

Thinking and Practicing Like a Scientist?

Examining K-12 Student Mental Images of Scientists through a Large-Scale Survey-Based Study

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Received: 2 February 2023 | Revised: 3 May 2023 | Accepted: 3 May 2023

Abstract

This study aimed to develop a valid and reliable instrument, the Mental Images of Scientists Questionnaire (MISQ), and use the instrument to examine Chinese students' mental images of scientists' characters across school levels, regions, living settings, and gender. The final version of the MISQ consisted of four constructs: scientists' cognitive, affective, lifestyle, and job characters. The results showed that senior high school students gave higher scores for scientists' cognitive character construct than junior high and elementary school students did. Students from eastern regions, which have a more highly developed economy, gave the highest scores on cognitive and affective character constructs of scientists. Students from western regions, which have a less developed economy, had a relatively negative impression of scientists. Students' images of scientists' affective, lifestyle, and job characters were positively correlated with their interests in pursuing scientific careers. Future research to explore the relationships between students' mental images of scientists' characters and students' motivation to pursue science-related careers or to engage in scientific practices are recommended.

Keywords

affective character – cognitive character – job character – lifestyle character – mental images of scientists

1 Introduction

One major goal of science education is to advance students' scientific literacy and prepare students with the capacity to think, act, and practice like a scientist (Chen, 2019; Pearson et al., 2010). Researchers and teachers in science education have often conceptualized scientists as professionals, critical thinkers, creative talents, and brilliant experts producing scientific knowledge (Hunter et al., 2007). Several reform documents have established standards and goals for students based on how scientists are conceived to work and develop scientific knowledge of the natural world (e.g., NGSS Lead States, 2013; OECD, 2019). Students are expected to act, think, and practice like a scientist (Hunter et al., 2007). However, students' images and perceptions of scientists may differ from real-life scientists. Scientists have often been stereotyped by students as untidy, antisocial, mystical, and impersonal (Christidou et al., 2019; Scherz & Oren, 2006).

Students' perceptions of scientists vary with their living experience, age, country, culture, and information they obtain through social media (Bayri et al., 2016; Jones et al., 2000; Ozel, 2012). Several studies have suggested that images of scientists may influence how students view science, their epistemic beliefs, identity, and attitudes toward science learning, the science, technology, engineering, and math (STEM)-related careers they pursue, and their desire to be scientifically literate citizens (Chang et al., 2020; DeWitt & Archer, 2015; Finson, 2002; Schibeci, 1986; Schinske et al., 2015; She, 1998; Zeldin & Pajares, 2000). For example, Schneider (2010) found that undergraduate students are more likely to pursue STEM-related careers if they have positive stereotyped images of scientists (e.g., scientists are perceived as cooperative and work oriented). Schinske et al. (2015) reported that students' images of scientists were significantly correlated to their attitudes about learning science and success in science achievement, especially for women and students of color. Starr (2018) found that female university students' stereotypes about STEM affected their identity in STEM and motivation to pursue STEM careers. Several studies have reported that students' stereotyped images of scientists tended to be developed before early elementary school and thereafter become stable (e.g., Kang et al., 2005; Narayan et al., 2013; Song & Kim, 1999). It is particularly important for students to have positive perceptions of scientists, as they will likely influence educational and career decisions. Therefore, it is necessary to unpack students' images of scientists and how their images are related to their backgrounds (e.g., gender, school level, and social economics status) and professional interests in science.

Most of the studies that have described students' images of scientists have utilized drawing as a tool for student expression (Chang et al., 2020). A well-known technique called the Draw a Scientist Test (DAST) was originally developed by Chambers in 1983. DAST is an open-ended projective test to measure how students conceptualize their images of scientists through drawing technology tools. Over the last 3 decades, a number of studies have used it to understand student images of scientists (e.g., Cakmakci et al., 2011; Finson, 2002; Karaçam, 2016; Krajcovich & Smith, 1982). DAST asks students to draw their images of scientists in detail and use concise vocabulary to describe their drawing. Several researchers have reported that young students in Grades 1–7 may not have the necessary skills to complete this task (Sumrall, 1995; Symington & Spurling, 1990). In addition, the data collected from DAST depict *external* images of scientists, such as hairstyles, clothes, skin color, and gender. The *internal* or *mental* aspects of scientists, such as cognitive personality and moral characters, cannot be captured by DAST. In response to this

limitation in DAST, several researchers (Palmer, 1997; Barman, 1997; Ozel, 2012) have suggested the use of interviews and surveys that are often less structured. There is a need, therefore, for a valid and reliable instrument that is appropriate to unpack students' images of the *internal* aspects of scientists from elementary through high school. However, existing instruments for establishing validity have been poorly executed. None of them have examined construct validity, which is central to the concept of validity.

To fill this gap, this study aims at developing a valid and reliable questionnaire on the internal character of scientists. To test its validity and reliability, this instrument was applied in China, which is a developing country with a growing demand for STEM-related careers and has the world's largest population. To the best of our knowledge, the present study is the first to explore Chinese students' mental images of the internal character of scientists across different school levels, regions, and living settings. Therefore, this first goal of this study was to develop a valid and reliable questionnaire, the Mental Image of Scientists Questionnaire (MISQ), to examine students' images of scientists. The second goal was to apply this instrument to unpack Chinese students' mental images of scientists across school levels (elementary, junior high school, and senior high school), regions (east, northeast, west, and central), living settings (urban, town, and rural), and gender. In this study, a living setting is classified as urban when it has an area with a population size of more than 50,000 inhabitants in contiguous dense grid cells with a density of at least 1,500 inhabitants per km^2 , a town is an area with a population of at least 5,000 inhabitants in contiguous grid cells with a density of at least 300 inhabitants per km^2 , and a rural living setting is an area with a population size consisting mostly of low-density grid cells with a density of less than 300 inhabitants per km^2 . The third goal was to examine the impact of students' images of scientists on students' interest in science and their willingness to pursue STEM-related careers.

