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Examining preservice science teachers' perspectives on the social responsibility of scientists and engineers

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Abstract

This study aimed to examine preservice science teachers' views on the social responsibility of scientists and engineers. A total of 153 students enrolled in Russian public university formed as the participants. We assessed the social responsibility of pre-service teachers using a scale, "Views of Social Responsibility of Scientists and Engineers" (VSRoSE), developed by previous researchers, and included eight different areas of social responsibility. The results indicated that the preservice biology, chemistry, and science teachers who participated in this study had high awareness of human welfare and safety, a sustainable environment, and consideration for social risks and impacts. However, their awareness related to practice and participation was relatively low. Female students had more scores than male students in all areas. The results also revealed that chemistry students had slightly higher average scores than the other majors in all areas of the scale. The average scores in all age groups showed slight differences. This study provides a starting point for researchers and teachers to comprehend preservice science teachers' views on the social responsibility of scientists and engineers in resolving humanity's greatest problems from the perspective of preservice science teachers. With this respect, this study contributes insightful information to the literature and fills a gap in the research. We hope that future researchers will concentrate on enhancing pre-service teachers' understanding of the social responsibility of scientists and engineers and on educating more socially responsible teachers who recognize the importance of science and engineering research's impact on society. This study also indicates that PSTS were less concerned with the role of social responsibility in promoting scientific research in science and engineering. This finding suggests the necessity of emphasizing the positive impact of science and engineering research on society and the significance of incorporating social impact into teacher education. This emphasis on the significance of social responsibility will assist in comprehending the effects of science and engineering within a social context on professional responsibility.

Keywords: preservice science teachers, social responsibility, teacher education, social impact

INTRODUCTION

New advances in science and technology have sparked many debates, including ethical, moral, and social issues related to their use in daily life (Sedano Aguilar, 2022). For example, genetically modified products, hazardous chemicals in agriculture, pollution, and global warming have generated many debates in

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Contribution to the literature

- The social responsibility of scientists and engineers has become very important to help people with the negative and unprecedented consequences of scientific and technological research.
- Despite the importance of social responsibility and the development of students' views and perceptions of social issues in current educational standards, no research on preservice teachers who will be responsible for teaching and developing students' social responsibility in schools does not exist in the current literature.
- Since none of the previous studies have examined preservice teachers' perceptions of the social responsibility of engineers and scientists, the results of this study are new and an important contribution to scientific literature. The results of this study can serve as a starting point for comparing and assessing differences across contexts and demographic groups.

societies worldwide. Because it is difficult to predict the negative or positive consequences of technological advances and developments in science and technology, it is extremely difficult for anyone to predict and monitor the potential risks and negative effects of new technologies and products. For example, the emergence of the COVID-19 pandemic in 2020 was an unforeseen problem for everyone worldwide. Against the negative impact of COVID-19, scientists and engineers developed a virus vaccine to protect humanity in line with their responsibility. This responsibility of scientists and engineers was a great and meaningful contribution to protecting humankind in a sustainable world society. However, with the development of a virus vaccine against COVID-19, many debates about the use of the vaccine among university students and even scientists in many cultures of the world have been raised (Sharma et al.. 2021). The unprecedented developments in scientific and engineering research, such as the pandemic, have led to the need for scientists and engineers to take on a new social responsibility to protect all humanity from the negative consequences.

