STEM Education
https://www.aimsciences.org/journal/A0000-0006

STEM Education, 2 (4): 318–344
DOI: 10.3934/steme.2022020
Received: September 2022
Accepted: December 2022

Research article

A comparative study of pre-service teachers' perceptions on STEAM education in UK and China

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Academic Editor: William Guo

Abstract: As more countries emphasize the development of science, technology, engineering, art, and mathematics (STEAM) education, the training of professional pre-service teachers has received considerable attention. To explore Chinese and UK preservice teachers' understanding of STEAM education, their willingness to engage in STEAM-related occupations, and their attitudes toward various STEAM disciplines, this study designed a questionnaire to investigate the perceptions of 109 and 379 preservice teachers from the United Kingdom and China, respectively. A quantitative analysis revealed the following: (1) Preservice teachers lacked the understanding of STEAM education in general. (2) Chinese and UK preservice teachers had different overall understandings of STEAM education. (3) Both Chinese and UK preservice teachers had different opinions about the role of art in STEAM. (4) The scores of Chinese preservice teachers in the semantic questionnaire in each discipline were significantly higher than those of the UK teachers, and significant differences in gender and profession were observed. (5) No significant differences were observed between the total scores of the UK and Chinese participants on the career interest questionnaire. Finally, we combined the experiences of the Chinese and UK preservice teachers to provide recommendations for teacher training.

Keywords: preservice teacher; STEAM education; teacher training; China; United Kingdom

1. Introduction

STEM (science, technology, engineering, and mathematics) education has existed for more than 20 years. With the advances in society and the progress of science and technology, the demand for STEM professionals in the labor market has increased. STEM education is becoming increasingly important in many countries [1]. In China, the Ministry of Education has issued several guiding documents illustrating the importance of STEM education. In 2015, the government suggested "making effective use of information technology to promote the building of mass-creating spaces, exploring new educational modes such as STEAM (science, technology, engineering, arts, and mathematics) education and student-maker education so that learners have a strong awareness of information and innovation" [2]. Two years later, in the 2017 Compulsory Primary School Science Curriculum Standard, "technology and engineering" was added to the content of the course, which demonstrates the importance of engineering thinking and the recognition of STEM education.

Additionally, increasing importance is now being placed on humanities and arts education. The study of humanities and arts not only increases the enjoyment of students in STEM programs but also benefits students' comprehensive development. In 2010, Yakman was the first to propose that "A" (referring to the arts as well as to humanities and other subjects) should be incorporated into STEM [3]. The integration of arts subjects with STEM disciplines can better enable students to appreciate various sources of knowledge and the relevance of STEM to human development and culture.

Professional teacher training is essential for implementing and advancing STEAM education. Teacher ability to choose appropriate topics and learning materials is critical to the success of STEAM [4]. Wang et al. discuss many of the difficulties and challenges of K-12 STEM education. One of the main challenges is that few teachers can effectively integrate different disciplines [5]. Teachers often have different understandings of the reasoning for the interdisciplinary integration of STEM. Some teachers think that the focus of curriculum integration is the skill of problem solving, some teachers think that mathematics is only a tool to solve the problems of the other three subjects, and other teachers think that the main benefits of STEM are its real-world applications [5].

In addition to having different understandings of STEM, most teachers lack confidence in their ability to effectively integrate STEM disciplines. In a qualitative study, Chiang and Lyu observed that newly recruited STEM teachers often encounter problems in classroom teaching, teaching management, group cooperation, and teachers' understanding of STEM and evaluation [6]. The management of classroom time and discipline integration were major challenges. Hands-on training and professional development are required to cultivate qualified teachers and effectively integrate STEM [7].

In the United Kingdom, secondary teachers primarily specialize in teaching a single subject, such as science (e.g., physics, chemistry and biology), mathematics, technology, or engineering. Although efforts have been made to integrate these STEM subjects, most school curricula are not integrated, and teachers must prepare to teach the school curriculum. Adding the dimension of "art" would thus be a challenge. Therefore, to develop a better understanding of preservice teachers' perception of STEAM education, the current study focuses on preservice teachers' perception of and attitudes toward discipline integration. The preservice teachers were asked about their perspectives on the development of STEAM education to provide suggestions for policy makers and teacher-training programs.

2. Literature review

2.1. From STEM to STEAM

The American National Science Foundation initially proposed STEM as the aggregation of science, technology, engineering, and mathematics. STEM education enables students to understand the connection between different disciplines in an integrated manner by providing the context of authentic problems. Boy argued that the monolithic nonlinear design of complicated systems must be investigated and tested as a whole, which requires an interdisciplinary approach and fresh conceptual principles and tools in the 21st century. The four subjects that comprise STEM should also be combined with the arts to promote innovation and creativity. This emphasizes the potential benefits obtained over a long-term period rather than short-term financial expectations [8]. Many educators agree that STEM is missing a key component (i.e., art), which warrants renewed attention, enthusiasm, and funding. Science and arts education should be regarded as mutually beneficial [9].

What does "art" mean? Yakman refers to the STEAM Pyramid model, which defines art as "how society develops, impacts, is communicated and understood with its attitudes and customs in the past, present, and future." Specifically, it includes many subjects related to the humanities, such as sociology, education, politics, and philosophy [3]. The term "art" encompasses numerous arts and humanities subjects, including language, social studies, music, fine arts, and performing arts. Art provides an excellent complement to the four disciplines of STEM by strengthening student's understandings and applications of the disciplines. Students can share knowledge more effectively by using language, arts, and communication. Students' understanding of past and present culture, aesthetics, human nature, morals, freedom, and societal development can all be enhanced through the study of art [10].

2.2. Pre-service teachers' perception on STEM education

The literature on STEM teachers' teaching beliefs and practices is primarily divided into that concerning in-service and preservice teachers. The current study focuses on preservice teachers, who are mainly college student-teachers majoring in STEM disciplines.

Numerous studies have investigated student-teachers majoring in science and mathematics. They have observed that preservice science teachers generally have positive opinions on STEM education [11]. Researchers emphasize that STEM is mostly science-oriented and no major differences exist between the views of science and mathematics teachers [12]. Hacioglu et al. investigated preservice science teachers' cognitive structures on STEM and observed that a strong relationship between the preservice teachers' cognitive structures regarding science and science education existed and the relationship between science and other disciplines was weaker [13]. Preservice teachers have varied attitudes toward the five disciplines. Science is concerned with the investigation and comprehension of all events and phenomena in our lives, technology is concerned with electronic tools and their applications to enhance convenience, mathematics is concerned with numbers and operations, and engineering is concerned with machines, construction, and the products of professions related to electronics [13].

To elucidate the perceptions of STEM teachers more intuitively, researchers designed a drawing task. Bybee designed visualization questions to reflect an overall conception and the relationship between the five disciplines [14]. He presented nine perspectives with simple circles and lines, including "STEM means both science and mathematics", "STEM means science and incorporates technology, engineering, or mathematics," "STEM equals a quartet of separate disciplines," and "STEM means science and mathematics are connected by one technology or engineering program" [14]. Based on this research, Radloff and Guzey asked participants to visualize STEM by using the four letters and illustrate how they were connected [15]. Kim and Bolger's research, "webbed," "shared," and "integrated" were the three most commonly selected forms, and among them, 29.8% of the teachers selected the integrated model [16].

Understanding preservice teachers' perception of the character of STEM is crucial. One of the key features of STEM education is integration, particularly the incorporation of engineering with mathematics and science [17–19]. Yildirim and Selvi (2016) reported that preservice teachers have a general perception that STEM education is fun and that it can develop students' imagination, productivity, and psychomotor skills [20]. To fully realize the function of STEAM education and truly develop students' higher abilities, preservice teachers should have content knowledge and pedagogical knowledge related to STEM education planning, teaching instruction, and evaluation, and they should be provided with the necessary resources and materials [11,21–24]. Stolhmann et al. studied middle school STEM teachers of the "Project Lead the Way" to explore factors that must be considered in the integrated training of STEM teachers [22]. The study reported that teachers valued quality teaching methods such as student-led teaching, but in teaching practice, they had difficulties in time management for tasks and effectively guiding students to solve problems. A teacher's sense of efficacy is influenced by their beliefs regarding STEM education, knowledge, background, teacher teamwork, and other factors; therefore, teachers also require content and didactic support [22].

