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Original Paper

Stereotypical Images of STEM Professionals and STEM Career Interests in Chinese Elementary School Students

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Abstract

This study investigated stereotypical images of STEM professions and STEM career interest in Chinese elementary school students. The relationships between stereotypical images of STEM professionals and STEM career interests were also determined. Data for this study was gathered from two elementary schools in China, forming a convenience sample of 318 students enrolled from 3rd to 6th grade. Quantitative data of stereotypes about STEM professionals' social skills, positive images of STEM professionals, views on STEM implications for society, and STEM career interests were gathered by a questionnaire with Likert scale. Follow-up structured interviews were performed with 12 participants. Elementary school students had strong stereotypes about STEM professionals' social skills, slightly deep positive image of STEM professionals, and very positive views on STEM implications for society. However, their STEM career interests were not very high. Besides, elementary school students' stereotypes about STEM professionals' social skills have minor negative effects on their STEM career interests. Their positive image of STEM professionals and views on STEM implications for society have significant correlation with their STEM career interests.

Keywords

Stereotypical images, STEM professionals, STEM career interests, Chinese, Elementary school students

1. Introduction

Science, technology, engineering, and mathematics (STEM) careers are careers related to science, technology, engineering and mathematics (Blotnicky et al., 2018). With the development of science and technology, high-level and high-quality STEM talents have been increasingly demanded. The number of STEM jobs is increasing year by year. Although many countries take a large effort to STEM

education, they are facing problems about shortage of STEM professionals. Students' decline in enrolments and lack of interest or aspirations in STEM careers have been getting attention worldwide (Macisaac, 2019; Wang & Degol, 2017). Students' interests of STEM careers can reflect their expectations for future careers and affect their career as well as major choices (Kidd & Naylor, 1991). To inspire more students to pursue career paths in STEM, positively influencing their interests of STEM careers is very important (Salehjee & Watts, 2015; Wang & Degol, 2017).

1.1 STEM Career Interests

STEM career interests are very important for individuals to choose STEM careers. In general, students with more positive views of STEM careers are more likely to pursue STEM careers (Bian et al., 2017; Herbert & Stipek, 2005; Salehjee & Watts, 2015). It has been proved that one's preference for sciences at a very young age could be essential to one's career path decisions, by one-to-one interviews with scientists and non-scientists (Salehjee & Watts, 2015). Besides, students with higher interests in mathematics self-efficacy as well as technical and scientific skills are prone to choose STEM careers (Blotnicky et al., 2018). Students with constantly high beliefs about STEM would prefer to study science and mathematics and to pursue science careers (Chow et al., 2012; Sheldrake et al., 2019). In terms of gender difference in interest in STEM careers, there is a persistent gap in choosing STEM careers between boys and girls. Generally, girls presented lower interest in STEM careers and were less willing to take up STEM careers (Sadler et al., 2012; Wang & Degol, 2017).

Some studies showed that being exposed to STEM enterprises and activities at early ages positively influence elementary school students' perceptions and plans in STEM careers (DeJarnette, 2012; Sadler et al., 2012; Tai et al., 2006). It's never too early to foster students' interest in STEM. For example, a series of STEM inquiry activities were implemented for students aged 9 – 11 in four elementary schools (Chen et al., 2020). During the activities, students were provided with STEM role models, and were engaged in real and hands-on activities to mimic the STEM professional research work. It was found that these students' interests in STEM careers were significantly increased. Students show more confidence in STEM fields, when they have more opportunities to exchange ideas about opportunities in STEM in elementary school (Skamp, 2007). It is essential to support the development of STEM skills in students' earlier years of schooling, so that they can maintain interests in STEM and sustain believed that they are able to have a STEM career (Holmes et al., 2018).

