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Integrating STEM into Traditional Chinese Medicine Education: Impacts on Hong Kong Secondary Students' Knowledge, Attitudes, and Behaviors

Yeuk Lung Chow
Hong Kong Metropolitan University
Lok Yi Chan
Technological and Higher Education Institution of Hong Kong
Wing Sum Tong
Technological and Higher Education Institution of Hong Kong
Siu Kan Law
Technological and Higher Education Institution of Hong Kong
Hiu Tung Wong
Technological and Higher Education Institution of Hong Kong
Ching Tung Au
dawnau@thei.edu.hk

Technological and Higher Education Institution of Hong Kong

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Abstract

Background

With growing global emphasis on STEM education and renewed interest in Chinese herbal medicine (CHM), integrating these fields presents a unique educational opportunity. In Hong Kong, where Traditional Chinese medicine (TCM) is widely used but often misunderstood, innovative teaching methods are needed to enhance youth literacy and promote safe practices.

Objective

This quasi-experimental study evaluated the effectiveness of a STEM-based CHM education intervention in improving secondary students' knowledge, attitudes, and behaviors toward TCM.

Methods

A total of 132 Hong Kong secondary students from 12 schools completed a STEM-based CHM program comprising an online course, hands-on laboratory workshops, and a competition. A validated questionnaire assessing TCM-related knowledge (12 items), attitudes (4 items), and behaviors (4 items) was administered pre- and post-intervention. Data were analyzed using paired t-tests, Wilcoxon signed-rank tests, and chi-square tests.

Results

Following the intervention, students demonstrated significant improvements in knowledge (from 6.00 ± 3.80 to 7.50 ± 3.20, $p < 0.001$) and behavior scores (from 12.87 ± 3.66 to 13.59 ± 3.86, $p < 0.01$), while attitude scores remained stable (15.36 ± 2.49 to 15.48 ± 2.69, $p > 0.05$). Subgroup analyses revealed persistent gender and grade-level gaps: female and senior students scored significantly higher in knowledge both pre- and post-intervention ($p < 0.001$). Notably, students aged 12–13 showed a significant decrease in attitude scores post-intervention ($p < 0.05$). A significant association was found between STEM education and improved knowledge levels (χ^2, $p < 0.001$).

Conclusion

A STEM-based approach effectively enhances secondary students' factual knowledge of CHM in the short term, though attitudinal and behavioral changes may require longer-term intervention. This model shows promise for integrating traditional medical knowledge into modern science curricula, with implications for both health education and cultural preservation.

1 Introduction

Traditional Chinese medicine (TCM) has a wide range of applications in disease prevention, treatment, and health maintenance, and is also an integral part of Chinese culture. Many residents of Hong Kong rely on Chinese herbal medicine (CHM), especially herbs that serve as both food and medicine. In recent years, to facilitate the development of TCM. The Hong Kong government launched several large-scale projects and policies. In 2019, set up the Chinese Medicine Development Fund, which supports projects related to TCM cultural education, publicity, and promotion in schools in Hong Kong to raise students' awareness of TCM culture and encourage its inheritance and development [1]. Moreover, the first Chinese medicine hospital in Hong Kong and the Government Chinese Medicines Testing Institute have officially commenced service in late 2025. In addition, the Hong Kong Health Bureau issued the "Chinese Medicine Development Blueprint", which explicitly includes the objective of promoting TCM culture [2].

Despite policy support and cultural familiarity, TCM knowledge among Hong Kong residents remains superficial and unsystematic. A 2021 territory-wide survey revealed a critical knowledge-practice gap: while 73.4% of respondents reported some awareness of CHM, nearly half (48.9%) could not correctly answer basic questions about the appropriate use of common remedies such as "An Gong Niu Huang Pill" [3]. This knowledge deficit has tangible public health consequences: herbal and proprietary Chinese medicines ranked among the top three substances involved in poisoning cases reported to the Hong Kong Poison Information Centre in 2020, accounting for 8.1% of all incidents [4].

This situation underscores the urgent need for systematic, evidence-based TCM education beginning early in life. Traditional Chinese Medicine is inherently interdisciplinary, drawing on botany, chemistry, pharmacology, and cultural history—making it ideally suited for integration into STEM curricula. STEM education, characterized by its emphasis on inquiry-based learning, real-world problem-solving, and cross-disciplinary integration [5], has been shown to enhance students' scientific inquiry skills, learning motivation, and cognitive outcomes [6–7]. In Hong Kong, STEM has been a strategic educational priority since 2015, with government funding supporting school-based initiatives [8].