2 Literature Review

2.1 Student Images of Scientists' External Character

Studies on exploring students' *external* images of scientists have established substantial evidence about students' perception of scientists. A seminal study conducted by Mead and Metraux (1957) in the United States drew this conclusion from the essays written by approximately 35,000 high school students:

The scientist is a man who wears a white coat and works in a laboratory. He is elderly or middle aged and wears glasses. He is small, sometimes small and stout, or tall and thin. He may be bald. He may wear a beard, may be unshaven and unkempt. He may be stooped and tired.

MEAD & METRAUX, 1957, pp. 126–127

Inspired by this work, Chambers (1983) used the DAST with 4,807 students from kindergarten to fifth grade in Canada and the United States. Seven characters were identified in the students' drawings of scientists: (a) lab coat (usually but not necessarily white), (b) eyeglasses, (c) facial growth of hair (including beards, mustaches, and abnormally long sideburns), (d) symbols of research (scientific instruments and laboratory equipment), (e) symbols of knowledge (principally books and filing cabinets), (f) technology, and (g) relevant captions (e.g., formulae, taxonomic classifications, and the "eureka!" syndrome). Miller et al. (2018) reviewed 78 studies that utilized the DAST technique that had been conducted in the United States. Their results confirmed the character of scientists found by Mead and Metraux (1957) and Chambers (1983), with 79% of students' imaging scientists to be Caucasian, 78% perceiving a laboratory, 73% imaging scientists to be male, 50% seeing laboratory coats, and 38% imagining eyeglasses or goggles.

Looking more closely, Miller et al.'s (2018) review found an overall trend across age. The tendency for students to draw scientists as male increased with age, and at ages 7–8, at the elementary level, students began to draw significantly more male than female scientists. High school students drew four males to one female scientist. They suggested students developed stereotypic images of scientists through school curricula and textbooks and social media. Christidou et al. (2019) and Ozel (2012) also claimed that scientists in textbooks were predominantly characterized as male and that this may influence the development of students' stereotyped images of scientists. However, Miller et al. (2018) also noted that from 1960–2013, student images of scientists as female have increased, perhaps because the percentage of female scientists in the United States rose from 28% to 49% in biology, 8% to 35% in chemistry, and 3% to 11% in physics and astronomy. Textbooks have also included more representations and stories of female scientists.

Recent comparative cultural research has suggested that students' images of scientists are influenced by cultural background. Koren and Bar (2009) explored how Hebrew and Arab students in Israel drew their images of scientists. They found that Hebrew students' drawings were similar to the drawings by Western

students that had been described in previous research. The images created by Arab students had a strong ethnic trend, with classical Muslim elements and attire. Farland-Smith (2009) compared how elementary American and Chinese students drew their images of scientists, and found that American students drew characters that were similar to those drawn by Chinese students. Chinese students tended to draw robots or novel depictions while American students tended to draw the use of chemicals. Recently, Narayan et al. (2013) compared how students from China, India, South Korea, Turkey, and the United States drew images of scientists. They found that 91.4% of Turkish students drew scientists as Caucasian, compared to 20.3% of Chinese, 13.9% of Indian, 8.6% of South Korean, and 61.7% of American students. Chinese students (21.4%) were more likely to include technological elements in their drawings than Indian (8.6%), South Korean (12.2%), Turkish (18.9%), or American (5%) students. Their study echoed the finding of Farland-Smith (2009) that Chinese students tended to consider engineering and technology as unified parts of science.

2.2 Student Images of Scientists' Internal Characters

The focus of studies in this area has shifted from external to internal (mental) images of scientists' character (Marshall et al., 2007; Schinske et al., 2015; Wyer et al., 2010). Song and Kim (1999) examined 1,137 11-, 13-, and 15-year-old students in South Korea, finding that students' attitudes toward science tended to be influenced more by how they viewed scientists' personality and internal characters than by external characters and expressions. They found that students who had developed positive attitudes toward science interpreted scientists as having a strong spirit and warm character. They tended to have positive images about cognitive character (e.g., intelligent, imaginative, and accurate) and as they became older they developed more negative images about scientists' affective (e.g., selfish, unartistic, closed minded, and boring) and moral (e.g., irreligious, irresponsible, and non-peace loving) characters. Students' mental images of scientists' cognitive characters did not change across the three age groups.

A recent study conducted by Gheith and Aljaberi (2019) in Jordan explored how first-year and fourth-year college students conceptualized their mental images of scientists with a survey adapted from Song and Kim (1999). Their study of 140 Jordanian preservice teachers showed that they had more balanced and positive images of scientists in most character aspects than had been reported in Korean studies. For example, students had positive images of scientists in the dimensions of cognitive (accurate, intelligence, creativity, and industrious) and affective (responsibility, open-mindedness, caution, and humane) character, even though they rated lower scores on some aspects

of affective (unartistic and empathetic) and moral (irreligious) characters. Comparing Year 1 and Year 4 college students, they did not find statistical differences among the characters, except for industriousness. Year 4 students showed higher scores on this item. They suspected that Year 4 students might have had more “science and research experience” (e.g., laboratory and projects) than Year 1 students.

Schinske et al. (2015) used a qualitative survey to explore second-year US college students’ mental images of scientists. Most of the 125 students held positive scientist stereotypes (e.g., curious, passionate, and dedicated). They found negative stereotypes (e.g., asocial, strange, and boring) were held by Asian students though they performed better in school science. They suspected that Asian students demonstrated comparatively low senses of belonging and academic integration in the college. However, they also pointed out that “Asian” included at least 48 ethnic groups, many of which are underserved in STEM. It is necessary therefore to examine what stereotypes students hold about scientists in different countries and ethnic groups.