2.3 Differences in student-teacher training between the United Kingdom and China

Huang et al. compared the training model of primary preservice science teachers in teacher colleges in China and the United Kingdom [25]. The objectives of preservice science teachers in primary schools in the United Kingdom were the same as those in China, all of which aimed at enhancing the scientific literacy of teachers and students through scientific inquiry [26]. The objectives of science curriculum standards in primary schools in China are divided into three levels: scientific knowledge and understanding, scientific processes and methods, and scientific attitudes and values. However, the preservice training objectives of science teachers in primary schools are not informed by these goals. The training objectives are overly comprehensive and place greater emphasis on teachers' general administration, teaching, and research skills. They do not particularly relate to the development of scientific literacy.

The United Kingdom provides specialized training for primary and secondary science teachers. Most science teachers graduate from science majors and have higher levels of scientific literacy and specialization [26]. In 2013, a master's degree in science education has been developed at the graduate level in China in addition to along the undergraduate major in educational technology. To train regular students, universities use a combination of subdiscipline and educational expertise. However, graduates from higher institutions in China are permitted to teach science in elementary schools, even though the majority of them lack specialized training. Thus, the quality of scientific teachers in China is generally rather low.

In the United Kingdom, the teacher-training curriculum places a greater emphasis on the value of educational theory, with particular attention placed on how theory and practice may be combined. The teacher program's goal is to develop educators with a solid understanding of science and scientific inquiry. In China, students lack sufficient teaching practice opportunities. For example, the general education courses account for 32.5% of the total credits, but educational internships account for only 3.14% of the total credits. Moreover, the teaching of pedagogical knowledge and subject knowledge is not well integrated.

Overall, broad differences in the teacher training of Chinese and UK preservice teachers exist. Few studies have investigated STEAM teachers in China. Although many international scholars have contributed to this field, international comparisons are rare. This study can complement research findings in STEAM teacher training by focusing on the perceptions and attitudes of preservice teachers.

3. Research design and methods

This study investigated Chinese and UK preservice STEAM teachers' perceptions of STEAM education and make comparisons between China and the United Kingdom. We proposed three research questions:

1. What are Chinese and UK preservice teachers' basic perceptions of STEAM education? (How do visualizations reveal their understanding of the connections among the five disciplines of STEAM education?)
2. What are Chinese and UK preservice teachers' attitudes toward STEAM disciplines and careers in STEAM areas? (Do STEAM dispositions and career interests differ in terms of country, gender, or major?)
3. What other opinions do preservice teachers hold regarding STEAM education? (e.g., what inspired your interest in STEAM? What abilities must teachers have to teach STEAM, and do you have any suggestions for policy makers to develop STEAM education?)

3.1. Participants

The participants in the study were 109 UK preservice STEAM teachers and 379 Chinese preservice STEAM teachers. The Chinese participants were student-teachers from a top teacher-training university, and the UK participants were trained at a top university in the United Kingdom. Table 1 presents the demographic information of the participants.

3.2 Measurement

The research instrument was designed specifically for this study. It comprises five sections (See Appendix). In the first section, we asked about participants' gender, age, educational background, academic degree, teaching experience, willingness to be a teacher in the future, and the subject they want to teach. In the second section, we attempted to answer the first research question by inquiring about participants' conceptions of STEAM, including three multiple-choice questions, one drawing question, and three open questions [15].

In the third section, the STEAM Career Interest Questionnaire (CIQ) was used to analyze participants' career interests [27,28]. The measurement uses a 5-point Likert scale for nine questions. The subscales of the CIQ consisted of education, supports, and career dimensions. Education referred to students' interest in pursuing opportunities that would lead to a career in science (items 1–3), supports referred to the support environment for pursuing a career in science (items 4–6), and career referred to the perceived importance of a career in science (items 7–9). The questionnaire has good reliability with a Cronbach's alpha of 0.878. We also included the STEAM Semantics survey to measure participants' attitudes toward each discipline and STEAM career. It uses a 7-point rating scale for 30 questions. The STEAM Semantics Survey was adapted from the Teachers' Attitude Toward Technology Questionnaire [29], which was derived from an earlier semantic study [30]. The questionnaire was reviewed and revised by three professors from China, United Kingdom, and Canada.

The STEAM CIQ and STEAM semantics survey were used to address the second research question.

Table 1. Description of participants' demographic information

	Descriptions	UK	China
Gender	Male	42 (38.5%)	108 (28.5%)
	Female	65 (59.6%)	269 (71.0%)
	Missing	2 (1.8%)	2 (0.5%)
Age	under 20	0	266 (70.2%)
	21-25	71 (65.1%)	106 (28.0%)
	26-30	17 (15.6%)	1 (0.3%)
	over30	21 (19.3%)	1 (0.3%)
	Missing	0	5 (1.3%)
Education Background	Math	20 (18.3%)	64 (16.9%)
	Science (physics, chemistry, geography, biology)	34 (31.2%)	190 (50.1%)
	Humanities (English, History, Music, Anthropology)	28 (25.7%)	22 (5.8%)
	Education Technology	0	45 (11.9%)
	Computer science	0	52 (13.7%)
	Others	8 (7.3%)	6 (1.6%)
	Missing	19 (17.4%)	0
Teaching experiences	Yes	58 (53.2%)	144 (38.0%)
	No	50 (45.9%)	231 (60.9%)
	Missing	1 (0.9%)	4 (1.1%)
The willingness to be a teacher	Yes	97 (89.0%)	179 (47.2%)
	No	12 (11.0%)	42 (11.1%)
	Haven't decided	0	150 (39.6%)
	Missing	0	8 (2.1%)
The grade you will teach	Primary school	2 (1.8%)	38 (10.0%)
	Secondary school	98 (89.9%)	161 (85.2%)
	Tertiary Education	9 (8.3%)	180 (47.5%)
The subject you will teach	Math	59 (54.1%)	61 (16.1%)
	Science	35 (32.1%)	104 (27.4%)
	Others	15 (13.8%)	214 (56.5%)

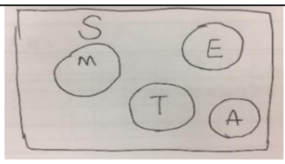
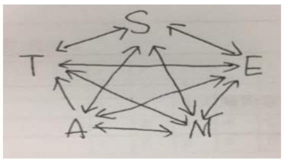
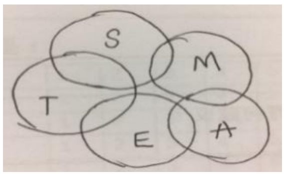
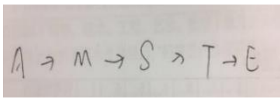
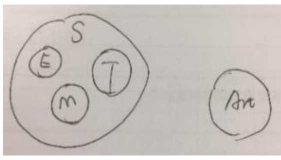
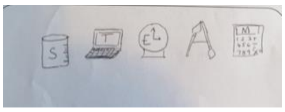
In the fourth section, we asked three open questions to answer the third research question. The first question asked the participants to review their life experience and determine any connections with

STEAM. The second question asked the participants' opinions on the necessary abilities for teaching STEAM. The last question asked participants for suggestions for STEAM education development.

3.3 Data analysis

All answers were initially translated into English and merged into one database. Descriptive statistics, reliability coefficients, correlations, *t*-test, and regression analysis were computed using SPSS Statistics 24.0 (IBM, Armonk, NY, USA).