Several pioneering local schools have already begun integrating TCM into STEM education. For example, St. Paul's Convent School developed a school-based TCM curriculum that led to a patented herbal tea formulation [9], while Yan Chai Hospital Lan Chi Pat Memorial Secondary School

established a "smart" Chinese medicine garden with QR-code-linked learning resources [10]. These initiatives demonstrate the feasibility and appeal of STEM-based TCM education. However, to date, no systematic empirical evaluation has been conducted to assess the actual impact of such programs on students' TCM-related knowledge, attitudes, and behaviors.

The present study addresses this gap by employing a pre-post comparative design to examine changes in these outcomes following a structured STEM-based CHM education intervention. Findings will provide evidence to inform the integration of TCM into mainstream secondary education in Hong Kong and beyond.

2. Method

2.1 Study Design and Objectives

The non-randomized, pre-post intervention study used self-designed questionnaires as an instrument to evaluate the impact of the STEM-based CHM education intervention on attitudes, knowledge, and behaviors of Hong Kong secondary students (Fig. 1). The results will help to enhance the understanding of STEM-based CHM education and serve as evidence for the integration of STEM education modes in the secondary school curricula.

2.2 Research Details

Participants

Participants were recruited by mail invitation distributed in local secondary schools. Students who have parental consent were eligible to participate. Schools/institutions that provide non-local curricula were excluded.

Intervention

STEM-based CHM education for secondary students was jointly developed by a panel of experts from the Technological and Higher Education Institute of Hong Kong (including Chinese medicine practitioners, Chinese medicine pharmacists, methodologists with expertise in STEM education, etc.). The educational design was tailored to the secondary level, and the course materials and practices were relevant to the study. The objective of this intervention was to impart CHM knowledge and skills to participants in a STEM manner.

Online Course

A 3-hour TCM course taught from May to October 2025 by a Hong Kong TCM practitioner. This session addresses the fundamental theories of TCM and the basic concept of using CHM, including how to master key techniques and recognize easily confused CHM.

Workshop

An 8-hour hands-on workshop was held from September to October 2025 at the laboratories on the Institute campus to practice microscopic identification and thin-layer chromatography testing experiments. Students will learn authentication techniques that apply to those confused CHM.

Competition

A 5-hour contest competition included CHM identification and project research, was held at the end of December 2025. Participants were required to use the knowledge gained from online courses and workshops to identify CHM on the spot and develop authentication plans for certain easily confused CHM during the competition.

Sample size estimation

Under normal circumstances, for social science research, the effect size is typically 0.5 (Medium); power is 0.8 [11]; and the allocation ratio is 1. According to calculations using G*Power (Ver: 3.1.9.7), the recommended sample size is 128 [12].

Data Collection

Data were collected via a self-administered online questionnaire implemented in Google Forms. Participants were not allowed to read summary and individual responses of other participants. The survey was conducted between September and October 2025, with a verified questionnaire (QR code) distributed to teachers in secondary schools participating in this STEM programme. The same questionnaire will be provided to participants before and after the intervention. No missing data were found in the valid questionnaire, as participants were required to complete all required fields before submission. Only participants who complete the pre- and post-intervention questionnaires will have their data included in the analysis.

Quality Control

All researchers are professional TCM, STEM educators or researchers. They will be trained to provide clear, unambiguous instructions to participants and to respond appropriately to participants during the study. They will also be trained to process any confidential and sensitive information involved.

2.3 Questionnaire Design

Questionnaire Structure

A questionnaire is an assessment tool used to evaluate knowledge, behaviour, and attitudes towards CHM. The question structure and score dimension(Fig. 2) are as follows:

Sociodemographic

Includes gender, education level and age range.

Knowledge Assessment

Includes 12 multiple-choice questions (MCQs). One mark will be awarded for each correct answer and none for incorrect answers. The scoring range is 0–12, with higher scores indicating greater knowledge of CHMs.

Attitude and Behavior Assessment

Includes 4 questions with a 5-point Likert scale (1–5). The scoring range is 4–20, with higher scores indicating more positive attitudes and behaviours toward CHM.

Content Validity

The content validity of all items of the questionnaires was assessed by a panel of 10 experts from the traditional Chinese medicine and science, technology, engineering, and mathematics (STEM) education domains, and the content validity index (CVI) was calculated for the justification of the questionnaire's validity. If the number of experts is greater than 5, the I-CVI and the S-CVI/ave should not be lower than 0.78 and 0.80, respectively [13]. For 26 questions, the I-CVI ranged from 0.80 to 1.00, and the S-CVI/ave was 0.98. It indicated that the questionnaire's content validity was good.

2.4 Data Analysis

Regarding the descriptive data, frequency, percentage, and central tendency will be presented, among which central tendency will be expressed by mean and standard deviation. For inter-group analyses of knowledge, attitude, and behavior scores, independent t-tests, paired t-tests and ANOVA will be used to compare group means. Corresponding nonparametric tests will be applied if assumptions are not satisfied. The Chi-square will be employed to examine the association among various scoring indicators. This multivariate approach will ensure comprehensive data analysis. All data analysis and processing will be conducted using SPSS (Version 29.0), with a significance level of 0.05 set for all tests.