In sum, studies have shown that students hold positive images of cognitive characters across different countries, ages, and cultures. However, other aspects of character (e.g., affective, moral, lifestyle, and job) have tended to be varied and inconsistent. There is still much to be learned about how students conceptualize the mental images of scientists’ characters. In addition, most studies used interviews to unpack and explore students’ mental images of scientists. Very few studies have developed questionnaires to explore students’ mental images of scientists’ characters (e.g., National Science Board, 2002; Song & Kim, 1999). Even though questionnaires have been used, their validity and reliability have never been texted and examined throughout. None have examined construct validity, which is central to the concept of validity.

2.3 *Theoretical Constructs of Student Images of Scientists’ Internal Characters*

In this study, we developed the Mental Images of Scientists Questionnaire (MISQ), a valid and reliable instrument to assess students’ mental images of scientists across different school levels, regions, and living settings. By reviewing the literature related to student mental images of scientists (Song & Kim, 1999; Painter et al., 2006; Parsons, 1997; Scherz & Oren, 2006; Schinske et al., 2015), five constructs of the internal images of scientists received more attention and have been explored in different contexts: (a) cognitive, (b) affective, (c) moral, (d) lifestyle, and (e) job. Table 1 shows a summary of the constructs mentioned by some of the studies that have explored students’ mental images of scientists’ internal characters.

TABLE 1 Dimensions of student images of scientists' internal characters

Scholars	Cognitive character	Affective character	Moral character	Lifestyle character	Job character
¹ Parsons (1997)	O	O	O	O	O
*Song & Kim (1999)	O	O	O		
*National Science Board (2002)				O	O
¹ Painter et al. (2006)	O	O		O	O
¹ Scherz & Oren (2006)	O	O			
¹ Schinske et al. (2015)	O	O			

O means that the authors directly mentioned and conceptualized the dimensions as one of the student images of scientists' internal characters.

* means that the authors used a questionnaire as a method to explore student images of scientists' internal characters.

¹ means that the authors used an interview as a method to explore student images of scientists' internal characters.

Cognitive character refers to the ways that scientists perceive, practice, and generate understandings of the natural world, such as intelligence, imagination, and diligence. Affective character refers to scientists' personal dispositions, mood status, and personality character, such as, empathy, loving nature, and humanity. Moral character refers to scientists' dispositions to think, feel, and behave in an ethical or unethical manner in aspects such as responsibility, religious belief, and working for peace. Lifestyle character refers to the ways in which scientists live and interact with their family and others. Job character refers to the judgement and cognition of scientists' work and job. In the present study, we first aimed to validate the MISQ in order to make sure that the items can fit within the five dimensions of the theoretical frameworks that we proposed. Second, we used the validated and reliable MISQ to study and unpack students' mental images of scientists across different school levels, regions, and living settings. Third, we used the MISQ to examine the impact of students' images of scientists on students' interest in science and their willingness to pursue STEM-related careers.

3 Research Objectives

Three research objectives guided this study:

1. To develop and validate the MISQ to assess students' mental images of scientists.
2. To use the MISQ to investigate the patterns of Chinese students' mental images of scientists across school levels (elementary, junior high school, and senior high school), genders, regions (east, northeast, west, and central), and living settings (urban, town, and rural).
3. To use the MISQ to further explore the relationships between Chinese students' mental images of scientists and their willingness to pursue science-related careers.

4 Methods

4.1 Development of the Questionnaire

The development of the questionnaire and its various measures of validity and reliability are summarized in Table 2. The five-step process used to develop this assessment instrument was based on recommendations outlined in the Standards for Educational and Psychological Testing (American Educational Research Association [AERA], American Psychological Association [APA], & National Council on Measurement in Education [NCME], 2014).

TABLE 2 Five steps for the development and validation of the MISQ

Step	Description of step
1. Conceptualization of student mental images of scientists (construct validity)	<ul style="list-style-type: none"> – Conducted literature review to identify essential constructs that are able to describe scientists' character. – Defined the meanings of each construct.
2. Identification of items for each construct (face validity)	<ul style="list-style-type: none"> – Identified existing surveys and items that could be applied and used for the questionnaire. – Translated items from English into Chinese.
3. Translation of items from English to Chinese (translate validity)	<ul style="list-style-type: none"> – Modified the translation by two of the authors to make sure the meanings of each item were the same as English version.
4. Analysis of construct validity	<ul style="list-style-type: none"> – Applied 2,758 students' responses to examine construct validity through principal component analysis with varimax rotation.
5. Analysis of reliability (internal reliability)	<ul style="list-style-type: none"> – Conducted internal reliability testing.