1.2 Students' Stereotypical Images of STEM Professionals

Stereotypes are 'beliefs about the characteristics, attributes, and behaviors of members of certain groups' (Hilton & Hippel, 1996). Stereotypes of STEM professionals were conceptualized as beliefs about the characteristics of the people who work in STEM-related domains (Garriott et al., 2017). Studies found that students often held stereotypes about STEM professionals (Capobianco et al., 2011; Holmegaard et al., 2014), and their stereotypes seem to be quite stable (Piatek-Jimenez et al., 2018). For example, scientists are usually regarded to be male and unattractive (Capobianco et al., 2011). With respect to social skills, stereotypes about scientists are working alone, working indoors, and having a

limited social life (Farland-Smith & Tiarani, 2016). In the students' drawings of engineers, eight actions were highlighted: fixing, problem-solving, scientific process, programming, measuring, presenting ideas, building, and professor (Farland-Smith & Tiarani, 2016). Researchers found that students' stereotypes of STEM professionals can influence their STEM career choices. Chan et al. (2019) surveyed 3724 students in Hong Kong about their perceptions of engineers, engineering-related experiences at school, and career interest in engineering. They found that students' perceptions directly influenced their career interest in engineering, and partially mediated the relationship between STEM experiences and engineering career interest. In a research, high school students' negative stereotypes of science, technology, engineering, and mathematics (STEM) professionals as predictors of math/science interests and career goals were examined. According to the findings, STEM stereotypes were a significant predictor of math/science self-efficacy, math/science self-efficacy was a significant predictor of math/science interests, and interests predicted math/science career goals (Garriott et al., 2017). It was also demonstrated that women who interacted with non-stereotypical role models had more self-efficacy in computer science than those who interacted with stereotypical role models (Cheryan et al., 2011).

1.3 Research Questions

In the current study, we investigated the stereotypical images of STEM professionals and STEM career interests in Chinese elementary school students. We also intended to study whether stereotypical images of STEM professionals among Chinese elementary school students are related to their STEM career interests. With an analysis of relationship between elementary students' stereotypical images of STEM professionals and STEM career interests, this study tried to provide useful evidence for promoting STEM career interests of students in elementary schools. The following research questions were considered:

(1) What are elementary school students' stereotypical images of STEM professionals in China?

(2) What are elementary school students' STEM career interests in China?

(3) To what extent do stereotypical images of STEM professionals relate to STEM career interests?

2. Design and Methods

2.1 Research Design

This study used a mixed methods approach to investigate the different dimensions of elementary school students' stereotypical images of STEM professionals as well as their STEM career interests, and the influence of stereotypical images of STEM professionals on STEM career interests. To establish the authenticity of the phenomena, quantitative data were initially collected via questionnaires to answer research questions one, two and three. Follow-up semi-structured interviews were undertaken to supplementarily answer research question one and two.

2.2 Participants

This study involved a total of 318 students enrolled from 3rd to 6th grade from two elementary schools

in Wenzhou, China. Respectively, 142 students from School A were in grade 3 to 6, and 176 students from School B were in grade 4 to 6. For grade, 9.1% are in grade 3, 29.9% are in grade 4, 36.5% are in grade 5, 24.5% are in grade 6. The two elementary schools are both public schools. Permission was acquired from all the participating students, teachers, and schools to ensure adherence to ethical standards. 12 elementary school students from grade three to six were interviewed. Among them, half are boys and half are girls.

2.3 Instruments

The questionnaire was composed of two parts: interest in STEM careers and stereotypical images of STEM professionals. The instruments for assessing interest in STEM content and careers was used in this study to measure elementary school students' STEM career interests (Tandra et al., 2010). Cronbach alpha's value for STEM career interests was found to be .789 in the present study. To measure elementary school students' stereotypical images of STEM professionals, a questionnaire was modified from a short form (Chen et al., 2020) and the Math and Science Stigma (MASS) Scale (Garriott et al., 2017). The questionnaire was composed with three parts: stereotypes about STEM professionals' social skills, positive images of STEM professionals, and views on STEM implications for society. Cronbach's alpha coefficients were found to be .715. All the instruments are 5-point Likert-type scales. 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The higher scores were, the higher interests towards STEM careers and stronger stereotypes of STEM professionals students had (So et al., 2021).

2.4 Data Analysis

All statistical analyses were run by an online data analysis platform SPSSAU (https://spssau.com/). The analytical methods included reliability analysis of scale, descriptive statistical analysis, and correlation analysis. Pearson's correlation and regression analysis were employed to determine the relationship between stereotypical images of STEM professionals and STEM career interests (Hauke & Kossowski, 2011). For the purpose of data analysis with regards to the interviews, we obtained responses from the field via notes and audio recordings. The data collected were repeatedly listened to and read.

