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CHINESE PRE-SERVICE SCIENCE TEACHERS' VIEWS OF THE SOCIAL RESPONSIBILITY OF SCIENTISTS AND ENGINEERS

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Abstract. *Scientific and technological research is important to everyone because their results affect humanity worldwide. Although science and technology bring many benefits to humanity, individuals and societies can face the negative consequences of science and technology. To prevent and solve the negative consequences of research in these fields, it is important to educate scientists and engineers to have social responsibility. However, no research has addressed pre-service science teachers' views of social responsibility in literature. Therefore, this study aimed to explore Chinese pre-service science teachers' views on the social responsibility of scientists and engineers. The research participants were 194 pre-service science teachers. A social responsibility instrument was administered for data collection. The results showed that participants had high mean scores in five areas of social responsibility and a good awareness of the role of scientists and engineers in addressing problems and risks related to human, environmental, and societal impacts. However, they had lower mean scores in three areas requiring action or involvement. In addition, the results did not show statistical differences by gender or grade level. In light of our findings, we conclude pedagogical and practical implications for teachers and researchers in teaching social responsibility.*

Keywords: *pre-service science teachers, science education, social responsibility, social responsibility of scientists and engineers, quantitative research*

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Introduction

The progress of research in science and technology is important to everyone because every person living in the world is affected by the results of science and technology. Although research in science and technology brings many benefits and advantages to humanity, individuals and societies may face negative consequences (Tonn & Stiefel, 2019). To minimize and prevent the negative consequences of research in these fields, it is important to educate engineers and scientists to be socially responsible (Bielefeldt & Canney, 2016; Ko et al., 2023; Varma, 2000). Social responsibility derives from the "ethics of theory" concept first proposed by Noddings (1984). Specifically, the ethics of theory refers to "*...the willingness and capacity to take responsibility that "something" is done to provide for the need in question*."(Sevenhuijsen, 2003, p. 21). Thus, this theory consists of attending to the needs of someone and something. In today's world, people and countries must have engineers and scientists to solve the more complex problems faced by people and societies, such as the coronavirus-19 epidemic, environmental pollution, dangerous chemicals, and global warming (Ambusaidi & Al Fulaiti, 2022; Kirby, 2021; Nkaizirwa et al., 2021). Considering that scientists and engineers use their unique knowledge and skills to solve the most complex problems, they have an increased responsibility to benefit humanity and protect it from the bad consequences of unprecedented developments such as COVID-19 (Bielefeldt & Canney, 2016; Buie, 2017; Canney & Bielefeldt, 2015; Kobylarek, 2019; Sakharov, 1981; Zandvoort, 2007). Having more socially responsible graduates in science, technology, mathematics, and engineering (STEM) fields requires understanding the societal impacts of scientific and engineering research (Bielefeldt & Canney, 2016; Godhade & Hundekari, 2018; Ko et al., 2022).

In the literature on science education, much more research has been conducted over the past three decades, using the "views on science, technology, and society (VOSTS)" instrument developed by Aikenhead and Ryan (1992) to examine the social responsibility of pre-service science and science teachers. However, the VOSTS instrument included a few items regarding being socially responsible (Ko et al., 2023). It is generally accepted that since