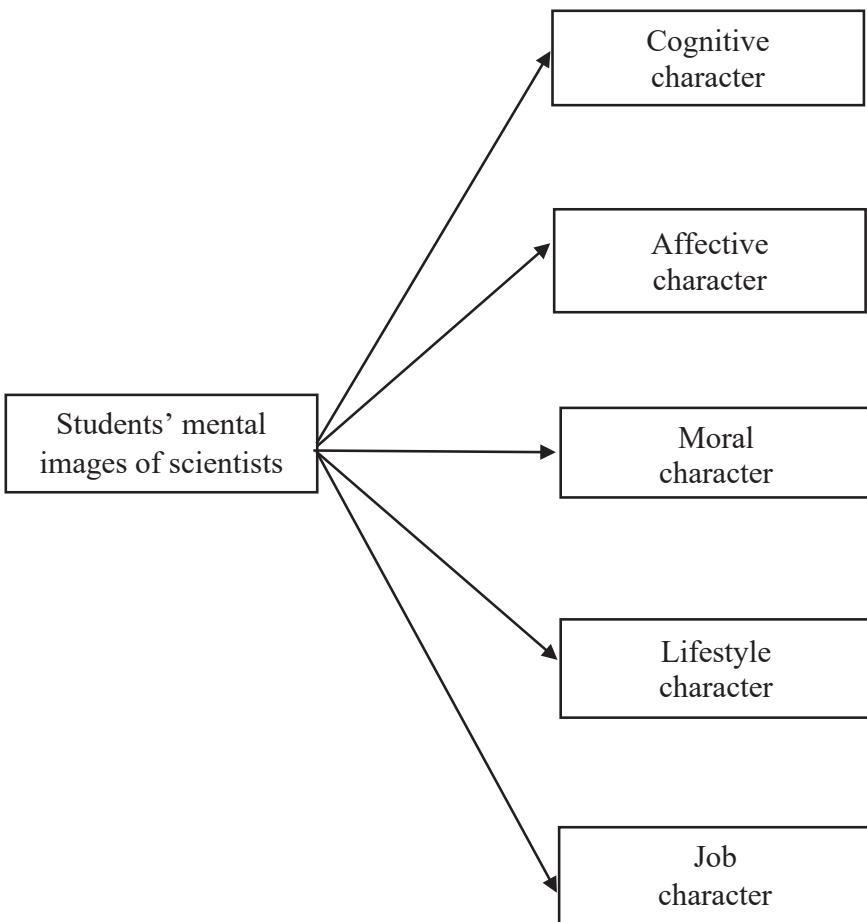


FIGURE 1 The structure of students' mental images of scientists

First, a thorough literature review was conducted to identify essential constructs of students' mental images of scientists. Table 1 shows that five constructs were the most commonly mentioned and explored in previous studies (e.g., Painter et al., 2006; Song & Kim, 1999). Therefore, the structure of student mental images of scientists' internal character was conceptualized into the five constructs. Figure 1 shows the overall structure.

Among the five studies examined related to this topic, only two studies explicitly used the technique of a questionnaire to explore student mental images of scientists' internal character (National Science Board, 2002; Song & Kim, 1999). The two questionnaires covered the five constructs identified in this study (see Table 1). Although some studies were found to use questionnaires (e.g., Wyer et al., 2010), they were developed based on Song and Kim

(1999) and National Science Board (2002). Therefore, we adapted the items from the two studies.

The first three constructs and questions were adopted from Song and Kim's (1999) survey. The first construct, cognitive, contains four items: "careless–accurate," "stupid–intelligent," "lazy–industrious," and "unimaginative–imaginative." The second construct, affective, contains five items: "selfish–caring," "closed minded–open minded," "boring–exciting," "unartistic–artistic," "inhumane–humane." The third construct, moral, contains three items: "irresponsible–responsible," "irreligious–religious," and "non-peace loving–peace loving."

The remaining two constructs and questions were adopted from the National Science Board's (2002) survey. The fourth construct, lifestyle, contains seven items, such as "A scientist usually works alone." It is worth noting that this construct is a reverse score, which means a higher score represents a more negative image of scientists. The fifth construct, job character, contains five items, such as "Scientists don't work for fame or money." It contains 24 items (Table 3), which were rated using a 5-point Likert scale for a possible total of 120.

Although our questions were adopted from Song and Kim (1999) and the National Science Board (2002), neither of their questionnaires had been tested for validity and reliability. Therefore, we conceptualized the questionnaire based on the two previous studies and tested its validity and reliability. For convenience, we adjusted the presentation sequence of the questions in Table 3 such that it is not completely consistent with our actual survey sequence.

Because the original items were written in English, all items were translated into simplified Chinese, with some items adjusted slightly for the mainland Chinese context. To perform the translation, two of the authors independently translated the questionnaire into simplified Chinese and compared their translations. No significant differences were identified, so the final version sent to the students was based on merging the three translations.

In addition to the 24 items, an item was created to measure the degree of student interest in pursuing a science-related career measured using a 4-point Likert scale: Do you want to pursue science-related career as your future job? On this scale, 1 represented a weak desire to become a scientist and 4 represented strong desire. This item was designed and used to test whether students' mental images of scientists correlated with their willingness to pursue a science related career.

To test the construct validity of the MISQ, principal-component analysis with varimax rotation was used "to obtain simple and interpretable factors" (Brown, 2009, p. 20). Cronbach's alpha was applied to examine the degree to

TABLE 3 Description of constructs and the items for each scale of the MISQ

Construct name	Description of scale	Item (survey question) (Likert scale 1–5)
1. Cognitive	The intelligence of scientists	1.1 <i>careless–accurate</i> 1.2 <i>stupid–intelligent</i> 1.3 <i>lazy–industrious</i> 1.4 <i>unimaginative–imaginative</i>
2. Affective	The affective intelligence of a scientist	2.1 <i>selfish–caring</i> 2.2 <i>closed minded–open minded</i> 2.3 <i>boring–exciting</i> 2.4 <i>unartistic–artistic</i> 2.5 <i>inhumane–humane</i>
3. Moral	Social attitudes of scientists	3.1 <i>irresponsible–responsible</i> 3.2 <i>irreligious–religious</i> 3.3 <i>non-peace loving–peace loving</i>
4. Lifestyle	Scientists' living conditions, personal character, etc.	4.1 A scientist usually works alone. 4.2 Scientists don't get as much fun out of life as other people do. 4.3 Scientists are apt to be odd and peculiar people. 4.4 Scientists have few other interests but their work. 4.5 Scientists can't deal with things in life well. 4.6 Scientists don't know how to interact with other people. 4.7 Scientists don't have much time for their families.
5. Job	The nature and value of a scientist's work	5.1 Scientists don't work for fame or money. 5.2 Scientific researchers are dedicated people who work for the good of humanity. 5.3 Most scientists want to work on things that will make life better for the average person. 5.4 Scientific work is dangerous. 5.5 Women are not well suited for scientific work.

