of their STEM self-concept was around the midpoint ($M = 2.86$ out of 4). This finding is in line with previous studies (e.g.Tuan et al., 2005; Wan, 2021; Wan & Lee, 2017). Significant differences in self-concept by gender and school level were also found (see Tables 3 and 4). Boys or primary school students were likely to express higher self-concept, whereas girls or senior secondary students reported less. The results concur with those of some recent studies (Liou et al., 2023; Rüschenpöhler & Markic, 2019; Wan, 2021; Wan & Lee, 2017), indicating the potential negative effects of gender or school grade level on students' self-concept. A positive relationship between self-concept and career aspirations was also found in this study, which aligns with previous findings (e.g.Kang et al., 2021; Rosenzweig & Chen, 2023; Rüschenpöhler & Markic, 2019; Wang et al., 2017) that self-concept significantly influences the career choices students make. For most Hong Kong students, their low self-concept in STEM seemed to largely decrease their

aspirations for relevant careers. They considered career options primarily according to personal interest and competence (Leung & Hou, 2005; Leung et al., 2014). Therefore, continuous efforts should be made to support students in developing adequate STEM self-concept.

Notably, this study revealed that the interaction (perceptions of STEM professionals × self-concept) was significantly related to students' career aspirations. The positive relationship between perceived STEM professionals' abilities and success and career aspirations was much stronger among students with high self-concept than among those with medium self-concept, while the relationship was non-significant for students with low self-concept. In line with this, the indirect effect of media consumption on aspirations via perceptions was found to be conditional on the level of students' self-concept. For students whose STEM self-concept was mid or high, the indirect effect of media and school opportunities on career aspirations was significant and positive. On the contrary, for students whose STEM self-concept was low, the indirect effect became non-significant. These findings are not surprising given that self-concept functions by influencing students' perceived similarity and attainability of role models, which ultimately affects students' inner role modelling process and then influences their aspirations, as explained by the motivation theory of role modelling (Morgenroth et al., 2015). As Bourdieu and Passeron (1977) argued, the level of an individual's aspiration is 'essentially determined by the probability of achieving the desired goal' (p. 111). Students with inadequate STEM self-concept might perceive a mismatch between the perceptions they have of STEM professionals and themselves on STEM-related abilities, resulting in their lack of ability to perceive a future for themselves in those fields. Hence, even though they were engaged in STEM activities to develop better perceptions of scientists or engineers, they were less likely to aspire to STEM careers.

Therefore, this study suggests that, on one hand, fostering students' STEM self-concept is important, as self-concept not only positively predicts STEM career aspirations, but also strengthens the positive impacts of media resources and school opportunities on career aspirations. According to Wan (2021), there was inconsistency between Chinese students' reported self-concept and their science achievement, which may be caused by the Chinese culture of valuing modesty. This implies that some Hong Kong students reporting relatively low self-concept might be under-evaluating their STEM-related capabilities. Hence, efforts should be made to support those students to develop a more concrete, clearer sense of their personal abilities in STEM (Liou et al., 2023), and this would perhaps be better at a young age as self-concept might be more easily developed in younger students, and then become stable as the students grow older (Rüschenpöhler & Markic, 2019). Strategies such as providing vicarious experiences or promoting students' use of deep learning strategies may be adopted by teachers to help increase their students' ability self-concept (Cheung, 2015). In this way, students' self-concept might be enhanced, and this in turn might encourage them to see STEM professions as thinkable and attainable, and to pursue future careers in STEM.

On the other hand, displaying a wider range of STEM practitioners and practices in and outside the classroom to encourage all students to see the possibility that work in these fields would be part of their future is needed. Students need support to deconstruct and diversify their perceptions of representations in STEM (Martin & Fisher-Ari, 2021), and opportunities to see STEM and its applications as being 'for us' in a non-stereotypical way. There was evidence that students might prefer other types of STEM professionals rather than outstanding STEM professionals as they may be able to perceive those STEM professionals as being more similar to themselves (Steinke et al., 2021). The findings of this study demonstrated the need to match students' self-concept and their views regarding STEM professionals throughout STEM experiences. Promoting a great variety of professions in STEM fields to our students can be beneficial for students to see the multiplicity of pathways that can emerge from their study of STEM-related subjects (Morgenroth et al., 2015; Tan et al., 2017). For instance, having access to STEM-speaking adults who talked about the use of STEM in their jobs was found to be helpful in developing their ideas of STEM careers and their hopes and dreams (Hudson et al., 2020). This may be particularly important and necessary for promoting STEM career aspirations for secondary school students whose self-concept was relatively negative. As students' self-concept becomes more stable over time, interventions that aim at developing students' self-concept are probably less effective for older as compared to younger students (Rüschenpöhler & Markic, 2019). Hence, when secondary school students are provided with STEM professions more broadly, they might feel it is easier to match themselves with professionals in diverse STEM fields, to perceive the careers of these professionals as possible and inspirational in comparison to their own abilities, and thereby to develop career aspirations, which contribute to their actual participation in STEM in the future.

Limitations and future research

There are several limitations to this study. First of all, the model can account for around 20% of the variance in students' STEM career aspirations, indicating that other

factors might affect their career choices. One potential reason for the limited power might be that there are many factors that may be associated with students' career aspirations and the mechanisms may be complex. For instance, several studies (e.g.Jones et al., 2021; Tzu-Ling, 2019) have indicated that task value might significantly predict STEM career aspirations. While the model does not include all possible variables, it examines the complex moderated mediation relationships among variables including perceptions of STEM professionals, self-concept, media consumption, school STEM opportunities, gender, and school level, and interactive latent variable (perceptions of professionals_x_self-concept). Notably, this is the first time that these variables have been combined in a single moderated mediation model to show how they jointly influence students' career aspirations in the STEM fields. Moreover, the comparison among the three models (see Appendix A) enables this study to provide more direct and reliable results by controlling gender and school level effects, particularly by controlling their potential moderating effects on the relationships between perceptions and career aspirations. Future studies may collect data on these variables (e.g., goal orientation, task value) and include them to develop broader models so as to better understand the underlying mechanism of career aspiration development.