Table 2. STEAM visualizations and explanations (modified from [31])

Type	Visualization	Explanation
(1) *Nested*		*Nested* visualizations conveyed that STEAM was an overarching discipline comprising five disciplines.
(2) *Interconnected*		*Interconnected* visualizations conveyed that there were connections between each of the five disciplines.
(3) *Overlapping*		*Overlapping* visualizations used a Venn diagram to convey that the disciplines were overlapping.
(4) *Sequential*		*Sequential* visualizations conceived of STEAM as disciplines in a sequence.
(5) *Art independent*		*Art independent* visualizations conveyed that there were connections among STEM's four disciplines, but that art was independent.
(6) *Siloed*		*Siloed visualizations* portrayed the manner in which STEM has been historically taught in schools—in isolation of each other.
(7) *Transdisciplinary*		*Transdisciplinary* visualizations suggested a focus on the real-world, application-based nature of STEM.
(8) *Pot*		*Pot* visualizations compared STEAM education to vapor from a pot.
(9) *Other*		Responses cannot be classified in the above categories.

For the coding of the drawing responses, Radloff and Guzey's code scheme in [15] was used to classify the themes of the drawings. Two experienced researchers coded separately first and reached consensus on the divergent responses through discussion later. Originally, the code scheme contained six types: (a) nested, (b) transdisciplinary, (c) interconnected, (d) sequential, (e) overlapping, and (f) siloed [15]. Li and Chiang [31] conducted a pilot study and reported "art independent" to be a new type. In the current study, we also observed the "art independent" type, which refers to the separation of art from the other STEAM disciplines. We observed a new type named "pot", which indicates the integration of art with other disciplines. Eight STEAM visualizations were observed in total, as presented in Table 2.

4. Results

4.1. Chinese and UK preservice teachers' basic perceptions of STEAM education

Only 21 (19.3%) UK preservice teachers and 48 (12.7%) Chinese preservice teachers have attended lectures or training on the teaching of STEAM in an integrated manner. Most preservice STEAM teachers (over 80%) did not have STEAM lecture experience. The percentage of teachers who have attended lectures in the United Kingdom was higher than that of those in China.

When asked about their degree of interest in STEAM education, 62.3% of UK teachers chose "agree" or "fully agree" and only 36.7% of Chinese teachers chose either of these two answers, whereas 43.8% of Chinese preservice teachers chose "not sure." The average score of preservice teachers in the United Kingdom (mean = 3.71, standard deviation [SD] = 0.958) was higher than that of the Chinese participants (mean = 3.18, SD = 1.023).

4.1.1. Self-reported connectedness of STEAM disciplines

Before visualizing STEAM education, participants were asked how connected they thought STEAM disciplines were on a scale of 1–9 (Table 3). The average scores of the UK (mean = 6.31, SD = 1.686) and Chinese participants (mean = 6.35, SD = 1.483) were similar. The answer 7 was chosen considerably more often than any other answers. A connectedness of 5 or greater was selected by approximately 80% of participants in the United Kingdom and approximately 90% of China. Most of the participants who chose 4 or lower explained that this was because, although STEAM disciplines have many links, they are separate subjects, especially art. Regarding the UK teachers' opinions on art, 76.2% of them regarded it to be unrelated to the other four subjects.

Participants were then asked to explain their choice of number (see Table 4). 64 UK participants and 290 Chinese participants responded to the question. We first classified the responses as either specialized responses, which discussed the relationship between specific subjects, or general responses, which simply stated that STEM disciplines were related. Within the specialized responses, we recorded five perspectives:

(1) Dependent: STEM disciplines were dependent on each other.
(2) Processes: STEM disciplines were connected through thinking processes or skills.
(3) Ranked: STEM disciplines were ranked based on their significance.
(4) Approval of art: The subject "art" is related to the other four disciplines.
(5) Negation of art: The subject "art" is not related to the other four disciplines.

Subtle differences were also observed in the general responses. For example, “Related but unique” indicates that respondents acknowledged the connectedness of the disciplines and could distinguish between disciplines. For example, “They are related in the sense that everything is connected to everything, but it’s a very broad category.”

Finally, some of the answers were vague. An example of a vague response is “in real-world to make innovative ideas”.

Table 3. Perceived connectedness of STEAM disciplines

Scale[a]	# (UK)	%	# (China)	%
9	9	8.3	16	4.2
8	14	12.8	63	16.6
7	29	26.6	132	34.8
6	24	22.0	45	11.9
5	13	11.9	90	23.7
4	7	6.4	14	3.7
3	4	3.7	13	3.4
2	2	1.8	2	.5
1	1	.9	2	.5
Missing	6	5.5	2	.5
Total	109		379	

[a] Scale 1-9； choosing 9 indicates the view that STEAM disciplines are completely connected

Table 4. Conceptual understanding of STEAM connectedness

Theme	Coding frequency	#(UK)	%	#(CHINA)	%
Specialized	Negate art	13	20.3	13	4.5
Specialized	Process	12	18.8	12	4.1
Specialized	Approve art	5	7.8	3	1.0
Specialized	Dependent	2	3.1	9	3.1
Specialized	Ranked	0	0	9	3.1
General	Related	8	12.5	101	34.8
General	Related, but unique	7	10.9	66	22.8
General	Related, process	3	4.7	21	7.2
General	Related, negate art	3	4.7	20	6.9
General	Related, dependent	2	3.1	18	6.2
General	Related, ranked	0	0	15	5.2
General	Unrelated	2	3.1	0	0
Other	Vague	7	10.9	15	5.2
	Total	64		290	

In all, 34.8% of Chinese teachers simply explained their answer with “related”, which indicates that they had only a general understanding of STEAM education and therefore could not describe it precisely. Chinese preservice teachers tended to understand the connectedness of STEAM from the perspective of Laozi (philosopher in the Spring and Autumn Period, founder of Taoism). For example, one participant wrote "Tao gave birth to the One; the One gave birth successively to two things, three things, up to ten thousand. Everything obeys the same rule, so does STEAM education".

4.1.2. Drawing results on the connectedness of STEAM disciplines

Participants were required to illustrate the rationale behind their choices through drawings. In all, 68 responses from UK teachers and 198 responses from Chinese teachers were obtained. Table 5 presents the frequencies of each type of visualization. To analyze preservice teachers' perceptions of the connectedness of STEAM, three themes namely specialized, general, and other were generated from the drawing responses (See Table 4).

Table 5. STEAM visualizations, explanations, frequency, and percentages

Type	#(UK)	%	#(CHINA)	%
(1) Nested	11	16.2	44	22.2
(2) *Interconnected*	6	8.8	61	**30.8**
(3) *Overlapping*	1	1.5	48	24.2
(4) *Sequential*	1	1.5	12	6.1
(5) *Art independent*	7	10.3	21	10.6
(6) *Siloed*	15	**22.1**	0	0
(7) *Transdisciplinary*	11	16.2	0	0
(8) *Pot*	8	11.8	0	0
(9) *Other*	8	11.8	12	6.1
Total	68		198	

Participants were asked to explain the reasoning behind their visualizations (Table 6). Answers such as "there must be some connection between any two subjects" and "these disciplines relate to each other without losing their separate identities" were coded as "related", and these answers accounted for 54% of responses from UK teacher and 52% of responses from Chinese teachers. Moreover, 34.2% of the Chinese teachers explained their visualization with "there is something in common among these five disciplines" to emphasize the interdependency of these disciplines.