Scientists and engineers must realize their full potential to make a meaningful contribution to individuals and society in solving the new problems they face (Godhade & Hundekari, 2018). Bielefeldt and Canney (2016, p. 1536) stated, "*Social responsibility is an ethical theory that individuals and collective groups have an obligation and duty to perform to benefit society, the environment, and the economy*." Societies and countries need the social responsibility of scientists and engineers because of their unique knowledge and skills to solve the problems that will save humanity from various dangers and harms (Bielefeldt & Canney, 2016; Ko et al., 2021; Sakharov, 1981). At this point, the social responsibility of scientists and engineers has become very important to help people with the negative and unprecedented consequences of scientific and technological research (Erna et al., 2023; Zandvoort et al., 2013; Zhang, 2023). Although the need for the knowledge and expertise of scientists and engineers has greatly increased since March 2020 with the emerging COVID-19 pandemic, the number of studies dealing with social responsibility is minimal. As far as we know, scholars have conducted few studies (e.g., Zhang, 2023) that have examined the views on the social responsibility of scientists and engineers. For example, Ko et al. (2022) studied the views of Korean STEM college students on the social responsibility of scientists and engineers. They found that students' mean scores on three factors (HUMAN, ENVIR, and CONSEQ) were relatively higher than those on the other five (NEEDS, COMGOOD, CIVIC, COMMU, and POLICY). Cluster analysis identified five distinct groups with similar patterns in social responsibility scores. The results suggested that low social responsibility students are not homogeneous. In a recent study, Lee et al. (2022) investigated the effects of a project to promote preservice science teachers' (PSTs) views on the social responsibility of scientists and engineers through socioscientific issues using problem-based inquiry approaches. The results showed that PSTs showed statistically significant changes in their views on social responsibility after the project. The results also showed an increase in the five sub-dimensions of social responsibility. The PSTs seriously considered the social responsibility of scientists and engineers through epistemological exploration of science and technology and problem-solving and action. Specifically, the researchers found that PSTs agreed more about addressing societal needs and demands, pursuing the common good, civic engagement and service using their expertise, communicating with the public about potential risks, and participating in policy decisions related to scientific and technological advances.

In one of the earlier studies in the literature, Canney and Bielefeldt (2015) investigated the views of students in civil, environmental, and mechanical engineering programs at various institutions to determine the developmental model of professional social responsibility. They administered a survey instrument to engineering undergraduate students who completed the survey at the beginning of the year. Their results showed that engineering students agreed more with questions about their awareness of people in need but less about their personal or professional commitment to helping others. Student respondents also agreed to a high degree, and with a lower standard deviation, with

questions related to the importance of engineering skills and the ability of engineering to have a positive effect on society. Another study by Bielefeldt and Canney (2016) examined how engineering students' views of their responsibility toward helping individuals and society through their social responsibility profession change over time. They conducted the study with senior-year and graduate students studying mechanical, civil, and environmental engineering. Their results showed that most students (57%) had not changed significantly in their attitudes toward social responsibility, but 23% decreased and 20% increased. Students whose attitudes toward social responsibility increased, decreased, or remained the same over time did not differ significantly in gender, academic rank, or major. They found some differences across institutions. Students who decreased their social responsibility attitudes had more positive social responsibility attitudes, were less likely to report that college courses influenced their social responsibility views, and were less likely to participate in volunteer activities than students who did not change or increase their social responsibility attitudes.

Although the results of these studies help understand views on social responsibility, a few research studies have examined the views of STEM majors on social responsibility (Erna et al., 2023; Zhang, 2023). In light of Beckwith and Huang's (2005, p. 1479-1480) statements that "*few students of science receive as an integral part of their scientific education an analysis of the social impact of science and rarely is there any mention of social responsibility,*", teaching and understanding social responsibility as it relates to future scientists and engineers have become necessary for educators and researchers. Despite the importance of social responsibility and the development of students' views and perceptions of social issues in current educational standards, no research on preservice teachers who will be responsible for teaching and developing students' social responsibility in schools does not exist in the current literature. Previous research on social responsibility has only focused on the views of engineering and STEM students in the science and technology field (e.g., Erna et al., 2023; Ko et al., 2022). At the same time, no information is known about pre-service teachers' views on social responsibility because we could not find any study that examined preservice teachers' views on social responsibility. In addition, as interdisciplinary fields become more integrated and collaboration across disciplines becomes more important, gathering students' views from different fields is valuable. Social constructs shape the views on the social responsibility of engineers and scientists. Various stakeholders, such as students, teachers, and educators, work together to develop a shared understanding of social responsibility, including promoting advancements in technology and science while being mindful of the impact on society and the scientific community. Hence, this study will fill this gap in the literature and inform teacher education policy and practice for educators. For these reasons, this study aims to fill this gap by examining preservice science teachers' views to provide a better understanding of social responsibility.

This study aims to collect data from a representative sample of students at a public university to examine potential differences in views of social responsibility along the sub-factors of the scale across different fields of study. Such a descriptive study will help accurately depict disciplinary differences and provide a clear starting point for developing discipline-specific interventions for teaching the social responsibility of scientists and engineers. Since none of the previous studies have examined preservice teachers' perceptions of social responsibility among engineers and scientists, the results of this study are novel and make an important contribution to academic literature. Researchers can use this study's findings as a starting point to compare and evaluate differences across contexts and demographic groups (e.g., engineering students versus prospective teachers). Through the analysis of views in this research, researchers can determine distinctive patterns among relevant factors in future studies on the social responsibility of scientists and engineers.