3. Findings

3.1 Quantitative Results

Table 1 shows the mean value, standard deviation, and median of stereotypical images of STEM professionals and STEM career interests. The mean scores were high in the stereotypes about STEM professionals' social skills, and low in the positive image of STEM professionals. This suggests that elementary school students have deep stereotypes about STEM professionals' social skills. For example, more than half of respondents strongly agreed that STEM professionals had bad hygiene and had a hard time making friends. (42.3%) of the respondents strongly agreed that STEM professionals were not good athletes. (32.6%) and (28.5%) of the respondents strongly agreed and agreed STEM professionals spend all their time alone, respectively. Although elementary school students presented high views on

STEM implications for society (M= 4.244), their STEM career interests were not high (M= 3.718). Elementary school students hold relatively consistent views on STEM implications for society (SD = 0.584). Their STEM career interests varied widely (SD= 0.777). Grade had significant correlation with elementary school students' positive images of STEM professionals (r=0.156, $p < 0.01$), and correlation with their stereotypes about STEM professionals' social skills (r= -0.131, $p < 0.05$). Senior students had deeper positive images of STEM professionals but fewer stereotypes about STEM professionals' social skills than junior students. As the age increased, there were no significant differences in views on STEM implications for society and STEM career interests.

Table 1. Descriptive Statistics of Variables

Grade		SSPSK	PISP	VSIS	SCI
3	Mean	4.267	3.566	4.283	3.641
	SD	0.582	0.535	0.559	0.636
4	Mean	4.300	3.547	4.236	3.680
	SD	0.610	0.659	0.583	0.759
5	Mean	4.155	3.757	4.243	3.790
	SD	0.644	0.544	0.569	0.768
6	Mean	4.061	3.787	4.241	3.687
	SD	0.742	0.641	0.612	0.861
total	Mean	4.186	3.684	4.244	3.718
	SD	0.658	0.610	0.581	0.777
r		-0.131	0.156	-0.010	-0.010
p		0.019*	0.005**	0.859	0.859

Note. SSPSK: Stereotypes about STEM professionals' social skills, PISP: Positive image of STEM professionals, VSIS: Views on STEM implications for society, SCI: STEM career interest.

Pearson's correlation was employed to estimate the linear correlation between elementary school students' stereotypical images of STEM professionals and STEM career interests. Results are shown in Table 2. Stereotypes about STEM professionals' social skills, positive images of STEM professionals, and views on STEM implications for society all showed strong positive correlations with STEM career interests ($p < 0.01$). Among the three dimensions, elementary school students' views on STEM implications for society had the greatest influence on their STEM career interests ($r = 0.620$). While elementary school students' stereotypes about STEM professionals' social skills have the least influence on their STEM career interests ($r = 0.164$).

Table 2. Correlations between Elementary School Students' Stereotypical Images of STEM Professionals and STEM Career Interests

Dimensions	r	*p*
Stereotypes about STEM professionals' social skills	0.164	0.003**
Positive image of STEM professionals	0.424	0.000**
Views on STEM implications for society	0.620	0.000**

Note. ** indicates significant relationship at $p < .01$.

The results (Table 3) from the first step of the regression model on STEM career interests showed that the demographic predictors 'grade' only accounted for 0.1% of the variance in the outcome variable. This result indicated that there was no difference in STEM career interests between elementary school students of different grades. The results from the second step of the regression model showed that the interactive effects of the variables included in this model accounted for 39.5% of the variance in the outcome variable. SSPSK ($\beta = 0.170$) and VSIS ($\beta = 0.531$) significantly contributed to the model. This generally means that an elementary school student who has a deeper positive image of STEM professionals and views on STEM implications for society will most likely be more interested in STEM careers.