Table 6. Preservice teacher rationale of visual representations

Code	#(UK)	%	#(CHINA)	%
Application	2	4.0	0	0
Art independent	2	4.0	31	11.0
Dependent	2	4.0	**96**	**34.2**
Independent	4	8.0	3	1.1
Related	**14**	**28.0**	71	25.3
Related, dependent, ranked	7	14.0	75	26.7
Related ranked	6	12.0	0	0
Vague	7	14.0	0	0
None	6	12.0	5	1.8

4.1.3. Characteristics of STEAM

The participants were asked to write the characteristics of STEAM (Table 7). “Creative” (or related terms such as “innovative”) was the most popular term, which accounted for nearly a quarter of UK preservice teacher responses. Related terms such as “real life situation,” “useful,” or “problem-solving” ranked second. These findings indicate that some teachers comprehended the core concept of STEAM. STEAM education is designed to stimulate students to explore "real problems” (i.e., those that are closely related to life) and to cultivate students' problem-solving abilities and creativity. However, 32.4% of preservice teachers described STEAM in terms of the five disciplines. These findings indicate that the preservice teachers have virtually no understanding of the characteristics of STEAM and that their understanding is based on the individual subjects.

Table 7. Characteristics of STEAM

UK			**China**		
Characteristics	#	%	Characteristics	#	%
Creative	**16**	**22.5**	**Integrated**	**126**	**29.8**
Real life	9	12.7	Practical	59	13.9
Inspiring	6	8.5	Fun	40	9.5
Science	6	8.5	Creative	37	8.7
Art	5	7.0	Professional	37	8.7
Technology	4	5.6	Logical	34	8.0
Engineering	4	5.6	popularize	32	7.6
Math	4	5.6	Scientific	26	6.1
Logical	4	5.6	contemporary	10	2.4
Academic	4	5.6	Knowledgeable	8	1.9
Necessary	3	4.2	Project-based learning	5	1.2
Making	3	4.2	Effective	3	0.7
Other	3	4.2	Other	6	1.4
Total	71 words		Total	423 words	

Regarding the ranking of characteristics, “integrated” was recorded 126 times for Chinese preservice teachers and accounted for 29.8% of all terms. The integration included both the interdisciplinary courses and all-round development of students. The term “practical/useful/real life” ranked second and accounted for 13.9% of all terms; this was similar to the data for the UK teachers. In contrast to the UK teachers, the Chinese preservice teachers used the terms “fun,” “professional,” and “popularize”. Chinese preservice teachers conceptualized STEAM as a vibrant, interesting, and attractive course for primary or middle school students. Teachers used the term “professional” to convey that they had received professional training and high-quality teaching materials. The term “popularize” was used to express that the course was simple, intuitive, and accessible to most students. The frequencies for “logical” and “scientific” were similar among the teachers from the two countries. More UK teachers valued the term “creative” highly than Chinese teachers, which may be a reflection of the differences in education ideology between the two educational systems.

4.2. Chinese and UK preservice teachers' attitudes toward STEAM disciplines and careers in STEAM areas

Mean and SD scale scores for the combined sample of the UK and Chinese preservice teachers are presented in Table 8. No significant differences were observed in the total score of the career interest survey. Chinese preservice teachers obtained significantly higher scores than the UK teachers in every item of the STEAM semantic survey, including those in the science, mathematics, engineering, technology, art, and career domains.

Table 8. Career Interest Questionnaire scales and STEAM semantic survey scales

		N	Mean	Std. dev.	Sig.
Career Interest Questionnaire scales					
Career interest-total scale score	UK	91	3.46	.75	.985
	China	379	3.46	.72	
Career interest – education	UK	99	3.17	1.06	.013*
	China	379	3.44	.92	
Career interest – support	UK	95	3.43	.79	.076
	China	379	3.27	.79	
Career interest – career	UK	97	3.81	.82	.165
	China	379	3.68	.83	
STEAM semantic survey scales					
Science average	UK	92	3.73	.54	.000***
	China	379	5.58	1.07	
Math average	UK	94	4.01	.82	.000***
	China	379	5.10	1.38	
Engineer average	UK	93	4.00	.73	.000***
	China	379	4.62	1.27	
Technology average	UK	90	3.89	.75	.000***
	China	379	5.09	1.26	
Art average	UK	91	3.94	.76	.000***
	China	379	5.80	1.25	
Career average	UK	92	4.08	.80	.000***
	China	379	5.07	1.16	

Note. $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$, same below.

We also performed an independent sample t test to compare the scores between gender and major subgroups. A difference was only observed in the technology average score, which indicated that UK female preservice teachers obtained higher scores than their male counterparts. The Chinese female preservice teachers obtained significantly higher scores than their male counterparts on the items related to art on average (Table 9).

We also observed differences between subgroups categorized by major. UK preservice teachers who majored in science obtained significantly higher scores in the education and support dimensions of the career interest scale than did those studying other majors. In the STEAM semantic survey, students who majored in mathematics expressed relatively positive attitudes toward science, technology, art, and career interest. Students who majored in science obtained low scores in science and high scores in art. Similarly, students who majored in arts obtained high scores in science and low scores in art (Table 10).

Table 9. Analysis by gender for career interest and semantic survey in United Kingdom and China

		UK				China			
		N	Mean	SD	Sig.	N	Mean	SD	Sig.
Career Interest Questionnaire scales									
Career interest-total scale score	Male	34	3.43	.90	.686	108	3.51	.74	.273
	Female	55	3.49	.65		269	3.45	.71	
Career interest – education	Male	39	3.21	1.12	.842	108	3.52	.97	.645
	Female	58	3.16	1.03		269	3.41	.90	
Career interest – supports	Male	36	3.36	.90	.467	108	3.30	.77	.794
	Female	57	3.49	.73		269	3.26	.80	
Career interest – career	Male	36	3.83	.99	.835	108	3.70	.84	.462
	Female	59	3.80	.71		269	3.67	.82	
STEAM semantic survey scales									
Science average	Male	35	3.59	.45	.070	108	5.67	1.11	.292
	Female	55	3.80	.56		269	5.54	1.05	
Math average	Male	35	4.17	.96	.152	108	5.24	1.32	.226
	Female	57	3.92	.73		269	5.05	1.40	
Engineer average	Male	35	3.83	.69	.086	108	5.15	1.42	.524
	Female	56	4.11	.75		269	5.06	1.18	
Technology average	Male	34	3.69	.59	.044*	108	4.74	1.41	.241
	Female	54	4.02	.82		269	4.57	1.21	
Art average	Male	35	3.89	.78	.783	108	5.26	1.54	.000***
	Female	54	3.94	.74		269	6.02	1.04	
Career average	Male	34	4.16	1.01	.497	108	4.99	1.31	.356

Because approximately 50% of the participants were majoring in science, we differentiated the science majors and performed post hoc analysis. As presented in Table 11, the total career interest scores of participants who majored in science and technology education were significantly higher than those of the participants who majored in biology (p = .03) and education technology (p = .028). The scores of preservice teachers who majored in education technology were significantly lower than those of teachers who majored in mathematics (p = .004) and science and technology education (p =.019) in part 1 of the career interest scale. Participants who majored in physics and astronomy obtained significantly higher scores than did the participants who majored in computer science (p = .024; p = .017, respectively) and education technology (p = .016; p = .013, respectively).

Participants who majored in mathematics obtained higher scores than those who majored in biology (p = .041), chemistry (p = .001), computer science (p = .017), and geography (p = .011). Significant differences were also observed between the scores of those who majored in astronomy and in education technology (p = .013). Preservice teachers who majored in physics obtained both higher technology average scores (p = .037) and career average scores (p = .034) than those who majored in education technology.

We predicted the career interest of participants by analyzing the STEAM semantic disposition findings. Only career average scores significantly predicted career interest (Table 12). Career semantic disposition explained 33.2% of the variance of the career interest.