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the emergence of COVID-19, the importance of scientists and engineers using their knowledge and skills to benefit society seems to have increased at a higher level. Therefore, it is necessary to emphasize the importance of promoting the social responsibility of scientists and engineers. In this parallel, it is important to research the views of individuals who will implement the teaching profession in STEM fields. In particular, it is a revealing question to what extent the students in teacher education programs are aware of the social responsibility of scientists and engineers. However, in the research literature, only a few studies have examined pre-service teachers' views of scientists and engineers. For example, a study by Ko et al. (2022) explored STEM undergraduate majors' views on the social responsibility of scientists and engineers in South Korean universities. Their results showed that the average scores for three factors (HUMAN, ENVIR, and CONSEQ) were relatively higher than the other five factors (NEEDS, COMGOOD, CIVIC, COMMU, and POLICY). Their cluster analysis revealed five distinct groups with similar patterns of social responsibility. Another study by Lee et al. (2022) studied the views of PSTs on the social responsibility of scientists and engineers on socioscientific issues and a problem-based inquiry approach. Their results showed that pre-service science teachers' views on social responsibility had changed statistically significantly after the project. The pre-service science teachers seriously engaged with the social responsibility of scientists and engineers by studying science and technology and engaging in problem-solving and action. Specifically, the researchers found that PSTs agreed to address societal needs and demands, pursue the common good, use their expertise to engage and help the community, communicate about potential risks, and participate in policy-making. In addition to these, researchers have conducted some studies to explore and understand the views of engineering students and graduates in STEM fields (Bielefeldt & Canney, 2016; Canney & Bielefeldt, 2015). In general, the results of these studies showed that engineering students in STEM fields accepted the importance of engineering skills to impact society positively and have an awareness of helping people in need. However, the results showed that the awareness of participating in science and technology research is lower (Canney & Bielefeldt, 2015).

A review of existing studies on social responsibility in science education reveals that very little information about social responsibility is known to scientists. However, much is not known about prospective science teachers' understanding of the social impact of scientific and engineering research and what factors are effective in understanding social responsibility from the perspective of pre-service teachers who will teach future STEM majors in schools. Only one study on social responsibility examined prospective science teachers' views (Lee, Ko, & Hong, 2022). Therefore, there is a need to examine how PSTs think about social responsibility. For this reason, the present study aimed to examine pre-service science teachers' views on the social responsibility of scientists and engineers. The research question guiding this study was: What are pre-service science teachers' views on the social responsibility of scientists and engineers? The present study helps to fill a research gap in the literature by providing new insights for educators and scientists and a better understanding of views on social responsibility.

Research Methodology

Design

The present study was conducted using a quantitative research design to answer the research question. The quantitative research design, as Creswell states, "*employs strategies of inquiry such as experimental and surveys and collects data predetermined instruments that yield statistical data*" (Creswell, 2003, p. 18). The nature of this research design includes collecting quantitative data on several variables studied to answer the research question. Researchers (Cohen & Manion, 1994; Creswell, 2003) have pointed out that research that uses questionnaires or surveys to collect data can be classified as quantitative research design. Quantitative data in this research were collected using an instrument developed by Ko et al. (2023). The independent variables were gender and grade level, and the dependent variable was pre-service science teachers' views about the social responsibility of scientists and engineers. The study was conducted over two weeks in October 2022. The participants who enrolled in the Faculty of Education at a public research university in Beijing, People's Republic of China, were invited to the research. Under the scope of this study, the participants were invited through university professors who gave courses at the faculty. Two hundred fifty copies of the instrument consisting of thirty items were administered to the participants. In this study, random sampling was used. All of the participants agreed to participate voluntarily in the research. Of the 228 copies answered by the participants, 194 valid questionnaires were responded to by the participants, with a retrieval rate of 86%. The participants were enrolled in the Department of pre-service science teacher education. While collecting the data, the participants' demographic information and their responses to the instrument's

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items were asked. The participants did not write their names and last names while responding to the items. All the participants had the opportunity to give their responses freely.

Participants

A total of 194 PSTs were invited to participate in the present study because they were easily accessible and convenient sampling for research and also had some characteristics necessary for the research, such as being PST and belonging to different gender and grade levels to allow for comparison across genders and grade levels (Creswell, 2003). The participants' demographic information is presented in Table 1. Of the participants, 52.6% were male, while 47.4% were female. Most participants were in the fourth grade at Tsinghua University in 2022 (53.6%). The percentages of other grades in 1, 2, and 3 were 15.5%, 19.1%, and 11.9%, respectively. The participants received courses about the history of science and technology, science-technology-society, and science communication and museum.