Table 3. Hierarchical Multiple Regression Results of Factors that Influence Elementary School Students' STEM Career Interests

Variable	Model 1		Model 2	
	B (*p*)	β	B (*p*)	β
(Constant)	3.619**		-0.274	
Grade	0.021 (0.659)	0.025	0.007 (0.862)	0.008
SSPSK			0.036 (0.500)	0.031
PISP			0.216** (0.001)	0.170
VSIS			0.710** (0.000)	0.531
R^2	0.001		0.395	
F	F (1,316) = 0.196, p=0.659		F (4,313) = 53.352, p=0.000	
$\triangle R^2$	0.001		0.405	
$\triangle F$	F (1,316) = 0.196, p=0.659		F (3,313) = 71.027, p=0.000	

Note. SSPSK: Stereotypes about STEM professionals' social skills, PISP: Positive image of STEM professionals, VSIS: Views on STEM implications for society, SCI: STEM career interest, B: unstandardized regression, β: standardized regression, ** indicates significant relationship at $p < .01$.

3.2 Qualitative Results

All the participants interviewed said that they knew STEM professionals from various ways. However, most (10 out of 12) of them interviewed said they have little contact with STEM professionals. They learnt about STEM professionals mainly through the Internet, movies, textbook, and introduction by teachers. When asked about the most impressive STEM professionals, many interviewees mentioned famous scientists, such as Isaac Newton and Einstein, and engineers, such as Thomas Edison. Some modern STEM professionals were also mentioned, for example, Youyou Tu, Longping Yuan, and Steve Jobs. However, they cannot explicitly list the names of well-known mathematicians and technicists. Almost all the STEM professionals referred to were male. Only three students mentioned female STEM professionals (Marie Curie and Youyou Tu).

Most (11 out of 12) of the participants presented negative stereotypes about STEM professionals' social skills. They thought STEM professionals were very busy with their work and had a hard time making friends. One student enrolled in sixth grade believed that work was not STEM professionals' whole life, and they had their own interests and social activities. She passionately expressed her view on support by saying:

> *Work related to STEM, especially science and engineering, was usually a teamwork. Collaboration is the one of most important factors to success. My father is an engineer. He works with his workmates nearly every day.*

Concerning the positive image of STEM professionals, students held mixed views. Junior students generally thought STEM professionals were very smart and made a lot of money. However, senior students believed that STEM professionals may make a lot of money, but not all of them were very smart. From their point of view, diligence is more important than intelligence for a STEM professional.

All 12 participants interviewed highlighted the importance of STEM for society and thought STEM made human life better. While 3 out of the 12 participants expressed that STEM sometimes may harm humans. Two sixth-grade students emphasized that every coin has two sides, and gave examples of plastics. One of the sixth-grade students expressed his thoughts on this issue by saying:

> *Scientists invented plastics. Engineers made plastics widely applied. Although plastics have greatly facilitated our life, they were difficult to be decomposed naturally. This would cause white pollution and may be harmful to the environment as well as human health. For example, the incineration of waste plastics produces a lot of toxic gases. A large number of landfill waste plastics would pollute groundwater to a certain extent. I learned it in science class. From here we can see that the work of STEM professionals sometimes might bring negative consequences.*

As for STEM career interests, only half of (6 out of 12) participants thought careers in STEM was interesting. Furthermore, merely 4 participants thought careers in STEM was appealing for them. When asked would like to have a job that involves STEM, 4 out of 12 students were uncertain. 3 out of 12 students said they were willing to, and 2 of 12 students showed great willingness. These 5 students all thought STEM professionals made great contributions to humans, and jobs related to STEM were

interesting. Nevertheless, 2 of 12 students did not want to carry on occupations related to STEM. A girl student enrolled in fifth grades said she wanted to be an artist in the future. She didn't think she was smart enough and STEM was too difficult for her. She didn't like working in the lab, either. A boy student enrolled in sixth grades expressed that he wished to be a policeman. He said policemen contribute more to society compared to STEM professionals.