Table 10. Analysis by major for semantic survey in the United Kingdom

		N	Mean	Std. dev.	Sig.
Career interest-total scale score	Math	15	3.34	.52	.003**
	Science	30	3.81	.69	
	Humanity and Arts	25	3.16	.86	
	Other	8	2.97	.50	
Career interest – education	Math	18	3.11	1.00	.002**
	Science	31	3.69	.93	
	Humanity and Arts	26	2.82	1.03	
	Other	8	2.42	1.15	
Career interest – support	Math	17	3.33	.59	.011*
	Science	30	3.72	.69	
	Humanity and Arts	25	3.27	.93	
	Other	8	2.75	.79	
Career interest – career	Math	17	3.80	.59	.129
	Science	31	3.99	.76	
	Humanity and Arts	26	3.46	1.04	
	Other	8	3.75	.66	
STEAM semantic survey scales					
Science average	Math	16	3.76	.46	<.001***
	Science	27	3.52	.35	
	Humanity and Arts	27	3.84	.49	
	Other	7	4.37	.78	
Math average	Math	16	4.36	1.31	.165
	Science	28	3.81	.52	
	Humanity and Arts	27	3.99	.58	
	Other	8	4.02	.69	
Technology average	Math	15	3.96	.84	.035*
	Science	27	3.70	.56	
	Humanity and Arts	27	3.92	.65	
	Other	7	4.43	1.49	
Engineering average	Math	15	4.29	.82	.169
	Science	28	3.75	.61	
	Humanity and Arts	27	4.02	.70	
	Other	8	4.50	1.10	
Art average	Math	14	4.41	1.00	.043*
	Science	28	3.99	.73	
	Humanity and Arts	27	3.73	.73	
	Other	7	3.63	.56	
Career average	Math	15	4.65	1.19	.002**
	Science	27	3.75	.61	
	Humanity and Arts	27	3.86	.64	
	Other	8	4.28	.58	

Table 11. Analysis by major for career interest and semantic survey in China

		N	Mean	Std. dev.	Sig.
Career interest-total scale score	Biology	68	3.29	.67	.008**
	Physics	36	3.60	.77	
	Chemistry	31	3.49	.70	
	Math	63	3.60	.76	
	Computer science	52	3.52	.70	
	Science and Technology Education	20	3.90	.53	
	Astronomy	17	3.48	.97	
	Geography	38	3.30	.58	
	Education Technology	25	3.38	.60	
	Other	29	3.18	.76	
Career interest – education	Biology	68	3.23	.81	<.001***
	Physics	36	3.67	.95	
	Chemistry	31	3.46	.90	
	Math	63	3.72	.96	
	Computer science	52	3.54	.95	
	Science and Technology Education	20	3.90	.76	
	Astronomy	17	3.51	1.19	
	Geography	38	3.17	.65	
	Education Technology	25	3.31	.63	
	Other	29	2.89	1.07	
Career interest – support	Biology	68	3.10	.78	.132
	Physics	36	3.30	.84	
	Chemistry	31	3.20	.88	
	Math	63	3.42	.78	
	Computer science	52	3.33	.76	
	Science and Technology Education	20	3.67	.67	
	Astronomy	17	3.25	.80	
	Geography	38	3.24	.69	
	Education Technology	25	3.24	.75	
	Other	29	3.03	.91	
Career interest – career	Biology	68	3.55	.78	.243
	Physics	36	3.85	.87	
	Chemistry	31	3.81	.73	
	Math	63	3.66	.87	
	Computer science	52	3.69	.82	
	Science and Technology Education	20	4.12	.66	
	Astronomy	17	3.67	1.12	
	Geography	38	3.51	.74	
	Education Technology	25	3.60	.67	
	Other	29	3.62	.96	
STEAM semantic survey scales					
Science average	Biology	68	5.69	.98	<.001***
	Physics	36	6.06	1.03	
	Chemistry	31	5.63	1.05	
	Math	63	5.51	.98	
	Computer science	52	5.28	1.08	
	Science and Technology Education	20	5.87	.82	
	Astronomy	17	6.31	.83	
	Geography	38	5.41	.84	

	Education Technology	25	5.30	1.40	
	Other				
Math average	Biology	68	5.10	1.21	<.001***
	Physics	36	5.36	1.36	
	Chemistry	31	4.64	1.52	
	Math	63	5.86	1.02	
	Computer science	52	4.99	1.47	
	Science and Technology Education	20	5.42	1.09	
	Astronomy	17	4.94	1.04	
	Geography	38	4.87	1.32	
	Education Technology	25	4.89	1.42	
	Other	29	4.16	1.73	
Technology average	Biology	68	5.09	1.20	.027*
	Physics	36	5.48	1.20	
	Chemistry	31	5.14	1.06	
	Math	63	4.99	1.36	
	Computer science	52	5.11	1.19	
	Science and Technology Education	20	5.63	.93	
	Astronomy	17	4.96	1.41	
	Geography	38	5.26	.89	
	Education Technology	25	4.85	1.55	
	Other	29	4.39	1.53	
Engineering average	Biology	68	4.46	1.20	.024*
	Physics	36	4.95	1.33	
	Chemistry	31	4.49	1.28	
	Math	63	4.64	1.29	
	Computer science	52	4.50	1.16	
	Science and Technology Education	20	5.13	.75	
	Astronomy	17	4.98	1.38	
	Geography	38	4.68	1.20	
	Education Technology	25	4.93	1.27	
	Other	29	3.93	1.54	
Art average	Biology	68	5.83	1.24	.888
	Physics	36	5.54	1.45	
	Chemistry	31	5.85	1.23	
	Math	63	5.87	1.24	
	Computer science	52	5.78	1.21	
	Science and Technology Education	20	5.76	1.05	
	Astronomy	17	5.74	1.65	
	Geography	38	6.05	.80	
	Education Technology	25	5.85	1.33	
	Other	29	5.57	1.43	
Career average	Biology	68	4.83	1.19	.001***
	Physics	36	5.48	1.19	
	Chemistry	31	5.26	.88	
	Math	63	5.32	1.12	
	Computer science	52	4.84	1.10	
	Science and Technology Education	20	5.62	.68	
	Astronomy	17	5.25	1.48	
	Geography	38	5.10	.91	
	Education Technology	25	4.90	1.42	
	Other	29	4.46	1.30	

Table 12. Model significance for STEAM semantic disposition measures predicting career interest (China)

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	1.676	.209		8.002	<.001
Science	.033	.035	.048	.939	.348
Math	-.007	.024	-.013	-.271	.787
Technology	-.044	.034	-.077	-1.308	.192
Engineering	.044	.031	.077	1.407	.160
Art	-.024	.026	-.042	-.930	.353
Career	.354	.032	.574	11.026	<.001

4.3. What other opinions preservice teachers hold regarding STEAM education

We divided the major reasons for being interested in STEAM education into three categories. The first one was that they were skilled at (or enjoyed) mathematics or science. The second reason was the influence of their teachers and families. When the participants had dedicated teachers and parents who worked in related fields, participants were more likely to be interested in STEAM. The third reason was related to the character of STEAM. Participants wrote that “it is interesting and useful to humankind” or that they were interested in “investigation, discovery, rigor of questions at a young age”, which indicate that the nature of STEAM education was attractive to the participants.

The participants were asked to report the qualities that they believe to be necessary for teaching STEAM. We classified the answers into 15 types (Table 13). Approximately 30% of UK preservice teachers reported that “innovation ability” is a quality that STEAM teacher must possess; this differs from the answers of Chinese teachers. The top three necessary abilities reported by UK preservice teachers were “innovation ability”, “having comprehensive knowledge”, and “logic thinking ability”, whereas for the Chinese participants these were “having comprehensive knowledge”, “professional knowledge”, and “integrate interdisciplinary knowledge”. Both preservice teachers in the United Kingdom (21.5%) and China (24.3%) recognized that “having comprehensive knowledge” is helpful to teaching.