Note 1. Items 1.1–3.3 used a 5-point Likert-type scale. 1 and 5 indicate strongly agree with the two ends of the spectrum of various aspects of the attributes of the scientist.

Note 2. Items 4.1–5.5 used a 5-point Likert-type scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

which the questionnaire consistently measured each construct it was designed to measure.

4.2 *Participants and Data Collection*

A method for large-scale surveys (Rowan et al., 2002) was used to collect data from students in China between April and July in 2014. The Chinese Academy of Science and Technology for Development (CASTED) in Beijing led the dissemination of the MISQ (see Appendix for the Simplified Chinese version). To ensure coverage of different regions, 60 urban, town, and rural schools were selected from 19 provinces and municipalities in northeastern (Heilongjiang and Liaoning), eastern (Beijing, Hebei, Shanghai, Zhejiang, and Guangdong), central (Anhui, Henan, Shanxi, Hubei, and Hunan), and western (Sichuan, Chongqing, Inner Mongolia, Ningxia, Yunnan, Xinjiang, and Tibet) portions of China.

To balance the proportion between the living settings of urban, town, and rural, the same proportion of schools in each living setting was selected from the four regions: Sixty percent of schools were selected from urban areas, 25% were selected from town areas, and 15% were selected from rural areas.

CASTED mailed the MISQ to the selected schools, and the school liaison officers were responsible for collecting the questionnaire from the selected classes and sending the questionnaire responses back to the research team. This process of collecting students' MISQ responses took about 4 months to finish. For each school, only one class was randomly selected to complete the questionnaire. The grades selected were fifth grade at the primary school level, eighth grade at the middle school level, and eleventh grade at the high school level. A total of 4,143 questionnaires were issued to 30 primary school classes (1,300 students), 30 middle school classes (1,301), and 28 senior high school classes (1,542).

Of these, 93.1% (3,856) were returned, with response rates of 93.3% (1,213) from primary school classes, 94% (1,223) from middle school classes, and 92.1% (1,420) from high school classes. The survey process was approved for ethics clearance by the institution and vetted by school principals. The students completed the questionnaires in class with teachers' guidance. Students were informed that completing in the questionnaire would not affect their grades and evaluations. All questionnaires were anonymous to protect students' confidentiality.

By receiving and reviewing the 3,856 responses, we removed 1,098 responses from the pool due to missing and incomplete information. This resulted in 2,758 students' responses to the MISQ being used for the item analysis and validation.

4.3 Data Analysis

4.3.1 Research Objective 1: The Development and Validation of the MISQ to Assess Students' Mental Images of Scientists

The development, content validity, and translation validity were described in Section 4.1. In this section, construct validity and internal consistency reliability will be discussed. Construct validity is essential to the validity, particularly "when inferences must be made concerning unobservable or latent variables" (Hayton et al., 2004, p. 191). The construct validity of the MISQ was tested using principal component analysis and varimax rotation in order to reduce redundant items and clarify the questionnaire structure. Positive loadings indicate that a variable and a principal component are positively correlated: The variable tends to increase when the principal component increases. The loading, which only included coefficients equal to or greater than 0.50, was used to select items to retain in the final questionnaire (Lin & Tsai, 2018). Items with many cross loadings were also discarded.

A classical psychometric test of the internal consistency reliability of the MISQ was applied by calculating Cronbach's alpha for the questionnaire as a whole and for each retained construct. A construct is considered reliable in the field of education when Cronbach's alpha value is greater than 0.6 and acceptable between 0.6 to 0.9 (Chen & Terada, 2021; Taber, 2018).

4.3.2 Research Objective 2: The Use of the MISQ to Investigate the Patterns of Chinese Students' Mental Images of Scientists across School Levels, Genders, Regions, and Living Settings

The multivariate analysis of variance (MANOVA) was used to test whether there were differences in the four characters of students' mental images of scientists among school levels, regions, and living settings. This was followed by an independent-sample *t*-test to analyze whether there was a difference in the cognitive character of scientists among students of different genders. Post hoc comparisons with Sidak correction analyses following the univariate MANOVAs were then performed. As a method of post hoc comparison, the Sidak method is suggested to have more power than other methods (e.g., Bonferroni method) because this method assumes that each comparison is independent of the others (Abdi, 2007). In this study, the school level, region, and living setting differences were independent. Therefore, the post hoc with Sidak correction analyses was selected to reveal whether there were statistical differences in students' mental images of scientists among China's urban, town, and rural regions. Statistical significance was determined at an alpha level of .05 for all tests. Non-significant results were not reported.

4.3.3 Research Objective 3: The Relationships between Chinese Students' Mental Images of Scientists and Their Willingness to Pursue Science-Related Careers

The Pearson correlation analysis was used to calculate the statistical relationships between the MISQ and student interests in pursuing a science-related career (e.g., do you want to pursue science-related career as your future job?).

5 Results

5.1 *Research Objective 1: The Development and Validation of the MISQ to Assess Students' Mental Images of Scientists*

5.1.1 Factor Analysis

Principal component analysis with varimax rotation was used to generate orthogonal factors. The results of factor analysis led to a decision to delete six items with factor loadings lower than 0.5 (Wold et al., 1987), which resulted in the final 18 items of the MISQ. Apart from the deletion of certain items, the factor analyses confirmed the validity of the original structure of the questionnaire without the need to change the scale allocation of any item or the name of any scale. The deleted items included three items (3.1, 3.2, and 3.3) in the moral construct, one (4.7) in lifestyle, and two in job (5.4 and 5.5). The factor analysis showed that the only three items related to moral character were deleted, thus the subscale of the moral construct no longer existed in our final MISQ. The final MISQ included the four remaining constructs of mental images of scientists: cognitive, affective, lifestyle, and job. Table 4 shows the factor loadings of the final 18 items.