METHOD

In this study, we surveyed 153 biology, chemistry, and science education students at a public research university in Russia to investigate their perceptions of the social responsibility of scientists and engineers. Of the participants, 10.5% were male, while 89.5% were female. Most participants were aged 18-19 years (57.5%). The percentages of participants aged 20-21 and over 22 were 28.1% and 14.4%, respectively. By major, most participants were science education students in the education faculty. Biology and chemistry students accounted for 29.4% and 18.3%, respectively (see **Table 1**). To include participants in this study, we invited preservice teachers enrolled in biology, chemistry, and science courses at a major public research college. We asked participants to participate in the study voluntarily, and students who did not consent to the study did not receive a response on the data collection instrument. We used the responses of participants who agreed to participate in the study. In this study, we only collected gender, college name, field of study, age, and responses to the survey instrument. We did not request any personally identifiable information from participants.

Data Collection Instrument

We used a data collection instrument developed by Ko et al. (2022), which they called Views of Social Responsibility of Scientists and Engineers (VSRoSE), to measure participants' views of the social responsibility of scientists and engineers. The instrument included

Table 1. Demographic information of the participants

		N	%
Gender	Male	16	10.5
	Female	137	89.5
Age	18-19	88	57.5
	20-21	43	28.1
	22 and above	22	14.4
Branch	Science Education	80	52.3
	Chemistry Teacher Education	28	18.3
	Biology Teacher Education	45	29.4
	Total	153	100.0

Table 2. Reliability for each factor of the instrument

Factors	Number of Items	Cronbach's Alpha
Concern for human welfare and safety HUMAN	5	.851
Concern for environmental sustainability ENVIR	3	.915
Consideration of societal risks and consequences CONSEQ	5	.935
Consideration of societal needs and demands NEEDS	3	.882
Pursuit of the common good COMGOOD	3	.861
Civic engagement and services CIVIC	5	.920
Communication with the public COMMU	3	.888
Participation in policy decision making POLICY	3	.882

eight factors and 30 items, with acceptable Cronbach's alphas for all eight scales, and was a five-points-Likert type. Since the instrument is the latest social responsibility scale developed by its authors, the researchers preferred to use it for data collection (see for more detail, Ko et al., 2021). The factors in the instrument are (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. VSRoSE integrates all the different understandings of social responsibility among scientists and engineers in literature. Ko et al. (2022) developed the scale based on psychometric analyzes. Their results showed strong evidence of validity and reliability to use the scale in educational research. As the newest social responsibility instrument in the literature, we can emphasize that VSRoSE encompasses a broader range of social responsibilities. To use the scale in this study, two experienced authors first translated it into Russian. Then, two experts in English and Russian reviewed the translation of the items in the scale and provided feedback to the authors. Following this feedback, we completed translating and adapting the scale to the Russian context.

The researchers created an online survey link via Google Forms and invited students to participate through professors who teach biology, chemistry, and science education in the faculty of education. For this aim, the researchers invited involved preservice teachers in STEM fields to answer the data collection instrument. The main criterion for participation in this study was enrollment in one of the teacher training programs related to the STEM fields. All participants volunteered to participate in the study. Reliability analyses in this study showed adequate internal consistency reliability (Cronbach's α). **Table 2** provides reliability scores for each factor. The subfactors we used in this study correspond to the original scale developed by Ko et al. (2022). These factors are (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.

RESULTS

Table 3 shows the results of the biology, chemistry, and science teachers' social responsibility awareness (VSRoSE) scores of scientists and engineers. Overall, the results show that the biology, chemistry, and science teacher-candidates who participated in this study had high awareness of human welfare and safety (HUMAN, 4.55 points) and sustainable environment (ENVIR, 4.59 points), while social participation and service (POLICY, 4.10 points) were the lowest. In general, the average scores for interest in and consideration for impacts on humans, the environment, and society (HUMAN, ENVIR and CONSEQ, COMMU, and COMGOOD) tended to be higher than the average for areas directly related to social practice (CIVIC, NEEDS, and POLICY).