Regarding the participants’ suggestions on developing STEAM education for policy makers, we combined the answers from the United Kingdom and China and observed eight primary suggestions. These can be classified into four suggestions for universities and teachers. From the perspective of national education policy formulation, promoting STEAM education in primary and secondary schools, increasing financial support, reforming test-oriented evaluation, and learning from other countries where STEAM education is well-developed were all reported as effective methods for developing STEAM education. As for universities, who are primarily responsible for STEAM teacher training, they should establish interdisciplinary education major and develop online training courses for both preservice and in-service teachers. Furthermore, they should cooperate with primary and secondary schools to perform educational research. Teachers should enhance the integration of disciplines in their daily teaching and ensure that STEAM courses are fun and stimulate students’ interest in learning.

Table 13. Preservice Teachers' Reporting on STEAM Teachers' Abilities

Codes	#(UK)	%	#(China)	%
1. Have comprehensive knowledge	**17**	**15.6**	**92**	**24.3**
2. Professional knowledge	8	7.3	**42**	**11.1**
3. Integrate interdisciplinary knowledge	2	1.8	29	7.7
4. Innovation ability	**23**	**21.1**	28	7.4
5. Be an interesting teacher	1	0.9	19	5.0
6. Logic thinking ability	**10**	**9.2**	17	4.5
7. Communication ability	5	4.6	14	3.7
8. Teaching skills	2	1.8	9	2.4
9. Practical ability	0	0.0	8	2.1
10. Make connections between knowledge and real life	2	1.8	2	0.5
11. Problem solving skills	6	5.5	1	0.3
12. Determined	4	3.7	0	0
13. Patience	3	2.8	0	0
14. Open attitude	2	1.8	0	0
15. No idea	1	0.9	35	9.2
16. Missing	23	21.1	83	21.9
17. Total	109		379	

5. Discussion

This study investigated Chinese and UK preservice teachers' perceptions of STEAM education and their desire to pursue STEAM careers. Teachers' perceptions of STEAM education may influence their attitudes toward STEAM disciplines, which may influence their future career interest in STEAM. Their responses regarding which teaching abilities they regard as necessary may also influence their career interests. We proposed the model illustrated in Figure 1 to summarize the main findings of this study. Most Chinese preservice teachers perceived of STEAM education as one area of study comprising integrated disciplines. They obtained higher scores on the STEAM Semantics survey, which indicates that they had positive attitudes toward STEAM disciplines. Most Chinese preservice teachers regarded comprehensive and professional knowledge to be the most important ability in STEAM teaching. Most UK preservice teachers regarded STEAM education to be a grouping of independent disciplines, and they obtained lower scores on the semantic survey, which indicates a somewhat positive attitude toward STEAM disciplines. UK preservice teachers emphasized the necessity of innovation ability and comprehensive knowledge in STEAM teaching. For future careers as STEAM teachers, both Chinese and UK preservice teachers obtained high scores on perceived environmental support and the importance of STEAM, and Chinese preservice teachers obtained higher scores in the education dimension, which was related to interest in pursuing opportunities that may lead to a career in STEAM.

This study noted that both UK and Chinese preservice teachers required further training opportunities in STEAM education because more than 80% of the participants had never attended training or lectures on STEAM education. The average score in the perceived connectedness of STEAM disciplines was approximately 6.3, which indicates that most preservice teachers consider the five subjects to be related. Participants were also asked to explain their choice, and most participants explained their choice in general terms rather than providing detailed explanations. These results indicate that the preservice teachers had a relative superficial understanding of STEAM education [32]. Most participants did not have an in-depth understanding of the relationships between the subjects, educational objectives, and pedagogies.

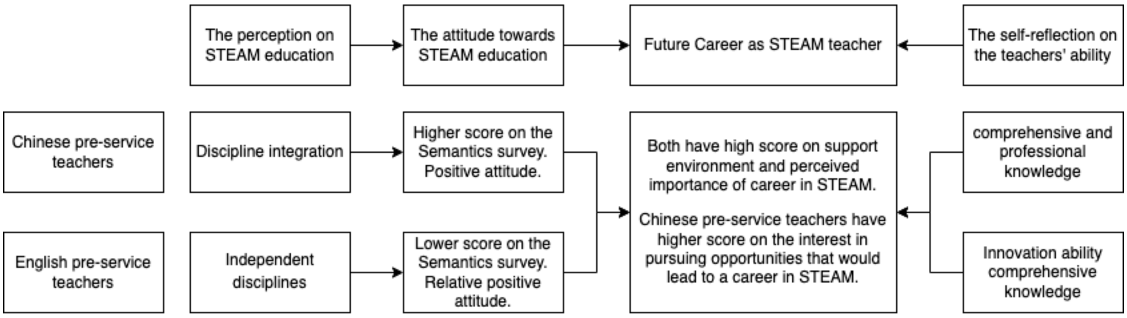


Figure 1. The perceptions, attitudes, future career interest, and reflected teaching ability in STEAM education of Chinese and UK preservice teachers

Participants were asked to define STEAM by drawing a visualization using the letters S-T-E-A-M. Our findings were partially consistent with those reported in [14] using theoretical visualizations and the outcomes reported in [15]. “Pot” and “art independent” are two new types of visualization identified in this study. Chinese preservice teachers’ responses were primarily categorized as interconnected (30.8%), nested (22.2%), or overlapping (24.2%). Conversely, the responses of 22% of UK teachers were categorized as belonging to the “siloed” type, and they used “science”, “technology”, “engineering”, “art”, and “mathematics”, which accounted for 32.3% of descriptions of STEAM education. These results indicate that Chinese preservice teachers focused more on discipline integration, whereas UK teachers were more inclined to view the five disciplines as being independent from each other.

We also observed that the inclusion of art in STEAM education was questioned by both Chinese and UK preservice teachers. Teachers who exhibited lower scores on the connection of the five disciplines argued that art was not related to the other four disciplines. More UK preservice teachers think art education should taught separately to the STEM disciplines. In the drawing question, approximately 10% of the teachers conveyed the separation of art from the other subjects; this constituted the new “art independent” type. This finding reflects the different understandings of STEAM education held by the preservice teachers. This finding is also consistent with the research reported in [5] that teachers have different understandings of STEM interdisciplinary integration. Therefore, it is imperative to provide systematic and standardized training for STEAM teachers so that teachers understand the importance of art to STEAM education.

The semantic questionnaire was used to measure the attitudes of the participants to the five disciplines and to STEAM careers. Chinese preservice teachers scored significantly higher in each discipline than their counterparts in the United Kingdom did, which indicates that Chinese preservice teachers had a more positive attitude toward STEAM education. We also observed significant differences in results dependent on the gender and major of the participants. Female preservice teachers’ technology average scores were higher than those of men. Chinese women’s average scores in art were higher than those of their male peers. UK preservice teachers who majored in science (e.g., physics, chemistry, biology, and geography) scored lower on science and scored higher in the arts than those who majored in the humanities (e.g., foreign language, history, and philosophy) did. The Chinese participants who majored in astronomy and physics had higher score in science and technology, and participants who majored in mathematics had the highest score in mathematics.

Finally, no significant differences in the total scores in the CIQ were observed between the UK and Chinese participants. In the supports and career dimension of CIQ, Chinese preservice teachers obtained higher scores in the education dimension, which indicated interest in pursuing opportunities that would lead to a career in science. Chinese parents perceive mathematics as a skill that can be improved with appropriate support and practice. They care about students' performance in mathematics, science, and engineering, and strongly encourage students to select a major in one of these areas. This attitude has a positive impact on students' attitudes toward mathematics [33]. We also observed that Chinese students majoring in science and technology obtained higher scores in the education dimension. Chinese preservice teachers majoring in science and technology education obtained significantly higher scores in the career interest survey. The Science and Technology Education program in China aims to train teachers for primary science and secondary technology classes. Because this major is science-related, the participants tended to have a relatively positive attitude.