Second, since the aim of this study was to investigate students' aspirations for a wide range of STEM-related careers, this study identified STEM 'as a whole' and investigated students' STEM perceptions and career aspirations at a more general level. It is important to promote students' aspirations to pursue diverse STEM careers so as to enlarge the possibilities for them to see their potential in those careers. Further research may explore how and why students formulate their aspirations to specific STEM careers but not to others.

Third, this study examined the STEM career aspirations of Hong Kong primary and secondary school students, while under-represented groups (e.g., ethnic minority groups) in STEM areas were not included. This limits the generalization of the findings to other groups of students (e.g., ethnic minority students) or students in other contexts (e.g., Asian regions other than Hong Kong). Plus, as mentioned above, although the students were nested within schools, only six schools were involved in this study. Future studies can address these limitations by collecting data from students of different backgrounds and from more schools.

Fourth, this study was a survey study, and the data collected were cross-sectional. Hence, the results of this study cannot be interpreted as causal effects. Future studies can address this limitation by collecting longitudinal data. For instance, future research can investigate how changes in STEM experiences or self-concept may be associated with changes in career aspirations over time, or how early career aspirations may be linked to students' later STEM-related behaviors using growth models to further explore the impacts of school level on students' STEM experiences, self-concept, and career aspirations. Besides, this study used self-reported scales. A qualitative method may be employed in the future to reveal more information about the implementation of STEM education in Hong Kong schools to better understand why school STEM opportunities showed limited impacts on students' career aspirations in STEM.

Finally, the measures of engineering self-concept and engineering-related opportunities in school were not included, as engineering education is not provided in most Hong Kong schools. Given the increasing emphasis on engineering integration in primary and secondary schools, research into students' engineering self-concept and its effects on their choices of STEM career paths is warranted.

Conclusions

Despite its limitations, this study contributes to understanding the underlying mechanisms of how the interaction between perceptions of STEM professionals and self-concept might affect the impacts of media and school experiences on students' STEM career aspirations. This study indicates that for students with adequate STEM self-concept, enhancing their perceptions of STEM professionals' abilities in science or mathematics domains and career prospects through a diversity of STEM experiences (e.g., media-related or in school) can help raise their STEM career aspirations. However, for students with relatively inadequate STEM self-concept, increased school experiences or enhanced perceptions of STEM professionals in terms of abilities or career success may not matter for their career aspirations in STEM. This suggests that greater attention needs to be paid to students' levels of STEM self-concept when trying to connect students with STEM careers and professionals through media or school activities. There is a need to help strengthen students' beliefs, particularly those of students who lack self-concept, that they are able to match themselves with STEM people, so as to inspire the STEM participation of more students. It is expected that by fostering students' self-concept or providing STEM professions more broadly, students, including those lacking self-concept, can be better supported to perceive the possibilities of the attainability of STEM professionals, and to fulfill their potential in the future.

Appendix A

See Table 5.

Table 5 Coefficients of the paths in the tested models

Path	Model A	Model B	Model C
Career aspirations ON			
1. Positive perceptions of STEM professionals	0.286***	0.305***	0.349**
2. Self-concept	0.172*	0.160*	0.166*
3. Media consumption	0.118*	0.120*	0.110*
4. Gender	0.234***	0.205**	0.211**
5. Parental STEM-related jobs	0.113*	0.108*	0.106*
6. Positive perceptions of professionals*self-concept		0.354**	0.331**
7. Positive perceptions of professionals*gender			0.085
8. Positive perceptions of professionals*school level_junior			− 0.196
9. Positive perceptions of professionals*school level_senior			− 0.247
Perceptions of STEM professionals ON			
1. Media consumption	0.094*	0.093*	0.099*
2. STEM opportunities inside school	0.145**	0.143**	0.140**
Media consumption ON			
1. Gender			0.121
2. School level _ Junior secondary			− 0.343***
3. School level _ Senior secondary			− 0.545***
School opportunity inside school ON			
1. School level _ Junior secondary			− 0.316***
2. School level _ Senior secondary			− 0.331***
AIC	38492.113	38483.006	38605.564
BIC	38924.310	38919.613	39059.812
RMSEA	0.042	n.p	n.p
CFI	0.927	n.p	n.p
TLI	0.919	n.p	n.p
SRMR	0.060	n.p	n.p
Variance explained	18.0%	20.3%	18.4%

Model A refers to the reference model; Model B refers to the hypothesized model. Model C refers to the model with gender and school level effects further controlled. School level_primary was used as the reference group

*$p < 0.5$

**$p < 0.01$

***$p < 0.001$

Abbreviations

AIC	Akaike information criterion
BIC	Bayesian information criterion
CFA	Confirmatory factor analysis
CFI	Comparative fit index
EDB	Education Bureau
IFI	Incremental fit index
RMSEA	Root mean square error of approximation
SRMR	Standardized root mean square residual
STEM	Science, Technology, Engineering, and Mathematics
TLI	Tucker–Lewis index

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Availability of data and materials

The data sets analysed during the current study are not publicly available due to confidentiality considerations.

Declarations

Ethics approval and consent to participate

The research study reported in this article was approved by the Education University of Hong Kong.

Competing interests

The authors have no competing interests to declare.

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