Table 1
The Participants' Demographic Information

		n	%
Gender	Male	102	52.6
	Female	92	47.4
Grade Level	1	30	15.5
	2	37	19.1
	3	23	11.9
	4	104	53.6
	Total	194	100.0

Data Collection Instrument

To collect data in this study, an instrument developed by Ko et al. (2022) was used to measure participants' views on the social responsibility of scientists and engineers. Ko et al. (2022) named the scale: "Views of Social Responsibility of Scientists and Engineers (VSRoSE)". The instrument consists of thirty (30) items and eight factors. These factors are referred to by the researchers as (1) concern for human welfare and safety, (2) concern for environmental sustainability, (3) consideration of societal risks and consequences, (4) consideration of societal needs and demands, (5) pursuit of the common good, (6) civic engagement and services, (7) communication with the public, and (8) participation in policy decision making.

When Ko et al. (2022) developed the VSRoSE, they aimed to include all aspects of social responsibility based on the ethics of theory. The studies of Ko et al. (2022) resulted in a valid and reliable instrument to measure people's views on the social responsibility of scientists and engineers. The VSRoSE is the most recent instrument developed in the literature to cover a broader spectrum of social responsibility.

After using the VSRoSe instrument in this study, a reliability analysis and calculated Cronbach's alpha value for thirty items were performed. For all items used in this study, obtained a Cronbach's alpha value of .88 was found. This value suggests that the data collection instrument is reliable for data collection and analyses.

Procedure

To use the VSRoSE instrument in this study, a bilingual science educator fluent in Chinese and English translated it into Chinese. Following this translation, another science educator fluent in both languages translated the instrument from Chinese to English. Then the researchers asked three scientists who teach courses in the same

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department to review and rate the original and back-translated versions of the instrument to compare and assess the comprehensibility of the language and items. They gave the researchers some minor feedback on the words and items. Once the experts' feedback on the translated and back-translated versions was available, the researchers finalized the final version of the instrument and began to use it in the research. The VSRoSE instrument was administered to prospective teachers in October 2022. A total of 194 students responded to the instrument with surveys, with a response rate of 86%. Two researchers asked pre-service teachers and their professors to assist participants in responding to the data collection instrument. The researchers informed the participants of the purpose and scope of the survey and guaranteed that their responses would not be shared with third parties. Researchers answered participants' questions about the research and the elements of the data collection instrument. The researchers found that participants could answer the instrument in 20 to 40 minutes. Participants answered the instrument in their classroom at the faculty of education. To answer the research question, participants were limited to prospective teachers.

Data Analysis

We performed descriptive statistical analyses for the instrument by performing measures and normality checks by skewness, kurtosis, mean, and standard deviations to generate the results. Table 2 presents the results regarding the descriptive statistics. We checked all assumptions for normality and parametric analyses during the descriptive analysis. After performing the analysis, the results revealed a normal distribution and the option of performing parametric analyses. In addition, we performed a t-test to understand the differences between the mean scores of male and female participants. Additionally, a one-way ANOVA analysis was conducted to identify significant and nonsignificant differences between grade levels, and Cronbach's alpha value to test the instrument's consistency and reliability in this study. Because Cronbach's alpha value (Cronbach's alpha value was 0.85) is higher than > 0.7, the instrument used in the study was appropriate for this study. All statistical analyzes were performed using the SPSS 29.0 data editor.

Research Results

Table 2 shows the descriptive results of the participants' views of the social responsibility of scientists and engineers. The results revealed that the participants' views were within a specific range. Their views vary in range from 3.87 to 4.12. The results also revealed that the participants had a good awareness of concern for environmental sustainability (ENVIR), civic engagement and service (CIVIC), consideration of societal risks and consequences (CONSEQ), communication with the public (COMMU), and the pursuit of the common good (COMGOOD), while concern for human welfare and safety (HUMAN), Consideration of societal needs and demands (NEEDS), and participation in policy-making (POLICY) were the lowest. In sum, mean scores for interest in and consideration of human, environmental, and social impacts (ENVIR and CIVIC, CONSEQ, COMMU, and COMGOOD) tended to be higher than mean scores for areas directly related to social practice (NEEDS and POLICY).