6. Conclusions

The current study constitutes a major contribution to the STEAM education field. First, the comparison between Chinese and UK preservice teachers revealed similarities and differences in their understandings of STEAM education. Second, the detailed description of preservice teachers' perceptions may benefit both local teacher-training programs and international STEAM teacher development and certification. Teacher training is essential for promoting the development of STEAM education. To attract more talent in this field, teacher training requires the combined effort of both governments and universities.

Education policymakers should provide strong policy and financial support for the development of STEAM education. Although the Chinese government has clearly expressed their desire to develop STEAM education in numerous policy documents, more practical teacher-training programs should be established. The United Kingdom established the National STEM Learning Center to support STEM education with thousands of curriculum-related resources. They provide free online courses and in-person workshops for teachers to develop their planning, teaching, learning assessment, and policy skills. However, the center has not yet included art as part of its objectives for STEM learning.

Most STEAM teachers are trained through university programs. For student-teachers, colleges, and universities should provide a master's degree in science education and establish sound curricula that also include art. For teachers who are already engaged in teaching, universities should develop STEAM training online courses as professional development packages to allow them to transition to roles as professional STEAM teachers and master the required knowledge, teaching strategies, teaching methods, and evaluation methods. Notably, integrated teacher education programs can improve the attitudes of preservice mathematics and science teachers toward mathematics and science integration when compared with those of teachers who attended departmentalized programs [16,34].

Future STEAM teachers must gain an understanding of the core of STEAM education. Through the use of diverse teaching methods, they should familiarize themselves with the ultimate goal of

STEAM education. If discipline integration is a primary characteristic of STEAM education, teachers must consider how to integrate different subjects in their daily teaching. For example, to increase students' interest in STEAM lessons and to promote their appreciation of its integration of disciplines, teachers must consider how to design STEAM lessons that appeal to students by implementing both applied traditional teaching methods. The quality of STEAM education is primarily determined by the quality of schoolteachers. Thus, both preservice and in-service teachers should be encouraged to study and work in a manner that reflects the core values of STEAM education.

This study has some limitations. First, the Chinese participants were enrolled in highly ranked teacher-training universities and the UK participants were enrolled in a teacher-training program of a top university. The sample of the current study only represents a specific population rather than all preservice teachers in China and the United Kingdom. Therefore, researchers must be cautious when generalizing these results to other contexts. Second, the questionnaire included many open-ended questions, and we performed quantitative analyses to investigate the responses. To explore the nuances of the participants' perceptions and causes of the differences between Chinese and UK preservice teachers, qualitative methods such as focus group interviews should be used.

Conflict of interests

We declared that there were no conflict of interests.

References

1. Lacey, T.A. and Wright, B., Occupational employment projections to 2018. *Monthly Labor Review,* 2009, 132(11): 82–123.
2. Ministry of Education, China (2015). Notice of the General Office of the Ministry of Education on Soliciting Opinions on the Guiding Opinions on Comprehensively Promoting the Work of Educational Informatization during the 13th Five Year Plan Period. Retrieved September 02, 2015, from http://www.moe.gov.cn/srcsite/A16/s3342/201509/t20150907_206045.html
3. Yakman, G., What is the point of STEAM? A Brief Overview. Steam: A Framework for Teaching Across the Disciplines. *STEAM Education,* 2010, 7: 3–7.
4. Son, Y., Jung, S., Kwon, S., Kim, H. and Kim, D., Analysis of prospective and in-service teachers' awareness of STEAM convergent education. *Institute for Humanities and Social Sciences,* 2012, 13(1): 255–284 [in Korean]. https://doi.org/10.15818/ihss.2012.13.1.255
5. Wang, H.H., Moore, T.J., Roehrig, G.H. and Park, M.S., STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER),* 2011, 1(2), 2.
6. Chiang, F.K., Lyu, Q.R., A Pilot Study of STEM Teachers' Teaching Reflection in an Elementary School. *Open Education Research,* 2017, 23(3), 80–86. [in Chinese]
7. Nowikowski, S.H., Successful with STEM? A qualitative case study of pre-service teacher perceptions. *The Qualitative Report,* 2017, 22(9): 2312–2333. Retrieved from: https://search.proquest.com/docview/1938994712?accountid=8554
8. Boy, G.A., From STEM to STEAM: toward a human-centred education, creativity & learning thinking. *Proceedings of the 31st European conference on cognitive ergonomics,* 2013, 1–7. https://doi.org/10.1145/2501907.2501934

9. Pomeroy, S.R., From STEM to STEAM: Science and Art Go Hand-in-Hand, 2014. Retrieved from: https://blogs.scientificamerican.com/guest-blog/from-stem-to- steam-science-and-the-arts-go-hand-in-hand/
10. Zhao, H.C. and Lu, X.T., Carrying out Steam Education to Improve Students' Creative Ability - An Interview with Prof. Yakman, G, a Famous American Steam Education Scholar. *Open Education Research,* 2016, 22(5): 4–10 [in Chinese].
11. Erdogan, I. and Ciftci, A., Investigating the Views of Pre-Service Science Teachers on STEM Education Practices. *International Journal of Environmental and Science Education,* 2017, 12(5): 1055–1065.
12. Cinar, S., Pirasa, N. and Sadoglu, G.P., Views of Science and Mathematics Pre-Service Teachers Regarding STEM. *Universal Journal of Educational Research,* 2016, 4(6), 1479–1487. https://doi.org/10.13189/ujer.2016.040628
13. Hacioglu, Y., Yamak, H. and Kavak, N., Pre-service science teachers' cognitive structures regarding science, technology, engineering, mathematics (STEM) and science education. *Journal of Turkish Science Education,* 2016, 13: 88–102.
14. Bybee, R., *The case of STEM education: challenges and opportunities*. NSTA Press, Arlington, 2013.
15. Radloff, J. and Guzey, S., Investigating preservice stem teacher conceptions of stem education. *Journal of Science Education & Technology,* 2016, 25: 1–16. https://doi.org/10.1007/s10956-016-9633-5
16. Kim, D. and Bolger, M., Analysis of Korean elementary pre-service teachers' changing attitudes about integrated steam pedagogy through developing lesson plans. *International Journal of Science & Mathematics Education,* 2017, 15(4): 1–19. https://doi.org/10.1007/s10763-015-9709-3
17. Roehrig, G.H., Moore, T.J., Wang, H. and Park, M.S., Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics,* 2012, 112(1): 31–44. https://doi.org/10.1111/j.1949-8594.2011.00112.x
18. Baxter, J.A., Ruzicka, A., Beghetto, R.A. and Livelybrooks, D., Professional development strategically connecting mathematics and science: the impact on teachers' confidence and practice. *School Science and Mathematics,* 2014, 114(3): 102–113. https://doi.org/10.1111/ssm.12060
19. Yoon, S.Y., Dyehouse, M., Lucietto, A.M., Diefes-Dux, H.A. and Capobianco, B.M., The effects of integrated science, technology, and engineering education on elementary students' knowledge and identity development. *School Science and Mathematics,* 2014, 114(8): 380–391. https://doi.org/10.1111/ssm.12090
20. Yildirim, B. and Selvi, M., Examination of the effects of STEM education integrated as a part of science, technology, society and environment courses. *Journal of Human Sciences,* 2016, 13(3): 3684–3695. https://doi.org/10.14687/jhs.v13i3.3876
21. Gonzalez, H.B. and Kuenzi, J.J., *Science, technology, engineering, and mathematics (STEM) education: A primer.* Congressional Research Service, Library of Congress, 2012.
22. Stohlmann, M., Moore, T.J. and Roehrig, G.H., Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER),* 2012, 2(1): 28–