2.5 Ethical Issues

This study has been reviewed and approved by the Human Subjects Ethics Committee of the Technological and Higher Education Institute of Hong Kong, 2025 (HE2025-11). Participants were informed of the purpose of the study and the confidentiality of their contribution. The participants were fully voluntary and could withdraw at any time from the study. Informed consent was obtained in each survey data collection. The data will be handled in an anonymous and confidential manner and destroyed within two years after the completion of the study.

3. Results

3.1 Descriptive Finding

A total of 227 secondary students from 12 local Hong Kong schools participated in one or more components of the STEM-based CHM education program (online course, workshop, and/or competition). However, only students who completed all three components were eligible to complete both the pre- and post-intervention questionnaires. Of the 227 initial participants, 132 students (58.1%) fulfilled this criterion and provided valid paired questionnaire data. The remaining 95 students participated in some but not all activities and were therefore excluded from the analysis, as the full intervention dose was necessary for evaluating its impact. The demographic data and scoring results are presented in Tables 1 and 2, respectively. As shown in Table 2, except for a slight decrease in the attitude mean score among Junior (-0.08) and age 12–14 (-0.84) groups, STEM-based CHM education improved students' CHM knowledge, attitudes, and behaviors. Pre- and post-test mean scores increased to varying degrees (from + 0.07 to + 2.29).

The average scores obtained by students for each question, where knowledge, attitude, and behavior correspond to Q7-18, Q19-22, and Q23-26, respectively. The pre- and post-intervention average scores for each item increased by 0.13 (+ 26.0%), 0.03 (+ 0.78%), and 0.18 (+ 5.59%), respectively (Table 3). Before the STEM education intervention, the mean and standard deviation of students' knowledge, attitude, and behavior scores were 6.00 ± 3.80 (moderate), 15.36 ± 2.49 (high), and 12.87 ± 3.66 (moderate), respectively. After the STEM education intervention, the mean

and standard deviation of students' knowledge, attitude, and behavior scores were 7.50 ± 3.20 (moderate), 15.48 ± 2.69 (high), and 13.59 ± 3.86 (moderate), respectively, with no change observed in the score dimension (Table 4).

Table 1
Demographic Data from the Questionnaire on Hong Kong Secondary Students' Knowledge, Attitudes, and Behaviors Regarding Traditional Chinese Medicine (N = 132)

Items	Characteristics	Frequency (Percentage)
Gender	Male	58 (43.9%)
	Female	74 (56.1%)
Education Level	Junior (Secondary 1 to 3)	24 (18.2%)
	Senior (Secondary 4 to 6)	108 (81.8%)
Age Range	12–13	13 (9.85%)
	14–15	43 (32.57%)
	16–17	76 (57.58%)

Table.2. Comparison of each parameter in Knowledge, Attitude, and Behavior Scores Before and After STEM Intervention (N = 132)

Items	Parameters	Mean Score(SD)		Mean difference
		Pre	Post	
Knowledge	Male	4.64(3.33)	5.93(3.19)	+ 1.29
	Female	7.11(3.74))	8.78(2.67)	+ 1.67
	Junior	2.88(2.69)	5.17(2.79)	+ 2.29
	Senior	6.72(3.61)	8.06(3.09)	+ 1.34
	Age 12–13	2.23(2.17)	4.00(2.65)	+ 1.77
	Age 14–15	6.53(4.22)	7.98(3.18)	+ 1.45
	Age 16–17	6.38(3.35)	7.88(3.00)	+ 1.50
Attitude	Male	15.17(2.56)	15.26(2.99)	+ 0.09
	Female	15.51(2.45)	15.65(2.43)	+ 0.14
	Junior	14.75(2.15)	14.67(2.51)	-0.08
	Senior	15.50(2.55)	15.66(2.70)	+ 0.16
	Age 12–13	14.54(2.15)	13.70(2.14)	-0.84
	Age 14–15	15.63(2.26)	16.09(2.63)	+ 0.46
	Age 16–17	15.36(2.67)	15.43(2.69)	+ 0.07
Behavior	Male	12.97(4.04)	13.41(4.37)	+ 0.44
	Female	12.80(3.35)	13.73(3.43)	+ 0.93
	Junior	12.29(3.28)	13.08(2.75)	+ 0.79
	Senior	13.00(3.74)	13.70(4.07)	+ 0.70
	Age 12–13	11.69(3.52)	12.15(1.82)	+ 0.46
	Age 14–15	13.09(4.19)	14.02(4.31)	+ 0.93
	Age 16–17	12.95(3.35)	13.59(3.83)	+ 0.64

Table.3 Comparison of each question score pre- and post- STEM education (N = 132)