For reliability related to internal consistency, Cronbach's alpha was applied to estimate the degree to which the MISQ consistently measured each of the grouping constructs that it was designed to measure. Cronbach's alpha values of 0.6 or higher can be considered acceptable, values between 0.7 and 0.9 good, and 0.9 or higher excellent (American Educational Research Association [AERA], American Psychological Association [APA], & National Council on Measurement in Education [NCME], 2014).

5.1.2 Internal Reliability

The overall Cronbach's alpha coefficient was 0.70 for the MISQ, and the subscales' Cronbach's alpha were 0.78 for the cognitive character, 0.81 for affective character, 0.75 for lifestyle character, and 0.60 for job character. This shows that the questionnaire displayed satisfactory internal consistency reliability

TABLE 4 Factor loading of the construct items in the MISQ (Loadings smaller than 0.5 have been omitted)

Old item number	Cognitive	Affective	Lifestyle	Job
1.1	0.71			
1.2	0.84			
1.3	0.79			
1.4	0.73			
2.1		0.63		
2.2		0.61		
2.3		0.82		
2.4		0.85		
2.5		0.82		
4.1			0.50	
4.2			0.60	
4.3			0.65	
4.4			0.76	
4.5			0.77	
4.6			0.76	
5.3				0.70
5.4				0.81
5.5				0.69

Note. The following items were removed from original survey: 3.1 (*irresponsible-responsible*), 3.2 (*irreligious-religious*), 3.3 (*non-peace loving-peace loving*), 4.7 (Scientists don't have much time for their families.), 5.1 (Scientists don't work for fame or money.), 5.2 (Scientific researchers are dedicated people who work for the good of humanity.).

and factor validity. Thus, further analyses supported the ability of the MISQ to investigate students' perception about scientists across different school levels, genders, regions, and living settings.

5.2 *Research Objective 2: The Use of the MISQ to Investigate the Patterns of Chinese Students' Mental Images of Scientists across School Levels, Genders, Regions, and Living Settings*

5.2.1 School Level Differences

Table 5 shows that students across different school levels had different perceptions of scientists' cognition, affects, lifestyles, and jobs. For the scientists'

TABLE 5 School-level differences of the four image constructs of the MISQ

Construct	F-test	Post hoc	Mean (SD)		
			Elementary school (N = 762)	Junior high school (N = 870)	Senior high school (N = 1,126)
Cognitive	44.385***	SH > JH*** SH > E***	4.29 (0.80)	4.34 (0.77)	4.57 (0.59)
Affective	23.786***	E > JH*** E > SH***	3.78 (0.85)	3.55 (0.86)	3.51 (0.87)
Lifestyle	2.812	No significant	2.08 (0.52)	2.10 (0.53)	2.05 (0.52)
Job	148.232***	E > JH > SH***	3.47 (0.54)	3.32 (0.54)	3.04 (0.55)

E = Elementary school, JH = Junior high school, SH = Senior high school.

*** $p < 0.001$.

cognitive character, senior high school students' scores were higher (4.57) than junior high school students' (4.34) and elementary school students' (4.29). However, in terms of affect, senior high school students scores were lower (3.51) than junior high school students' (3.55), while the elementary school students' scores were the highest (3.78). Similarly, elementary school students' job character scores (3.47) were highest, followed by junior high school students' (3.32) and senior high school students' (3.04).

Post hoc analyses revealed that senior high school students scored cognitive character higher than junior high and elementary school students did, but there was no statistical difference between junior high and elementary school students' scores (see Table 5). In contrast, elementary students scored affective character higher than junior high and senior school students did, but there was no statistical difference between junior high and senior school students' scores. In terms of job character, elementary students scored affective character higher than junior high and senior school students did, and junior high school students gave it a higher score than senior high students did.

5.2.2 Gender Differences

The cognition character was the only construct that was significantly different between boys and girls ($t(3774) = -2.248, p < 0.05$). Table 6 shows the mean and t -test results for gender.

TABLE 6 Gender differences of the four image constructs of the MISQ

Construct	Mean (SD)		df	<i>t</i> value	<i>p</i>
	Boys	Girls			
Cognitive	4.32 (0.81)	4.38 (0.77)	3,774	-2.248	0.025*
Affective	3.56 (0.88)	3.56 (0.86)	3,772	0.136	0.892
Lifestyle	2.40 (1.08)	2.45 (1.05)	3,796	-1.349	0.177
Job	3.38 (0.86)	3.39 (0.78)	3,796	-0.364	0.716

**p* < 0.05.

5.2.3 Regional Differences

As shown in Table 7, post hoc results showed that there were significant differences among different regions, regardless of the four subscales. Students in the east region (4.59) scored scientists as significantly higher in cognitive character than did students in the central (4.37), northeastern (4.31), and western (4.24) regions. Students in central region gave significantly higher scores in cognitive character than did students in central western. Students' responses showed a similar pattern for scientists' affective character. Students in the east region (3.72) scored scientists significantly higher in affective character than did students in the northeastern (3.65), central (3.53), and western (3.49) regions. However, students in the northeast region gave significantly higher scores than did students the central and western regions.

On the other hand, it appears that the students in the west (2.56) gave the highest scores for scientists' lifestyle (e.g., a scientist usually works alone), with higher lifestyle scores indicating more negative perceptions. Those in the east (2.28), central (2.36), and northeast (2.41) gave lower scores than those in the west did. In terms of job character (e.g., scientific researchers are dedicated people who work for the good of humanity), only the northeast and central regions were significantly different, with the scores from the northeastern (3.45) students higher than those of the central (3.34) students.

Overall, the highest student scores for scientists' character of cognition and affect were given by eastern students, indicating they thought scientists have higher cognitive and affective characters. The western students scored highest

on the scientist's lifestyle, suggesting they have more negative impressions of scientists. Compared to other regions, northeastern students gave the highest ratings in terms of scientists' job character. A significant difference was found between northeastern students and central students.