Regarding the individual subfactors, the HUMAN area consisted of items about social responsibility in scientific and technological research and the impact of the results on human health and safety. All items in this area generated moderate awareness of the impact of scientific and technological research on humans. The average scores ranged from 3.79 to 4.15 points (See Table 3). In particular, item five, "Prevent humans from the risks at the least," received the highest mean scores compared to the first four items. This result shows that the participants agreed with using science and technology to prevent humans from facing risks.

Table 2
The Descriptive Statistics Results

	Number of items	Min.	Max.	*M*	*SD*	Skewness	Kurtosis
HUMAN	5	1.60	5.00	3.87	0.76	-.766	.410
ENVIR	3	2.33	5.00	4.12	0.59	-.507	-.155

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	Number of items	Min.	Max.	*M*	*SD*	Skewness	Kurtosis
CONSEQ	5	3.00	5.00	4.05	0.49	-.265	-.804
NEEDS	3	2.00	5.00	3.91	0.72	-.648	-.180
COMGOOD	3	3.00	5.00	4.09	0.54	-.346	-.717
CIVIC	5	2.40	5.00	4.12	0.57	-.739	.237
COMMU	3	2.33	5.00	4.11	0.72	-.436	-.890
POLICY	3	1.33	5.00	3.93	0.79	-.593	.057

The second subfactor, consideration of the sustainable environment (ENVIR) area, included the responsibility of scientific and technological research to minimize various risks to the ecosystem and environment. The participants rated the items in this area with higher mean scores. All items in this factor had a high average score of 4.11 to 4.15. This result means that the participants approve of using science and technology to promote the ecosystem and environment and increase sustainable development.

The third subfactor, consideration of societal risks and consequences (CONSEQ), included five items about identifying and recognizing social problems during science and technology research. These five items received high recognition ranging from 3.96 to 4.19 points. The results demonstrated that the pre-service teachers support science and technology to avoid societal risks and problems.

Regarding the fourth subfactor, the Social Needs and demands (NEEDS) area consisted of three items. The items in this area are related to the responsibility of scientists and engineers for the needs of society in scientific and technological research. These items' mean scores are between 3.78 and 4.10 points. One statement, item 15, asked about conducting research following society's values and expectations, received a lower score than the other two items in this factor.

Results on the fifth subfactor, the pursuit of the common good (COMGOOD) area, included three items that asked about the purpose of research to promote human life and welfare. Mean scores ranged from 3.98 to 4.18 on this factor. For example, the 17th item, emphasizing that research can improve the quality of human life, received a good score (4.13 points). Another item (18), which asks about promoting human welfare and safety as the main goal of one's research, received a better average score (4.18 points). This result means that participants approve of the scientist and engineers' responsibility to foster the quality of people's lives.

The sixth subfactor, civic engagement and services (CIVIC) included five items related to the responsibility of scientists and engineers to solve societal problems related to science and technology. The mean scores of the items in this factor ranged from 4.01 to 4.26 points. Item 23, which asked about collaborating with knowledgeable and interested citizens to solve problems related to science and technology, had the lowest score in this factor. Another item, 20, which asked about willingness to participate in civic affairs in solving problems related to science and technology, had the highest mean scores in this domain. Communication with the public (COMMU), the seventh subfactor of the VSRoSE instrument, contained three questions that asked about the responsibility of scientists and engineers to communicate with the public, to use simple language that all people can understand, and to explain to the public knowledge and research needed to solve societal problems. The result shows that all three items received a good average score between 4.11 and 4.12.

The last subfactor, participation in political decision-making (POLICY), had the lowest scores, ranging from 3.84 to 4.13. The items in this area asked about participation in the policy-making process related to science and technology. In particular, item 29, which refers to active participation in the policy-making process related to science and technology, received the lowest recognition in the survey (3.85 points). Table 3. Descriptive statistics of VSRoSE responses according to items.