Questions			Pre- STEM education			Post- STEM education			Mean difference of each question	Mean difference of each dimension
			Mean	Standard deviation	Average	Mean	Standard deviation	Average		
knowledge	Q7	Which of the following combinations of TCM are commonly confused in Hong Kong?	0.32	0.47	0.5	0.33	0.47	0.63	+ 0.01	+ 0.13 (+ 26%)
	Q8	What is the efficacy of Croci Stigma?	0.62	0.49		0.72	0.45		+ 0.1	
	Q9	which TCM have distinguishing feature of "Holding the moon in the arms" (□□□□)?	0.42	0.5		0.63	0.48		+ 0.21	
	Q10	What category of TCM does "Cordyceps" belong to?	0.64	0.48		0.75	0.43		+ 0.11	
	Q11	Which of the following correctly matches the "Five Elements" (□□) with their corresponding five viscera(□□) in TCM theory?	0.53	0.5		0.6	0.49		+ 0.07	
	Q12	In the four diagnostic methods of TCM “visual, auditory, olfactory, and questioning”(□□□□), what does " questioning " refer to?	0.64	0.48		0.64	0.48		0	
	Q13	What is the therapeutic effect of TCM herbs with a sour taste?	0.49	0.5		0.58	0.49		+ 0.09	
	Q14	Which of the following is not part of the basic theory of TCM?	0.49	0.5		0.62	0.49		+ 0.13	
	Q15	What is the distinguishing characteristic of Croci Stigma?	0.40	0.49		0.59	0.49		+ 0.19	
	Q16	What are the purposes of HPLC and TLC in the identification of TCM?	0.49	0.5		0.59	0.49		+ 0.10	
	Q17	What are the main observation targets when using microscopy to identify TCM?	0.61	0.49		0.83	0.38		+ 0.22	
	Q18	What is the distinguishing feature of Fraxini Cortex?	0.36	0.48		0.66	0.48		+ 0.3	
Attitude	Q19	I am interested in knowledge TCM.	3.93	0.84	3.84	3.80	0.95	3.87	-0.13	+ 0.03 (+ 0.78%)
	Q20	I am very resistant to using TCM.	4.08	1.03		4.23	0.91		+ 0.15	
	Q21	I believe that TCM should be included in the regular curriculum of secondary schools.	3.08	0.97		3.23	1.13		+ 0.15	
	Q22	I believe that TCM is not scientific enough.	4.27	0.89		4.22	0.94		-0.05	
Behavior	Q23	I will take the initiative to learn about TCM.	3.16	1.06	3.22	3.39	1.10	3.4	0.23	+ 0.18 (+ 5.59%)
	Q24	I will actively participate in activities	3.27	1.11		3.40	1.07		0.13	

	related to TCM.					
Q25	I will proactively use TCM to regulate my body and prevent diseases (such as drinking tea and soup).	3.36	1.21	3.49	1.23	0.13
Q26	I will proactively promote TCM or related information to my relatives and friends.	3.08	1.15	3.30	1.15	0.22

3.2 Inferential Statistics

Except for no significant change in students' attitudes toward traditional Chinese medicine, both knowledge ($p < 0.001$) and behavior ($p < 0.01$) demonstrated significant improvement (Table 4).

Further subgroup analyses by socioeconomic background revealed that female students consistently demonstrated significantly higher knowledge scores than male students both before ($p < 0.001$) and after ($p < 0.001$) the STEM education intervention. Although male students also showed significant improvement ($p < 0.001$) following the intervention, they maintained a persistent knowledge gap compared to female students. Additionally, comparing knowledge levels between junior and senior students before and after STEM education revealed that senior students consistently demonstrated significantly higher knowledge levels than juniors both before ($p < 0.001$) and after ($p < 0.001$) the educational intervention. Although junior students also showed significant improvement ($p < 0.001$) following STEM education, they still maintained a noticeable gap in knowledge levels compared to senior students. There were no significant differences in changes to attitude and behavior scores between gender or education levels before and after STEM education (Table 5).

In the inter-age group analysis, both knowledge ($p<.001$) and attitude ($p<.05$) scores showed significant differences after the intervention. The knowledge and attitude data indicate that older secondary school students benefited significantly more from short-term STEM-based CHM education than younger students. Furthermore, knowledge scores significantly improved after the intervention in all age groups ($p<.05–.001$); behavioral scores also significantly improved in 16–17 year old students ($p < 0.05$). Unexpectedly, attitude scores significantly decreased in the 12–13 year old age group ($p < 0.05$).