We observed that students from east regions, where the regions' economy has been highly developed, gave the highest scores on the cognitive and affective characters of scientists. Students from western regions, however, where the regions' economies are less highly developed, had a relatively negative impression of scientists. Perhaps, it is the liberal culture, information-rich, and human-connective environment of the east area that enabled students to hold a compressive and holistic view of scientists.

TABLE 7 Regional differences of the four image constructs of the MISQ

Construct	F-test	Post hoc	Mean (SD)			
			East	Central	West	Northeast
Cognitive	26.467***	East > Central*** East > West*** East > Northeast*** Central > West**	4.59 (0.59)	4.37 (0.78)	4.24 (0.85)	4.31 (0.79)
Affective	11.504***	East > Central*** East > West*** Northeast > Central** Northeast > West***	3.72 (0.84)	3.53 (0.86)	3.49 (0.87)	3.65 (0.91)
Lifestyle	12.532***	West > Central*** West > East*** West > Northeast*	2.28 (1.00)	2.36 (0.96)	2.56 (1.22)	2.41 (0.96)
Job	2.619*	Northeast > Central* Northeast >	3.37 (0.82)	3.34 (0.76)	3.40 (0.90)	3.45 (0.80)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

5.2.4 Living Setting Differences

Urban students scored scientists' cognitive character higher than did those in towns and rural areas did. Students who lived in towns rated affective, lifestyle, and job characters higher than those in rural and urban settings (Table 8). Post hoc analyses showed a consistent pattern that students who lived in town areas scored affective, lifestyle, and job characters significantly higher than did students in urban areas. This means that compared with urban students, they thought that scientists are high in affective character (e.g., selfish–caring) and have a worse lifestyles (e.g., scientists don't get as much fun out of life as other people do) and that their job (scientists don't work for fame or money) is valuable. Due to a tendency toward conservative culture and lower availability of information, town and rural students' evaluation of the lives and images of scientists tends to be incomplete and not all-inclusive (Whyte, 2010). In this situation, the asymmetry in information acquisition and cognition of science and technology professions provided us with possible explanations.

In contrast, urban students gave the highest scores for scientists' cognitive character, while students from towns gave the lowest. These results are consistent with the regional analysis finding indicating the importance of an environment of openness of culture and connection among humans. Compared with students in town and rural areas, however, urban students gave the lowest scores for scientists' lifestyle character and job character.

TABLE 8 Urban-rural differences of the four image constructs of the MISQ

Construct	F-test	Post hoc	Mean (SD)		
			Urban	Town	Rural
Cognitive	49.717***	Urban >	4.51	4.21	4.46
		Rural***	(0.66)	(0.83)	(0.60)
Affective	4.865**	Town >	3.51	3.68	3.57
		Urban**	(0.87)	(0.86)	(0.84)
Lifestyle	4.481*	Town >	2.05	2.11	1.98
		Urban**	(0.52)	(0.52)	(0.53)
Job	45.129***	Town >	3.18	3.49	3.40
		Urban***	(0.57)	(0.55)	(0.54)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

TABLE 9 The correlation between the four image constructs and interest in a science-related career

Construct name	Professional interest in science-related careers
Cognitive character	.037
Affective character	.214***
Lifestyle character	.086***
Job character	.209***

Note. The six items of lifestyle character were phrased in a negative way (e.g., scientists have few other interests but their work). Therefore, when calculating the correlation, the scores of the six items were reversed.

*** $p < 0.001$.

5.3 *Research Objective 3: The Relationships between Chinese Students' Mental Images of Scientists and Their Willingness to Pursue Science-Related Careers*

In general, the student mental images of affective, lifestyle, and job characters were positively correlated with their interests in pursuing science-related careers (Table 9), while cognitive character was not. It is important to note that the six items of lifestyle character were phrased in a negative way (e.g., scientists have few interests other than their work). Therefore, when calculating the correlation, the scores of the six items were reversed.

6 Discussion and Implications

In the present study, a factor analysis and Cronbach's alpha were used to test the construct validity and internal consistency reliability of the MISQ. Although the MISQ was adopted from the survey of Song and Kim (1999) and the questionnaire of the National Science Board of the United States (2020), neither had been tested for validity and reliability. The final version of the MISQ, consisting of four constructs, scientists' cognitive, affective, lifestyle, and job character, was tested for validity and reliability based on a large sample size of 2,758.

The moral construct was eliminated from the final version of MISQ based on the statistical results of principal component analysis. The three items included in the moral construct were related to three aspects: religion, responsibility,

and working for peace. We interpreted that students might not understand the meanings of these three aspects and the relationships between the three aspects and scientists' internal character. First, expressions of religious faith in public schools are strictly prohibited by an atheistic government in China (Nanbu, 2008). Students might not understand what religious belief is and the relationship between religious belief and scientists' internal character. Second, science curricula in China rarely mention scientists taking responsibilities in society and advocating for peace (Lee & Leung, 2006). Students lack opportunities to receive peace and social justice education. This probably is not the same in other countries when the items related to moral character are performed. Therefore, future research may need to test this construct in different countries and examine its construct validity.

The results of this study found that overall, Chinese students were highly positive in their perspectives on scientists' cognitive character and less positive about their affective character. Chinese students at different school levels held significantly different perceptions regarding the images of scientists' cognitive, affective, lifestyle, and job characters. Compared with middle and primary school students, high school students considered that scientists have a more positive cognition character and a less positive affective character. However, compared with high school and junior high school students, primary school students considered the work of a scientist more valuable. Our findings are in line with Gheith and Aljaberi's (2019) study of college students who were preservice teachers in Jordan that showed that they held positive attitudes toward scientists in terms of cognitive character and negative attitudes toward affective character. The present study uses the validated MISQ to move a big step beyond to provide evidence of Grades 1–12 students' perceptions about scientists.