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Table 3
Descriptive Statistics of VSRoSE Responses for Each Item

Factors	Items	*M*	*SD*
Concern for Human Welfare and Safety HUMAN	1. Not harm human health at the least	3.81	0.99
	2. Place utmost importance on human health	3.79	1.00
	3. Be vigilant whether his/her research risks human safety	3.82	0.98
	4. Consider the possible adverse effects on human health	3.81	0.99
	5. Prevent humans from the risks at the least	4.15	0.79
Concern for Environmental Sustainability ENVIR	6. Protect the environment during the research process	4.15	0.80
	7. Minimize the effects on the ecosystem	4.12	0.84
	8. Promote sustainable development in the environment	4.11	0.83
Consideration of Societal Risks and Consequences CONSEQ	9. Recognize the potential social problems in one's area of expertise values of multiple stakeholders	3.96	0.71
	10. Be able to identify social problems inherent in modern science and Technology	4.19	0.73
	11. Be cognizant of the contribution that one's work can make to the advancement of the field	4.09	0.76
	12. Be able to identify pressing social problems in one's area	4.00	0.76
	13. Carefully examine the conflicting	4.03	0.91
Consideration of Societal Needs and Demands NEEDS	14. Consider whether one's research generates knowledge needed by the society	4.10	0.99
	15. Conduct research consistent with the values and expectations of the society	3.78	1.08
	16. Identify the societal needs and expectations for scientific and engineering research	3.87	0.95
Pursuit of the Common Good COMGOOD	17. Conduct research that can enhance the quality of human life	4.13	0.74
	18. View the promotion of human welfare and safety as a primary goal of one's research	4.18	0.72
	19. View reducing the challenge that people experience in their daily life as an important goal of one's research	3.98	0.76
Civic Engagement and Services CIVIC	20. Be willing to participate in civic affairs if the goal of the affair is to solve the problems related to science and technology	4.26	0.71
	21. Collaborate with the general public and citizens to solve the problems related to science and technology	4.10	0.75
	22. Actively encourage others to participate in solving problems related to science and technology	4.14	0.75
	23. Collaborate with knowledgeable and interested citizens to solve problems related to science and technology	4.01	0.79
	24. Serve an advisory role for the public in their area of expertise	4.10	0.73
Communication with the Public COMMU	25. Make the public familiar with science using media such as books, articles, blogs, and lectures	4.11	0.81
	26. Explain the knowledge and research necessary for solving social problems to the public	4.11	0.81
	27. Knowledge or research regarding science and technology should be explained in a way that is easy for the general public to understand	4.12	0.85
Participation in Policy Decision Making POLICY	28. As a member of a professional organization of scholars, one must influence the policy-making process related to science and technology	4.13	0.87
	29. Actively participate in a policy-making process related to science and technology	3.85	0.92
	30. Emphasize its importance and this must attract investment in science and technology	3.84	0.94

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Table 4 shows the results of the mean scores of male and female prospective teachers on the social responsibility of scientists and engineers. Accordingly, male participants scored higher on the COMMU, CIVIC, ENVIR, CONSEQ, and COMGOOD subfactors. They scored lower on the subfactors HUMAN and POLICY. They had the lowest mean score on the subfactor POLICY. On the other hand, female participants had higher scores on ENVIR, CIVIC, COMMU, COMGOOD, and CONSEQ, POLICY. However, females had the lowest scores on the subfactors HUMAN and NEEDS. In addition, we found the lowest mean scores for males and females in the HUMAN area. As can be seen from the mean scores in Table 4, the results of the t-test showed no significant differences between all subfactors of the instrument.

Table 4
Comparison of Factors According to Gender

Factors	Male		Female		*t*	*p*
	M	*SD*	*M*	*SD*		
HUMAN	3.88	0.77	3.87	0.76	.132	.895
ENVIR	4.09	0.58	4.16	0.60	-.799	.425
CONSEQ	4.02	0.48	4.08	0.49	-.749	.455
NEEDS	3.95	0.63	3.86	0.80	.836	.404
COMGOOD	4.10	0.55	4.09	0.54	.090	.928
CIVIC	4.08	0.60	4.16	0.53	-1.056	.292
COMMU	4.16	0.74	4.05	0.70	1.138	.257
POLICY	3.87	0.85	4.01	0.72	-1.183	.238

Table 5 shows the results of a one-way ANOVA analysis to compare the mean scores in each subfactor according to grade levels among the PSTs. The results with students' grade levels show no significant differences in all sub-factors. The average scores in all grades revealed no significant differences.