We present the detailed results for each sub-factor of VSRoSE. Regarding the HUMAN factor, this area consisted of questions for the participants that aimed to ask about social responsibility in scientific and technological research and the fact that the results may affect human health and safety in advance. All questions in this area revealed a high average of 4.63 to 4.46 points.

Table 3. Descriptive statistics of VSRoSE responses according to items

		Female		Male		Total	
Factors	Items	Mena	SD	Mean	SD	Mean	SD
Concern for human welfare and safety HUMAN	1. Not harm human health at the least	4.50	0.92	4.47	0.85	4.50	.926
	2. Place utmost importance on human health	4.60	0.77	4.21	0.95	4.55	.835
	3. Be vigilant whether his/her research risks human safety	4.66	0.68	4.45	0.97	4.63	.760
	4. Consider the possible adverse effects on human health	4.68	0.66	4.41	1.05	4.63	.776
	5. Prevent humans from the risks at the least	4.52	0.76	4.22	1.03	4.46	.858
		4.59	**0.76**	**4.35**	**0.97**	**4.55**	**0.65**
Concern for environmental sustainability ENVIR	6. Protect environment during the research process	4.67	0.64	3.97	1.33	4.58	.809
	7. Minimize the effects on ecosystem	4.58	0.82	3.85	0.78	4.49	.926
	8. Promote sustainable development in the environment	4.56	0.74	4.13	1.04	4.50	.836
		4.60	**0.73**	**3.98**	**1.05**	**4.59**	**0.77**
Consideration of societal risks and consequences CONSEQ	9. Recognize the potential social problems in one's area of expertise values of multiple stakeholders	4.47	0.76	3.83	1.03	4.42	.848
	10. Be able to identify social problems inherent in modern science and Technology	4.39	0.79	4.13	1.01	4.35	.861
	11. Be cognizant of the contribution that one's work can make to the advancement of the field	4.49	0.73	3.83	1.03	4.43	.825
	12. Be able to identify pressing social problems in one's area	4.44	0.78	3.79	1.04	4.38	.866
	13. Carefully examine the conflicting	4.44	0.79	4.21	1.04	4.41	.869
		4.45	**0.77**	**3.96**	**1.03**	**4.39**	**0.76**
Consideration of societal needs and demands NEEDS	14. Consider whether one's research generates knowledge needed by the society	4.31	0.81	4.12	0.77	4.30	.882
	15. Conduct research consistent with the values and expectations of the society	4.11	0.94	3.88	0.74	4.08	.990
	16. Identify the societal needs and expectation for scientific and engineering research	4.15	0.91	4.00	0.74	4.13	.958
		4.19	**0.89**	**4**	**0.75**	**4.17**	**0.85**
Pursuit of the common good COMGOOD	17. Conduct research that can enhance the quality of human life	4.54	0.75	4.12	0.77	4.50	.836
	18. View promotion of human welfare and safety as a primary goal of one's research	4.39	0.83	4.17	1.03	4.36	.900
	19. View reducing the challenge that people experience in their daily life as an important goal of one's research	4.26	0.99	3.95	0.91	4.24	1.007
		4.40	**0.86**	**4.08**	**0.90**	**4.36**	**0.81**
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	4.15	0.90	4.09	1.11	4.12	.975
	21. Collaborate with the general public and citizens to solve the problems related to science and technology	4.15	0.95	4.17	1.00	4.14	.987
	22. Actively encourage others to participate in solving problems related to science and technology	4.09	0.97	3.55	1.37	4.05	1.035
	23. Collaborate with knowledgeable and interested citizens to solve the problems related to science and technology	4.23	0.89	4.04	0.78	4.21	.950
	24. Serve an advisory role for the public in their area of expertise	4.10	0.96	3.88	0.80	4.07	1.014
		4.14	**0.93**	**3.95**	**1.01**	**4.11**	**0.86**
Communication with the public COMMU	25. Make the public familiar with science using media such as books, articles, blog, and lectures	4.38	0.90	4.00	0.74	4.34	.954
	26. Explain knowledge and research necessary for solving social problems to the public	4.42	0.85	4.21	1.04	4.39	.911
	27. Knowledge or research regarding science and technology should be explained in a way that is easy for the general public to understand	4.46	0.80	3.79	1.04	4.40	.891
		4.42	**0.85**	**4**	**0.94**	**4.37**	**0.83**
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	4.16	0.90	3.92	0.73	4.13	.951
	29. Actively participate in policy-making process related to science and technology	3.97	1.04	3.76	1.02	3.95	1.072
	30. Emphasize its importance and must attract the investment for science and technology	4.24	0.85	4.00	0.74	4.22	.910
		4.12	**0.93**	**3.89**	**0.83**	**4.10**	**0.88**