After receiving STEM education, the proportion of students with low levels of TCM knowledge decreased from 37.9% to 18.2%, while the proportion of students with high levels increased from 28.8% to 46.2%. The chi-square test revealed a significant association between STEM education and students' knowledge levels ($p < 0.001$), indicating that STEM education effectively enhances secondary students' TCM knowledge. However, the result showed no association between STEM education and students' attitudes or behavioral levels. (Table 6)

Table.4 Comparison of total scores on knowledge, attitudes, and behaviors among all participants before and after STEM education (N = 132)

Knowledge	Score before STEM education (M ± SD)	Score after STEM education (M ± SD)	P value#
	6.00 ± 3.80	**7.50 ± 3.20**	***
Attitude	15.36 ± 2.49	15.48 ± 2.69	NS
Behavior	12.87 ± 3.66	13.59 ± 3.86	**
*p<.05, **p<.01, ***p<.001, NS: not significant			
# From Wilcoxon signed rank test			

Table.5A comparison of differences in total scores in knowledge, attitudes and behaviors before and after STEM education among participants from different backgrounds.

	Knowledge (Mean ± SD)				Attitude (Mean ± SD)				Behaviour (Mean ± SD)			
	Male	**Female**	**Mean difference**	**P value#**	**Male**	**Female**	**Mean difference**	**P value#**	**Male**	**Female**	**Mean difference**	**P value#**
Before	4.64 ± 3.33	7.11 ± 3.74	2.47	***	15.17 ± 2.56	15.51 ± 2.45	0.34	NS	12.97 ± 4.04	12.80 ± 3.35	0.17	NS
After	5.93 ± 3.19	8.78 ± 2.67	2.85	***	15.26 ± 2.99	15.65 ± 2.43	0.39	NS	13.41 ± 4.37	13.73 ± 3.43	0.32	NS
P value^	***	***			NS	NS			NS	**		
Score different	1.29 ± 2.84	1.68 ± 2.78	-	NS	0.09 ± 2.81	0.14 ± 1.91	-	NS	0.45 ± 2.87	1.18 ± 3.32	-	NS
	Junior	**Senior**	**Mean difference**	**P value#**	**Junior**	**Senior**	**Mean difference**	**P value#**	**Junior**	**Senior**	**Mean difference**	**P value#**
Before	2.88 ± 2.69	6.72 ± 3.61	3.84	***	14.75 ± 2.15	15.50 ± 2.55	0.75	NS	12.29 ± 3.28	13.00 ± 3.74	0.71	NS
After	5.17 ± 2.79	8.06 ± 3.09	2.89	***	14.67 ± 2.51	15.66 ± 2.70	0.99	NS	13.08 ± 2.75	13.70 ± 4.07	0.62	NS
P value^	***	***			NS	NS			NS	*		
Score different	2.29 ± 2.91	1.33 ± 2.75	-	NS	-0.08 ± 1.79	0.16 ± 2.45	-	NS	0.79 ± 2.64	0.87 ± 3.25	-	NS
	Age 12–13	Age 14–15	Age 16–17	**P value##**	Age 12–13	Age 14–15	Age 16–17	**P value##**	Age 12–13	Age 14–15	Age 16–17	**P value##**
Before	2.23 ± 2.1	6.53 ± 4.22	6.38 ± 3.35	***	14.54 ± 2.15	15.63 ± 2.26	15.36 ± 2.67	NS	11.69 ± 3.52	13.09 ± 4.19	12.95 ± 3.35	NS
After	4.00 ± 2.65	7.98 ± 3.18	7.88 ± 3.00	***	13.70 ± 2.14	16.09 ± 2.63	15.43 ± 2.69	* 0.021	12.15 ± 1.82	14.02 ± 4.31	13.59 ± 3.83	NS
P value^	*	**	***		*	NS	NS		NS	NS	*	
Score different	1.77 ± 3.06	1.44 ± 2.98	1.50 ± 2.72	NS	-0.85 ± 1.41	0.47 ± 2.25	0.08 ± 2.49	NS	0.46 ± 2.96	0.93 ± 3.05	0.88 ± 3.25	NS
*p<.05, **p<.01, ***p<.001, NS: not significant												
# From Mann-Whitney U-test												
## From Kruskal-Wallis Test												
^ From the Wilcoxon signed rank test												

Table.6 The Relationship Between STEM Education and Knowledge, Attitudinal, and Behavioral Levels

	Level	Before STEM education	After STEM education	p-value#
Knowledge	Low (0-3.99)	50 (37.9%)	24 (18.2%)	***
	Moderate (4-7.99)	44 (33.3%)	47 (35.6%)	
	High (8–12)	38 (28.8%)	61 (46.2%)	
Attitude	Low (4-8.99)	1 (0.76%)	1 (0.76%)	NS
	Moderate (9-13.99)	70 (53.03%)	68 (51.51%)	
	High (14–20)	61 (46.21%)	63 (47.73%)	
Behaviour	Low (4-8.99)	23 (17.4%)	13 (9.8%)	NS
	Moderate (9-13.99)	74 (56.1%)	78 (59.1%)	
	High (14–20)	35 (26.5%)	41 (31.1%)	
*p<.05, **p<.01, ***p<.001, NS: not significant				
# From Chi's square test				

4. Discussion

This study evaluated the effectiveness of a STEM-based Chinese herbal medicine (CHM) education intervention in enhancing Hong Kong secondary students' knowledge, attitudes, and behaviors toward Traditional Chinese Medicine (TCM). The findings demonstrate that a relatively brief, multi-component STEM intervention can significantly improve students' factual knowledge of CHM, with more modest effects on attitudes and behaviors. These results have important implications for curriculum design, educational policy, and the broader goal of promoting TCM literacy among younger generations.