34. https://doi.org/10.5703/1288284314653
23. Corlu, M.S., Capraro, R.M. and Capraro, M.M., Introducing STEM education: implications for educating our teachers for the age of innovation. *Education and Science,* 2014, 39(171): 74–85.
24. Kennedy, T.J. and Odell, M.R.L., Engaging Students in STEM Education. *Science Education International,* 2014, 25(3), 246–258.
25. Huang H.X., Gong D.J., Qin L.Y. and Wang F., A Comparative Study on Pre-service Cultivation Modes of Primary Science Teachers in Chinese and English Universities. *New Curriculum Research: Teacher Education,* 2011, 3*:* 52–54 [in Chinese].
26. OFSTED, Science in Primary Initial Teacher Training, 2002. Retrieved from: http://www.ofsted.gov.uk/Publications
27. Christensen, R., Knezek, G. and Tyler-Wood, T., Student perceptions of science, technology, engineering and mathematics (stem) content and careers. *Computers in Human Behavior*, 2014, 34(34): 173–186. https://doi.org/10.1016/j.chb.2014.01.046
28. Oh, Y.J., Jia, Y., Lorentson, M. and Labanca, F., Development of the educational and career interest scale in science, technology, and mathematics for high school students. *Journal of Science Education & Technology*, 2013, 22(5): 780–790. https://doi.org/10.1007/s10956-012-9430-8
29. Knezek, G. and Christensen, R., Internal consistency reliability for the teachers' attitudes toward information technology (TAT) questionnaire. *In Proceedings of the Society for Information Technology in Teacher Education Annual Conference,* 1998, 831–836.
30. Zaichkowsky, J.L., Measuring the involvement construct. *Journal of Consumer Research,* 1985, 12(3): 341–352. https://doi.org/10.1086/208520
31. Li, W. and Chiang, F.K., Preservice teachers' perceptions of STEAM education and attitudes toward STEAM disciplines and careers in China. In *Critical, transdisciplinary and embodied approaches in STEM education,* 2019, 83–100. Springer, Cham. https://doi.org/10.1007/978-3-030-29489-2_5
32. Bartels, S.L., Rupe, K.M. and Lederman, J.S., Shaping preservice teachers' understandings of STEM: A collaborative math and science methods approach. *Journal of Science Teacher Education,* 2019, 30(6): 666–680. https://doi.org/10.1080/1046560X.2019.1602803
33. Mok, A., "It's a Skill That Can Be Trained": How Chinese Parents View Mathematics and What This Means. *New Zealand Journal of Educational Studies,* 2020, 55(1): 73–89. https://doi.org/10.1007/s40841-020-00154-4
34. Corlu, M., *A pathway to STEM education: Investigating pre-service mathematics and science teachers at Turkish universities in terms of their understanding of mathematics used in science* Doctoral dissertation, Texas A & M University, 2012.

Appendix

Pre-service Teachers' perception of STEAM education

This survey aims to explore pre-service teachers' views of teaching STEAM subjects in an integrated way. This is part of a comparative study with pre-service teachers from China, where online courses for teaching integrated STEAM are being developed.

Instructions: Please indicate your opinion about each statement by circling the appropriate response or filling the blanks. There are no right or wrong answers. Your responses are confidential and will help to build the STEAM online course for teachers. Thank you very much.

1. Demographics

(1) Sex:【Male Female】 (2) Age:【under 20 21-25 26-30 over30】

(3) Education Background__________________

(4) Academic degree【B.A. or B.Sc. M.A. or M.Sc. Ph.D. Other】

(5) Have you had any teaching experience before? 【Yes No】

If yes, please give more details____

(6) Will you be a teacher after graduation? 【Yes No Haven't decided】

(If yes, answer the question (7) and (8), otherwise turn to the second part

(7) Where will you teach after graduation? 【Primary school Secondary school Tertiary Education】

(8) Which subject(s) will you teach? ________________

2.Pre-service Teachers' conception of STEAM

(1) I have attended lectures or training about teaching STEAM in an integrated way. 【YES NO】

(2) I am interested in STEAM. 【Fully disagree Disagree Not sure Agree Fully agree 】

(3) How related to one another do you perceive STEAM disciplines to be? Please choose a number from 1 to 9. "1" means complete independent, "9" means fully related. 【1 2 3 4 5 6 7 8 9】

(4) Why did you pick that answer (e.g. How are they related to one another or not).

____

(5) Please visualize STEAM in your mind and draw a diagram how you visualize it using the letter S-T-E-A-M, as well as how they are connected.

(6) Why did you draw it this way?

____

(7) Please write down the characteristics about STEAM

____

3. STEAM Career interest questionnaire

1= Fully disagree 2=Disagree 3=Not sure 4=Agree 5=Fully agree

(1)I would like to have a career in STEAM	1	2	3	4	5
(2) My family has encouraged me to study STEAM.	1	2	3	4	5
(3) My family has encouraged me to have a career in STEAM.	1	2	3	4	5
(4) I will work in a region where there is a shortage of STEAM professionals.	1	2	3	4	5
(5) I will have a successful professional career and make substantial contributions for STEAM.	1	2	3	4	5
(6) Some day when I tell others about my career, they will respect me for working in the STEAM area.	1	2	3	4	5
(7) A career in STEAM would enable me to work with others in meaningful ways.	1	2	3	4	5
(8) People who work in the STEAM area make a meaningful difference in the world.	1	2	3	4	5
(9) Having a career in science would be challenging.	1	2	3	4	5

4. Other opinions about STEAM education

(1) Please look back your experience of learning or living a life, and what made you start being interested in STEAM?

____

____

____

(2) What kind of abilities do you think are necessary for STEAM teachers?

____

____

____

(3) What suggestions do you have for our country to develop STEAM education?

____

____

____

STEAM Semantics survey

This six part questionnaire is designed to assess your perceptions of STEAM. Usually it is best to respond with your first impression without giving it much thought. Please choose one number between each adjective pair to indicate how you feel about the object.

To me, SCIENCE is

1	Fascinating	1	2	3	4	5	6	7	Mundane
2	Appealing	1	2	3	4	5	6	7	Unappealing
3	Exciting	1	2	3	4	5	6	7	Unexciting
4	Means nothing	1	2	3	4	5	6	7	Means a lot
5	Boring	1	2	3	4	5	6	7	Interesting

To me, MATHS is

1	Boring	1	2	3	4	5	6	7	Interesting
2	Appealing	1	2	3	4	5	6	7	Unappealing
3	Fascinating	1	2	3	4	5	6	7	Mundane
4	Exciting	1	2	3	4	5	6	7	Unexciting
5	Means nothing	1	2	3	4	5	6	7	Means a lot

To me, ENGINEERING is

1	Appealing	1	2	3	4	5	6	7	Unappealing
2	Fascinating	1	2	3	4	5	6	7	Mundane
3	Means nothing	1	2	3	4	5	6	7	Means a lot
4	Exciting	1	2	3	4	5	6	7	Unexciting
5	Boring	1	2	3	4	5	6	7	Interesting

To me, TECHNOLOGY is

1	Appealing	1	2	3	4	5	6	7	Unappealing
2	Means nothing	1	2	3	4	5	6	7	Means a lot
3	Boring	1	2	3	4	5	6	7	Interesting
4	Exciting	1	2	3	4	5	6	7	Unexciting
5	Fascinating	1	2	3	4	5	6	7	Mundane

To me, ART is

1	Means nothing	1	2	3	4	5	6	7	Means a lot
2	Fascinating	1	2	3	4	5	6	7	Mundane
3	Appealing	1	2	3	4	5	6	7	Unappealing
4	Exciting	1	2	3	4	5	6	7	Unexciting
5	Boring	1	2	3	4	5	6	7	Interesting

To me, a CAREER in STEM is

1	Means nothing	1	2	3	4	5	6	7	Means a lot
2	Boring	1	2	3	4	5	6	7	Interesting
3	Exciting	1	2	3	4	5	6	7	Unexciting
4	Fascinating	1	2	3	4	5	6	7	Mundane
5	Appealing	1	2	3	4	5	6	7	Unappealing

Author's biography

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