These results demonstrated that most students agreed to consider the impact on human safety and health. The consideration of the sustainable environment (ENVIR) area consisted of questions about the responsibility of the scientific and technological research process and their effects of the research process on the environment and ecosystem. All items had a high average score of 4.49 to 4.58 points for this factor. For the ENVIR, there were large differences between females and males in their mean item scores for sixty (4.67, 3.97) and seventy items (4.58, 3.85), respectively. These results show differences between females and males in terms of protecting the environment and the ecosystem.

The social risk and impact consideration (CONSEQ) included five questions to assess participants' views on social responsibility to identify and recognize social problems during the science and technology research process. The result showed that all five questions in this factor had high recognition ranging from 4.35 to 4.42 points. For the CONSEQ subfactor, there are differences between the mean scores of females and males for items 9, 11, and 12. These results show that females are more interested in social problems and support the work of modern science and technology to solve them. The results regarding the Social Needs, and Needs Consideration (NEEDS) were relatively low. The items in this domain included three questions about the responsibility of scientists and engineers to consider the needs of society in scientific and technological research. For example, item 15, consisting of questions about conducting research following society's values and expectations, received a relatively lower score than the other two items in this factor (4.08). The result showed that all three questions in this factor received a low score between 4.08 and 4.30 points.

For the striving for the common good (COMGOOD) area, the scale consisted of three items that aimed to ask participants about the purpose of research to promote human life and welfare. The results showed a distribution of 4.24 to 4.50 points in this factor. In particular, item 17, about the question of conducting research that can improve the quality of human life, received a high recognition (4.50 points) and a lower standard deviation than the other items in this factor. This result shows that participants agree with the responsibility of scientists and engineers to improve the quality of human life.

The Social Participation and Service area (CIVIC) included five questions. It aimed to inquire about the responsibility of scientists and engineers to participate in solving social problems related to science and technology. The items in this factor ranged from 4.05 to 4.21 points. Item 22, which asked about actively encouraging others to participate in solving problems related to science and technology, had the lowest score in this factor. Interestingly, we found a slightly higher standard deviation of responses in this factor than in other areas. This result shows that the participants had different views on participation in solving societal problems related to science and technology. In addition, for the subfactor CIVIC, it can be seen that there are differences between the mean scores of females and males for item 22. These results show that females are more interested in encouraging others to participate in solving problems related to science and technology.

The Communication with the Public (COMMU) area included three questions about scientists and engineers' responsibility to communicate with the general public and to use simple language to explain to the public at a basic level that all people can understand. The result showed that all three questions of this factor received a low score between 4.34 and 4.40 points. In particular, item 27 asked how knowledge or research in science and technology can be easily explained to the public. For the COMMU subfactor, it can be seen that there are differences between the mean scores of females and males for items 25, 26, and 27. These results show that females are more interested in communicating with the public about science and technology. The results for the domain POLICY showed the lowest scores between 3.95 and 4.22. The items in this factor consisted of three questions about the responsibility to participate in the policy-making process related to science and technology. Item 29, which refers to active participation in the policy-making process related to science and technology, received the lowest recognition in the survey (3.95 points). The results for item 30 show that participants emphasize the importance of science and technology and want to increase investment in these areas. For the POLICY subfactor, it can be seen that there are differences between the mean scores of females and males for items 28, 29, and 30. These results show that females are more interested in participating in professional organizations and policy-making processes in science and technology.

The results in **Table 4** show a comparison of gender variables regarding students' views on the social responsibility of scientists and engineers. The results show that female students had significantly higher scores than male students in all sub-factors of the scale. Accordingly, female students had more scores than male students in all areas. These results also show that females in all major areas had a higher awareness regarding the social responsibility of scientists and engineers than males in all subject majors. In addition, we found the lowest average scores for males and females in the POLICY area (M=12.37). The higher awareness is in the HUMAN area (M=22.92).