In terms of gender differences, female Chinese students rated scientists more positively. In terms of regional differences, eastern regions' students held more positive viewpoints about scientists. In terms of job and lifestyle characters, students in this study still held stereotypes about scientists that were similar to other studies (e.g., Gheith & Aljaberi, 2019), and the proportion of students who expressed that they felt scientists were virtuous (e.g., scientists do not work for fame or money or scientific researchers are dedicated people who work for the good of humanity) in towns or rural areas was higher than that in cities. Although scientists were still sacred in the minds of Chinese students, it is worth noting that the proportion of those who approved of the sanctification of scientists decreased with the increase of Chinese students' education level.

In terms of regional differences and grade differences, we found students in more highly developed regions and in higher grades tended to hold a more rounded view of scientists. It is possible that they can access information more easily through different channels to understand scientists, such as reading more books or magazines about scientists and scientific news, watching more science programs, and discussing the diversity of perceptions of scientists. Therefore, they may be able to build up a more comprehensive and profound understanding of scientists.

The correlation results showed that Chinese student mental images of scientists' affective, lifestyle, and job characters were positively correlated with their interest in working as scientists, although this was not true of cognitive character. It is possible that students who gave a higher score in cognitive character tended to have more belief that the intelligence of scientists is higher than others'. This implies that development of positive views toward scientists' affective, lifestyle, and job characters may potentially motivate students to pursue science-related careers in the future.

Although this study tested and validated four constructs related students' mental images of scientists' characters, there are several aspects related to the nature of scientists' work, jobs, and careers that have not yet been examined. For example, scientists deal with uncertainties and continuously work through waves of uncertainty to develop and further their understanding of phenomena (Chen, 2022; Chen et al., 2019; Kampourakis & McCain, 2019). What students understand about the nature of scientists' work and the relationship between this understanding and students' motivation to pursue their future science-related careers needs more study. In addition, future research may need to explore the relationships between students' mental images of scientists' characters and the ways students engage in scientific practices such as argumentation (Chen et al., 2022; Phua & Tan, 2018), modeling (Ke & Schwarz, 2021; Lin et al., 2022), and sensemaking (Gutierrez, 2019; Odden & Russ, 2019).

Abbreviations

CASTED	Chinese Academy of Science and Technology for Development
DAST	Draw-A-Scientist-Test
MISQ	Mental Images of Scientists Questionnaire
STEM	Science Technology Engineering Mathematic

Ethical Considerations

Approval to conduct this study was granted by the Ethics Review Board of Southwest University in Chongqing and Chinese Academy of Science and Technology for Development (CASTD) in Beijing. The data collected from this project were obtained with the necessary clearance from the partner institutions, guardians, and the students involved in the study. The names of the school and participants used in this study are all pseudonyms.

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Appendix: Simplified Chinese Version

全国青少年科学家公众形象调查 学生问卷

亲爱的同学：

你现在参加的是一项由国家教育部门开展的全国性调查，目的是了解我国青少年对科学家的看法和科技教育的基本状况。请你仔细阅读每一个问题，并认真、独立地回答。

这不是一次考试，填答结果没有对错之分，请你根据自己的实际情况和想法，如实填答。**我们会按照《统计法》规定对你们的填写结果严格保密**，请你放心。

谢谢合作！

中国青少年科学家公众形象课题组

☆ 注意:在填答前, 请仔细阅读填答方法, 按要求填答问卷。

• • •

【填答方法】

- 1) 选择题:请在所选答案的选项序号上划圈(“.”)，例如③。一般情况下每题只能选择一个答案，注明“可多选”的题目可选多个答案；
- 2) 填空题:请直接在_____上填写数字或文字。数字为0的直接填“0”；
- 3) 请独立完成，不要向别人询问或查阅资料。

•••

请记录开始问卷填答的时间: _____月_____日_____点_____分

下面列出了一些评价，你觉得你心目中的科学家更符合哪种评价？

以A为例，如果你觉得科学家是“非常粗心的”，请圈选1，如果觉得科学家“比较粗心，”请选2，觉得这些人“既不是粗心也不是精细的”请选3，觉得“比较精细”请选4，觉得科学家“非常精细”请选5。其他依此类推。

A	粗心的	1——2——3——4——5	精细的
B	愚蠢的	1——2——3——4——5	聪明的
C	懒惰的	1——2——3——4——5	勤奋的
D	缺乏想象力的	1——2——3——4——5	富于想象力的
E	自私的	1——2——3——4——5	关心别人的
F	思想保守的	1——2——3——4——5	思想开明的
G	呆板无趣的	1——2——3——4——5	激情洋溢的
H	不懂艺术的	1——2——3——4——5	有艺术感的
I	不近人情的	1——2——3——4——5	有人情味的
J	不负责任的	1——2——3——4——5	有责任感的
K	不信仰宗教的	1——2——3——4——5	有宗教信仰的
L	不关心和平的	1——2——3——4——5	关爱和平的

下面有一些关于科学家的说法。你同意这些说法吗？

A	科学家总是一个人独自工作	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
B	科学家的工作不是为了出名或挣大钱	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
C	科学家是为了人类利益而奉献的人	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
D	科学家没有机会享受生活的乐趣	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
E	科学家大都性格古怪，与众不同	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
F	大多数科学家做的是改善人类生活的事	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
G	科学家只知道工作，没有别的兴趣爱好	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意

(cont.)

H	科学家处理不好生活上的事情	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
I	科学家 <u>不知道</u> 怎样跟别人交往	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
J	科学家没有太多时间陪伴家人	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
K	科学家的工作比较危险	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意
L	女性不太适合做科学的研究工作	1 完全同意 2 基本同意 3 没意见 4 不太同意 5 完全不同意

问卷填答的结束时间:_____点_____分

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学生问卷调查到此结束, 谢谢你的配合。

祝你学习进步!