The substantial knowledge gains observed across most student subgroups are encouraging and consistent with the educational objectives of the intervention. The most pronounced improvements were evident in questionnaire items directly linked to hands-on workshop activities—for instance, questions concerning microscopic identification of herbs (Q17) and distinguishing features of specific TCM materials (Q18). This pattern suggests that experiential, inquiry-based learning—a cornerstone of effective STEM pedagogy—facilitates deeper cognitive engagement and knowledge retention. During the activities, informal observations and spontaneous comments from many students suggested that conducting experiments in the laboratory and undertaking independent research for the competition enhanced their enjoyment of learning and deepened their appreciation of the scientific basis of TCM. Although this qualitative feedback was not systematically collected or analyzed, it provides anecdotal support for the quantitative findings and aligns with previous research demonstrating that STEM activities enhance students' learning motivation and science process skills [6].

The differential impact on knowledge versus attitudes and behaviors can be usefully interpreted through the lens of the Knowledge-Attitude-Practice (KAP) model, a theoretical framework widely employed in health education research. According to this model, knowledge acquisition is a necessary antecedent to attitudinal and behavioral change, but the translation of knowledge into sustained practice typically requires time, reinforcement, and deeper cognitive and emotional engagement [14]. Our finding that a 16-hour intervention produced significant knowledge gains but limited attitudinal and behavioral shifts is therefore theoretically consistent. Attitude change, in particular, involves a progression through stages of compliance, identification, and internalization—processes unlikely to be completed within a short-term educational program [15]. This interpretation is supported by longitudinal research on integrated STEM education: Loof et al. found that measurable impacts on student outcomes only emerged after two years of sustained intervention, suggesting that the full benefits of STEM-based approaches may require prolonged curricular integration [16]. The fact that students in our study began with relatively high baseline attitude scores (mean 15.36 out of 20, classified as "high") further constrained the potential for detectable short-term improvement.

The significant knowledge gains observed among female and senior students, alongside persistent demographic gaps, warrant careful consideration. Female students consistently outperformed their male counterparts in knowledge assessments both before and after the intervention, a pattern consistent with previous research in Chinese populations. Luan and Lu reported that women in mainland China scored significantly higher than men on measures of TCM health literacy, a phenomenon likely rooted in traditional gender roles whereby women assume primary responsibility for family health and daily care, making them more receptive to TCM knowledge [17]. In contrast, male students in our study frequently expressed skepticism during activity reflections, with comments suggesting perceptions that "TCM is inferior to Western medicine" or questioning its scientific validity. Such attitudes, consistent with Chiu's finding that 7.9% of male respondents consider TCM "unscientific," may create psychological barriers to knowledge acquisition [3]. The persistent knowledge gap between junior and senior students similarly reflects developmental and educational factors. Senior secondary students, having received more extensive instruction in biology and chemistry, possess stronger foundational knowledge and more developed critical thinking skills, enabling them to connect new TCM concepts with existing scientific frameworks. The Hong Kong government's recent initiatives to promote TCM through media and public education may also disproportionately benefit older students, who are better equipped to actively seek out, comprehend, and integrate such information.

Perhaps the most intriguing finding of this study is the significant decline in attitude scores observed among the youngest participants (ages 12–13) following the intervention. While their knowledge scores improved (from 2.23 to 4.00, $p < 0.05$), their attitudes toward TCM became significantly more negative (from 14.54 to 13.70, $p < 0.05$). This unexpected result merits careful interpretation and has important implications for educational practice. Several mechanisms may explain this phenomenon. First, from a developmental perspective, Piaget's theory of cognitive development posits that early adolescents (typically ages 11–14) are in transition from concrete operational to formal operational thinking. During this stage, abstract concepts—such as the "Five Elements" theory, the biochemical basis of herbal actions, or the philosophical underpinnings of TCM—may be particularly challenging to grasp. The scientific, analytical approach inherent in STEM education may have demystified TCM in ways that disrupted younger students' pre-existing, more intuitive understandings, potentially replacing naive acceptance with skepticism. Second, the hands-on laboratory components, while engaging for older students, may have induced anxiety or frustration in younger participants who felt inadequately prepared for the technical demands of tasks such as thin-layer chromatography. Third, it is possible that the intervention inadvertently highlighted the complexity and uncertainty inherent in scientific authentication of herbs, challenging younger students' simplistic views of TCM as "natural" and therefore inherently safe and reliable. This finding underscores the critical importance of age-appropriate curriculum design in STEM-based TCM education. For younger adolescents, interventions should place greater emphasis on concrete, relatable applications—such as cultivating herbs or preparing simple TCM-based foods—and gradually introduce abstract concepts as students' cognitive capabilities develop.