The results with students' age show significant differences in all sub-factors (see **Table 5**). The average scores in all age groups show slight differences. However, the students over the age of 22 had significant differences in the three areas, including NEEDS, CIVIC, and POLICY areas, while 20-21 age students had

Table 4. Comparison of factors according to gender

Factors	Male		Female		t	p
	Mean	SD	Mean	SD		
HUMAN	21.18	5.65	22.95	2.87	-79.18	.000
ENVIR	11.50	4.09	13.81	1.97	-62.56	.000
CONSEQ	19.87	6.47	22.23	3.31	-66.06	.009
NEEDS	12.0	3.91	12.56	2.35	-51.59	.000
COMGOOD	12.37	3.40	13.18	2.29	-57.28	.011
CIVIC	19.56	6.70	20.70	3.97	-53.69	.000
COMMU	12.00	3.94	13.25	2.25	-56.37	.000
POLICY	11.69	3.91	12.37	2.47	-48.81	.000

Table 5. Comparison of factors according to age

Factors	18-19		20-21		22 and above		t	p
	Mean	SD	Mean	SD	Mean	SD		
HUMAN	22.54	3.12	23.89	2.13	22.55	5.00	-78.21	.040
ENVIR	13.58	2.11	13.74	1.97	13.18	3.81	-59.01	.000
CONSEQ	21.86	3.52	22.27	2.90	21.86	6.03	-65.34	.001
NEEDS	12.45	2.39	12.46	2.23	12.81	3.60	-51.62	.000
COMGOOD	13.04	2.38	13.19	2.14	13.18	3.17	-55.55	.000
CIVIC	20.67	4.12	20.42	3.81	20.68	5.94	-53.61	.040
COMMU	13.36	2.21	12.90	2.11	12.59	3.88	-53.31	.090
POLICY	12.36	2.46	12.09	2.50	12.45	3.56	-47.89	.000

Table 6. Comparison of factors according to major

Factors	Science		Chemistry		Biology		t	p
	Mean	SD	Mean	SD	Mean	SD		
HUMAN	22.66	3.63	23.10	2.45	22.75	3.17	-76.47	.000
ENVIR	13.73	2.39	13.75	2.15	13.18	2.50	-55.82	.000
CONSEQ	22.18	3.93	22.18	3.33	21.48	3.88	-62.94	.019
NEEDS	12.48	2.57	12.78	2.40	12.37	2.63	-49.19	.000
COMGOOD	13.06	2.61	13.71	1.84	12.80	2.39	-57.28	.011
CIVIC	20.50	4.17	21.35	4.69	20.27	4.38	-52.65	.390
COMMU	13.18	2.44	13.60	2.16	12.71	2.74	-51.99	.000
POLICY	12.05	2.74	13.00	2.52	12.31	2.51	-47.59	.000

significant differences in the four areas, including HUMAN, ENVIR, CONSEQ, and COMGOOD. The students aged 18-19 had only the highest mean scores significantly in the COMMU area. These students aged 18-19 did not show significant differences in the other seven areas of the scale. In addition, we found that the highest average scores are in the HUMAN area, while the lowest scores are in the POLICY area.

Table 6 shows that chemistry students had slightly higher average scores than the other majors in all areas of the scale. The results also showed that chemistry education majors significantly differed in the seven sub-areas. Their scores did not significantly differ from the other majors in only one area, including CIVIC. The results show that majors in three fields generally had similar average scores. The average scores for the three majors are generally very similar. However, chemistry education students' responses revealed statistically significant higher awareness in the seven sub-factors is significant. Science and biology education students showed less awareness in the five areas than chemistry preservice teachers. Students in the three major areas showed the same awareness regarding the other three areas. Regarding biology, chemistry, and science majors, the score related to NEEDS was relatively low. In addition, we found a higher awareness of the consideration of human welfare and safety (HUMAN) area for three major areas.