Table 5
One-Way ANOVA Results for Comparison According to Grade Level

ANOVA						
		SS	*df*	*MS*	*F*	*p*
Human	Between Groups	.708	3	.236	.399	.754
	Within Groups	112.509	190	.592		
	Total	113.218	193			
Envir	Between Groups	1.159	3	.386	1.098	.351
	Within Groups	66.816	190	.352		
	Total	67.975	193			
CONSEQ	Between Groups	1.169	3	.390	1.629	.184
	Within Groups	45.454	190	.239		
	Total	46.624	193			

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ANOVA						
		SS	*df*	*MS*	*F*	*p*
NEEDS	Between Groups	2.353	3	.784	1.515	.212
	Within Groups	98.383	190	.518		
	Total	100.736	193			
COMGOOD	Between Groups	1.040	3	.347	1.156	.328
	Within Groups	56.988	190	.300		
	Total	58.028	193			
CIVIC	Between Groups	1.743	3	.581	1.791	.150
	Within Groups	61.626	190	.324		
	Total	63.369	193			
COMMU	Between Groups	1.406	3	.469	.880	.452
	Within Groups	101.210	190	.533		
	Total	102.616	193			
POLICY	Between Groups	.442	3	.147	.230	.875
	Within Groups	121.412	190	.639		
	Total	121.854	193			

Discussion

This study aimed to explore Chinese PSTs' views on the social responsibility of scientists and engineers. The overall results revealed that pre-service teachers had a good awareness of ENVIR, CIVIC, COMMU, CONSEQ, COMGOOD, CONSEQ, and COMGOOD, while HUMAN, NEEDS, and POLICY areas were the lowest. Ko et al. (2022), who studied social responsibility with science and engineering students in South Korea, are very similar to the results in ENVIR, COMMU, CONSEQ, and COMGOOD. Our results are not comparable to those of Ko et al. (2022) regarding the HUMAN and CIVIC areas. In our study, in contrast to the results of Ko et al. (2022), the lowest average values for the area HUMAN.

The overall results demonstrate that the mean scores for interest in and consideration of human, environmental, and social impacts (ENVIR and CIVIC, COMMU, CONSEQ, and COMGOOD) tended to be higher than mean scores for areas directly related to social practice (NEEDS and POLICY). This result is very similar to the study of Ko et al. (2022). However, our study found the lowest mean scores for the HUMAN and higher mean scores for the CIVIC areas. Therefore, the results regarding HUMAN and CIVIC areas differ from Ko et al.'s study (2022). In light of the results, the participants had the lowest mean scores regarding the areas that required social participation and action in science and technology research. For example, the participants indicated the lowest mean scores in the policy area compared to the other areas. Such a finding appears in the study of Ko et al. (2002) for the same area. This result may be because Chinese pre-service teachers wanted to avoid being part of a process that requires engagement and participation in science and engineering research. The reason for these results may stem from cultural factors. Similar to our results, the other researchers (Canney & Bielefeldt, 2015; Ko et al., 2022) who studied social responsibility have reported similar results. For example, Canney and Bielefeldt's (2015) results showed that engineering students agreed more strongly with the importance of basic engineering skills and the ability of engineers to impact society positively. However, these same students agreed less regarding their personal or professional commitment to helping others. The agreement of participants in many

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areas of social responsibility can be explained by the nature of the ethics of care theory first proposed by Noddings (1984) in the early 1980s. This theory accepts social responsibility as its second dimension (Sevenhuijsen, 2003). According to this theory, social responsibility explains the willingness and capacity to take responsibility for doing something for a specific need.

This study showed no significant differences regarding participants' views of social responsibility across all subfactors (see Table 4). Part of this result is consistent with that of Ko et al. (2002), and the other part is not consistent with the study of Ko et al. (2022). They found significant differences in Human, Envir, and Conseq in favor of the female participants. Moreover, our results are not related to the studies suggesting the ethics of the theory with females (Bergmark & Alerby, 2006). For example, Bergmark & Alerby (2006) indicate that researchers have associated care ethics with females.