The absence of significant behavioral change among most subgroups, except female and senior students, further supports the need for sustained intervention. While behavior scores improved significantly for the overall sample ($p < 0.01$), subgroup analyses revealed that this effect was driven

primarily by female ($p < 0.01$) and senior ($p < 0.05$) participants. This pattern suggests that students with greater baseline receptivity to TCM—whether due to gender-role socialization or developmental maturity—may be better positioned to translate new knowledge into behavioral intentions within a short timeframe. For others, particularly male and younger students, behavioral change may require more extended engagement and targeted pedagogical strategies.

Several limitations of this study should be acknowledged. First, the absence of a control group limits causal inference; future research employing randomized controlled designs would provide stronger evidence of intervention effectiveness. Second, the reliance on self-reported behavioral intentions rather than observed behaviors introduces potential social desirability bias. Third, the relatively short follow-up period precludes assessment of long-term impacts on attitudes and behaviors. Fourth, while the questionnaire demonstrated strong content validity (S-CVI/ave = 0.98), its internal consistency reliability was not assessed due to the limited number of items in the attitude and behavior subscales and the exploratory nature of this pilot study. Future research should include a larger sample to enable a comprehensive psychometric evaluation, including confirmatory factor analysis and test-retest reliability assessment. Fifth, the sample consisted of students who voluntarily completed all three program components, which may introduce self-selection bias and limit generalizability to the broader secondary school population.

Despite these limitations, this study makes several important contributions. It provides the first empirical evidence, to our knowledge, of the effectiveness of a STEM-based approach to TCM education in a secondary school setting. It identifies demographic subgroups that may require targeted pedagogical support, particularly male and younger students. It highlights the critical importance of the developmental stage in designing culturally integrated STEM curricula. And it demonstrates the feasibility of translating traditional medical knowledge into modern scientific frameworks in ways that enhance rather than diminish student engagement—provided such translation is developmentally appropriate.

Future research should prioritize longitudinal studies tracking the trajectory of attitudinal and behavioral change over extended periods, ideally with multiple follow-up assessments. Qualitative research exploring students' cognitive and emotional responses to STEM-based TCM education would complement quantitative findings and illuminate mechanisms underlying observed effects. Intervention studies systematically varying curriculum components (e.g., hands-on activities vs. didactic instruction) could identify active ingredients most responsible for knowledge gains. Finally, cross-cultural comparative research examining how students in different educational systems respond to STEM-based traditional medicine education would advance theoretical understanding and inform global educational practice.

5. Conclusion

This study provides the first empirical evidence that a STEM-based approach to Chinese herbal medicine education can significantly enhance secondary students' factual knowledge of TCM within a relatively short timeframe. While attitudinal and behavioral changes were limited—and in the youngest cohort, unexpectedly negative—these findings are consistent with theoretical models of educational and behavioral change, which posit that knowledge acquisition precedes and enables longer-term transformation. The significant knowledge gains observed across all demographic subgroups and the strong association between STEM education and improved knowledge levels support the potential of this pedagogical model to promote both scientific literacy and cultural heritage.

For educational policymakers and curriculum developers, our findings suggest several actionable recommendations:

1. Integrate STEM-based TCM modules progressively across secondary school years, with age-appropriate content tailored to students' cognitive developmental stages.
2. Develop targeted strategies to engage male and younger students, who demonstrated lower baseline knowledge and, in the youngest group, attitudinal vulnerability.
3. Conduct longitudinal studies to track the trajectory of attitudinal and behavioral change over extended periods, ideally using randomized controlled designs.

Ultimately, by demonstrating that traditional medical knowledge can be effectively taught through modern scientific methods, this study contributes to a growing international literature on the integration of indigenous and local knowledge into formal science education—a goal increasingly recognized as essential for culturally responsive and globally relevant STEM pedagogy.

This study contributes to a growing international literature on the integration of indigenous and local knowledge into formal science education—a goal increasingly recognized as essential for culturally responsive and globally relevant STEM pedagogy.