4. Discussion

This study reports results related to Chinese elementary school students' stereotypical images of STEM professionals and their STEM career interests. Then the relationship of stereotypical images of STEM professionals and STEM career interests was determined. Elementary school students have strong stereotypes about STEM professionals' social skills, and these stereotypes got weaker with age. Elementary school students' perceptions of STEM professionals mainly come from the Internet movies, textbook, and introduction by teachers. As the grade increased, elementary school students are exposed to more news, texts, TV production and articles related to STEM professionals. Senior students took more science, technology, and mathematics classes (Toma et al., 2019). Likely with experiences participating in different STEM-related instructional activities, the students are exposed in later years to more-realistic and less-stereotypical models of STEM professionals. As a result, they tend to create more complete and realistic depictions of the activities of STEM professionals compared to younger children. Research studies (Bozzato et al., 2021) indicated similar findings. With regard to positive image of STEM professionals, as a whole, students present relatively positive views. The present data indicated that children in higher-level classes hold positive image of STEM professionals compared to younger children, as suggested by a series of indicators described in the results section. At the beginning of elementary school, Chinese students approach science and mathematics, and they start to learn information technology at the third grade. With these subjects, they may begin to confront attitudes toward and representations of STEM professionals more frequently. Positive images of STEM professionals are seen much frequently. Hence, older children may convey more positive stereotypes of STEM professionals. This finding is congruent with the results of previous study (Ozel, 2012). Chinese elementary school students hold very positive views on STEM implications for society, and there were no differences among different grades. Previous study also identified that there were no discernible differences across grade levels on this subject have failed to identify significant differences (Emvalotis & Koutsianou, 2018). Moreover, when referencing STEM professionals, famous scientists and engineers were certainly come to Chinese elementary school students' minds. However, they cannot clearly point out mathematicians and technicists.

We also indicated that Chinese elementary school students had STEM career interests, but their interests were not very high. Their STEM career interests varied widely, and there were no significant differences in STEM career interests across grade levels. Nowadays, students' lack of interest or aspirations in STEM careers has been a worldwide concern (So et al., 2022; So et al., 2018; Wang &

Degol, 2017).

Last but not least, the findings of this study indicated the influence of stereotypical images of STEM professionals on STEM career interests. Elementary school students' stereotypes about STEM professionals' social skills have minor negative effects on their STEM career interests. Elementary school students' positive image of STEM professionals and views on STEM implications for society have a significant correlation with their STEM career interests. This is in line with the previous studies about STEM career interests (Bian et al., 2017; Cheryan et al., 2011; Garriott et al., 2017; Silver & Rushton, 2008). Students with fewer stereotypes about STEM professionals' social skills, more positive images of STEM professionals, and stronger views on STEM implications for society are more likely to pursue careers in STEM. Maintaining students' interest in STEM in their earlier years of schooling can sustain their belief that they are able to have a STEM career (Holmes et al., 2018).

In order to address students' lack of STEM career interests, we provided practical suggestions from the perspectives of stereotypical images of STEM professionals. Firstly, aspects of the history of science can be incorporated into science, mathematics, and information technology class. Historicizing science in the classroom can improve the pedagogical experience of students and help them turn into more effective professional practitioners of science (Gooday et al., 2008; Roca-Rosell & Grap ŕVilumara, 2010). Stories of scientists can rich students' perceptions of this profession. Secondly, socioscientific issues can be applied in learning STEM subjects, by conveying the growing importance that science and technology have in our society. Socioscientific issues refer to "complex and contentious social issues with substantial connections to science ideas and principles" (Zeidler et al., 2019). Socioscientific issues are easily considered by students as real-world situations related to contemporary issues, thus bringing a sense of authenticity and relevance to the classroom (Genisa et al., 2020; Romero Ariza, 2017; Tekin et al., 2016). Because of the complexity of social problems, students can analyze problems from multiple perspectives, and get a fuller picture of the social and personal implications of STEM. Thirdly, in order to promote fewer stereotypes about STEM professionals' social skills among students, it is significant that more opportunities can be provided for students to experience STEM professionals' work during their schooling. Mercier et al. (2006) highlighted the relation between students' STEM experiences and their understanding of STEM professionals. A variety of activities, such as field trips that observe the work of scientists, visits to scientists, and reading stories about scientists, to show the actual work of STEM professionals should be designed in the lessons (Özel, 2012). Fourthly, to promote a balanced understanding of STEM professionals, measures should be taken to increase elementary students' understanding of mathematicians and technicists.

There were, however, some limitations to this study that should be noted. On one hand, this study was limited to investigating the relationships between stereotypical images of STEM professionals and STEM career interests. Future research can involve additional variables, for example, parents' STEM attitudes, teachers' STEM attitudes, or STEM self-efficacy, to investigate the underlying mechanism

involved in students' career choices. On the other hand, while the sample of this study was representative of the elementary school student population in China, future studies with a broader range of geographies and student populations can further evaluate the generalizability of the present findings.

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