The results regarding the grade levels of the participants showed no significant differences. This result is consistent with Ko et al. (2022), who found no significant differences among grades of science and engineering majors in all areas. This result is interesting because the participants who enrolled in the fourth grade of education faculty received some courses on the nature of science and science-technology-society. In these courses, they were taught about the impact of science and technology on society. However, the results showed no differences between grade levels. In light of these findings, taking some science and engineering education courses may produce a poor awareness of the social responsibility of scientists and engineers.

Conclusions and Implications

This study aimed to examine Chinese PSTs' views on the social responsibility of scientists and engineers. Since more information is needed about how PSTs view the social impact of scientific and engineering research, what factors are influential in understanding social responsibility from their perspective, and who will teach future STEM majors in schools, there has been a research gap in the literature. Because of this reason, the present study was necessary. The results revealed that pre-service science teachers had high mean scores in five areas of social responsibility and a good awareness of the role of scientists and engineers in addressing problems and risks related to human, environmental, and societal impacts. However, the results also revealed lower mean scores in three areas requiring action or involvement. In addition, the results did not show statistical differences according to gender and grade level. Considering there has been no research on the views of PSTs on the social responsibility of scientists and engineers, the results obtained from this study present new insights into researchers' knowledge and add new findings to the literature. Thus, the present study contributes to the literature by adding new perspectives for researchers. In addition, the study has helped to fill a critical research gap in the literature. This study is an important starting point to emphasize the importance of socially responsible teachers in the science education literature. Future researchers should put more effort into understanding pre-service teachers and the underlying factors that shape their understanding of social responsibility.

Recommendations

The present study presents critical implications for pre-service science teacher education. First, this study presents important findings about the social responsibility of PSTs. The results have the potential to contribute to the literature. Future research should continue to consider social responsibility as part of the STEM education of prospective teachers. The results of this study allow researchers to draw some conclusions about teaching social responsibility in science and engineering research. In particular, a greater emphasis on science and technology research in a societal context could enable prospective science teachers to develop their understanding of the impact of science and technology on society and social problems. To enhance pre-service teachers' understanding of the social responsibility of scientists and engineers, educators and scientists in teacher education should aim to provide prospective teachers with diverse experiences and learning opportunities about the societal impacts of science and technology. Teacher education that provides opportunities and courses that combine science, engineering, and social responsibility will result in socially responsible teachers who teach STEM in schools. The experiences and opportunities provided by educators and scholars to participate in a science and engineering research project or to observe the effects of science and technology developments will enhance pre-service teachers' awareness and understanding of the impacts of science and technology on society and

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social problems. To this end, pre-service teachers should be encouraged to participate in activities for everyone or students organized by professional associations of scientists and engineers. In addition, further research is needed to measure the impact of these types of activities on the social responsibility of prospective teachers.

The findings suggest that prospective science teachers need to be encouraged to educate them about the positive impact of science and technology on society and social problems. In this way, science education can achieve its goal of having socially responsible teachers and STEM graduates. Educators need to teach social responsibility in their courses by emphasizing the impact of science and engineering on society, and their social impact should be emphasized in the education of science teachers.

Second, because this research was conducted with a specific group of participants, future research must include diverse participants from different cultural and educational contexts. Given that the number of research studies on social responsibility and prospective science teachers is very limited, more research needs to be conducted with prospective science teachers in different countries and cultures. Third, the results showed that pre-service teachers are less fearful of participating in the research process in science and technology. Given the lack of educational interventions that emphasize the social responsibility of scientists and engineers in teacher education, tailored practical suggestions and educational programs are needed to be developed by educators and scholars.

Limitations

First, this research involved a limited number of PSTs. Second, a quantitative data collection method was used to answer the research question. Therefore, the results have some limitations related to the type of data collection instrument used. Although we used a newly developed and more comprehensive social responsibility instrument, additional data collection instruments may be considered by other researchers. The PSTs' views of social responsibility may vary depending on participants' backgrounds, cultural and educational contexts, and discipline. In light of these factors, our study may have some limitations.

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