Abbreviations

CHM
Chinese herbal medicine
TCM
Traditional Chinese medicine
STEM
Science, Technology, Engineering, and Mathematics

Declarations

Ethics approval and consent to participate

This study was reviewed and approved by the Human Subjects Ethics Committee of the Technological and Higher Education Institute of Hong Kong (Approval No. HE2025-11). Informed consent was obtained from all participants and their parents or legal guardians prior to data collection. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Clinical trial number

Not applicable

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Author Contribution

CYL participated in data analysis and writing of the paper. ACT participated in research design and oversaw the final publication. CLY participated in the performance of the research, data analysis and drafting of the paper. TWS, LSK, and WHT participated in the performance of the research. All authors read and approved the final manuscript.

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Not applicable

Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to privacy and ethical restrictions (the data contain identifiable information of minor participants) but are available from the corresponding author on reasonable request.

References

1. Chinese Medicine Development Fund. About CMDF. https://www.cmdevfund.hk/en/about-us/. Accessed 14 Jan 2026.
2. Health Bureau (HKSAR). Chinese Medicine Development Blueprint. Hong Kong: Health Bureau (HKSAR). 2025. https://www.healthbureau.gov.hk/CMDevBlueprint/pdf/CMDevBlueprint_tc.pdf. Accessed 13 Feb 2026.
3. Chiu WKS. Utilization of Chinese Medicine among Hong Kong Citizens: Socio-Economic Background, Decision-Making Process and Policy Dimension. Hong Kong: The Education University of Hong Kong; 2021. Report No.: 19B2/022A. https://www.cmdevfund.hk/media/vtejkbrd/67_1295_tc.pdf. Accessed 25 Feb 2026.
4. Chow TYA, Chan CK, Ng SH, Tse ML. Hong Kong poison information centre: Annual report 2020. Hong Kong J Emerg Med. 2023;30(2):117 – 30. 10.1177/10249079221127611
5. Ortiz-Revilla J, Greca IM, Arriassecq I. A theoretical framework for integrated STEM education. Sci Educ. 2022;31(2):383–404. 10.1007/s11191-021-00242-x.
6. Hiğde E, Aktamış H. The effects of STEM activities on students' STEM career interests, motivation, science process skills, science achievement and views. Think Skills Creat. 2022;43:101000. 10.1016/j.tsc.2022.101000.
7. Cao X, Lu H, Wu Q, Hsu Y. Systematic review and meta-analysis of the impact of STEM education on students' learning outcomes. Front Psychol. 2025;16:1579474. 10.3389/fpsyg.2025.1579474.

8. Ko B, Lai M. The development of STEM education of Hong Kong. STEM education in Hong Kong: Theory and classroom practice. Hong Kong: The Education University of Hong Kong CELT; 2020. pp. 5–17.
9. Chinese Medicine Development Fund. Modern Chinese herbal medicine in schools: learning and teaching, understanding and innovation. Hong Kong: Chinese Medicine Development Fund. 2026. https://www.cmdevfund.hk/sc/project-result/19b1-2004a/. Accessed 27 Feb 2026.
10. Yan Chai Education. LCP X STEM Cafe X TCM Garden. Hong Kong: Yan Chai Education. 2021 Feb. p. 3. https://www.lcp.edu.hk/LCPMakerspace/media/20210304/ych-013_Lcp.pdf. Accessed 27 Feb 2026.
11. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. New York: Routledge; 1988. 10.4324/9780203771587.
12. Kang H. Sample size determination and power analysis using the G*Power software. J Educ Eval Health Prof. 2021;18:17. 10.3352/jeehp.2021.18.17.
13. Terwee CB, Bot SD, de Boer MR, van der Windt DA, Knol DL, Dekker J, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol. 2007;60(1):34–42. 10.1016/j.jclinepi.2006.03.012.
14. Schwartz NE. Nutritional knowledge, attitudes, and practices of high school graduates. J Am Diet Assoc. 1975;66(1):28–31.
15. Kelman HC. Compliance, identification, and internalization: three processes of attitude change. J Confl Resolut. 1958;2(1):51–60. 10.1177/002200275800200106.
16. De Loof H, Boeve-de Pauw J, Van Petegem P. Integrated STEM education: the effects of a long-term intervention on students' cognitive performance. Eur J STEM Educ. 2022;7(1):13. 10.20897/ejsteme/12738.
17. Luan H, Lu Y. Analysis on the status quo and influencing factors of residents' health cultural literacy of traditional Chinese medicine. J Mod Med Health. 2022;23:4046–9.

Figures



Figure 1

Illustrates the flow of participants through the study. Of the 227 students who initially enrolled, 132 completed all three intervention components and both questionnaires, constituting the final analytic sample.

	Low level	*Moderate level*	*High level*
Knowledge score (0-12 points)	0-3.99	4-7.99	8-12
Attitude score (4-20 points)	4-8.99	9-13.99	14-20
Behavior score (4-20 points)	4-8.99	9-13.99	14-20

Figure 2

Score dimension for knowledge, attitude and behavior