DISCUSSION

This study aimed to investigate preservice teachers' views on the social responsibility of scientists and engineers. We involved preservice teachers enrolled a Russian public in this research. We analyzed differences among pre-service teachers in social responsibility by age, gender, and field of study. The results indicated that the preservice biology, chemistry, and science teachers who participated in this study had high awareness of human welfare and safety (HUMAN, 4.55 points), sustainable environment (ENVIR, 4.59 points), and consideration for social risks and impacts (CONSEQ). This result is very similar to those of Ko et al. (2022), who reported that science and engineering majors at the undergraduate level had more concerned with the consideration for human welfare and safety (HUMAN), consideration for the sustainable environment (ENVIR),

and consideration for social risks and impacts (CONSEQ) areas. In our study, preservice teachers were more concerned with the areas of communication with the public (COMMU), COMGOOD, social participation and service (CIVIC), and NEEDS than the participants of Ko et al. (2022). In general, our results showed that the average scores for interest in and consideration for impacts on humans, the environment, and society (HUMAN, ENVIR and CONSEQ, COMMU, and COMGOOD) tended to be higher than the average for areas directly related to social practice (social participation and service (CIVIC), consideration of societal needs and demands (NEEDS), and participation in policy decision making **(**POLICY). In only one area, including social participation and service (POLICY, 4.10 points) preservice teachers had the lowest level of awareness. This result confirms the result of the study of Ko et al. (2022).

In this research, we examined the sense of social responsibility of preservice science teachers who will educate students of future scientists and engineers. The sense of social responsibility of the preservice science teachers who participated in the study was generally high, but awareness related to practice and participation was rather low. Pre-service teachers' knowledge of the dangers of new technologies, the possibility of misuse, and understanding of the uncertainties of science and technology are high, and participation in community service as experts or deliberation on policies is low. These results are very similar to those of previous researchers investigating participants' social responsibility at the university level (Bielefeldt & Canney, 2016; Canney & Bielefeldt, 2015; Ko et al., 2022; Lee et al., 2022) and examined the moral issues of preservice science teachers regarding socioscientific issues (Lee et al., 2012). The results are particularly consistent with those of Lee et al. (2012), as they found that ecological worldviews are present in preservice science teachers' views concerning socioscientific issues in national and international contexts. Their results showed that PSTs focused on the welfare of their own country or comfortable life when making decisions and prioritized these issues. These results indicate that it is necessary to train social responsibility and its aspects related to participation in scientific and technological processes in science teacher preparation programs and to encourage scientists and engineers to participate in the policy-making process to increase the knowledge and awareness of the social responsibility of scientists and engineers. In addition, the results are very similar to those of Canney and Bielefeldt (2015), who found that engineering students agreed more strongly on questions about their awareness of what people need but agreed less on questions about their personal or professional commitment to helping others. In their study, engineering students also strongly agreed, with a lower standard deviation, on the importance of engineering skills and their ability to positively affect society.

The results showed that female students had significantly higher scores than those male students in all sub-factors of the social responsibility scale. Accordingly, female students had more scores than male students in all areas. These results also show that females in the three major areas had a higher awareness regarding the social responsibility of scientists and engineers than males in all subject majors. According to the theory of ethics of care developed by Noddings (1984), responsibility is accepted as the second dimension of the ethics of care theory. In this theory, responsibility consists of taking care of someone or something. Sevenhuijsen (2003, p. 21) wrote that "*taking care of consists of the necessary steps in the care situation in question. Taking care of is based on the willingness and capacity to take responsibility that "something" is done to provide for the need in question*". In light of this theory, researchers have associated the ethics of care with females (Bergmark & Alerby, 2006). The results of this study indicated that since females feel more responsible about the social responsibility concerned with society and the future, we believe that it is normal to anticipate that females will be more concerned with issues related to social responsibility. In addition, we found the lowest average scores for males and females in the POLICY area (M=12.37). The higher awareness is in the HUMAN area. These results also confirm the results of Ko et al. (2022).

The results regarding the major areas of preservice science teachers revealed that chemistry students had slightly higher average scores than the other majors in all areas of the scale. The results also showed that chemistry education majors differed significantly in the seven sub-areas except for the CIVIC area. These results are not consistent with the findings of Ko et al. (2022). They did not find any statistical differences between science and engineering majors in all areas of the scale. The differences in favor of preservice chemistry teachers may be explained due to considering or emphasizing human safety, welfare, and environmental considerations more than other majors. In this study, preservice science teachers' responses did not significantly differ from the other majors in only one area, including CIVIC. This result is consistent with the findings of Ko et al. (2022). This result is because the CIVIC concerns engagements and services in science and technology. Therefore, we think that all preservice science teachers in all areas could support the research activities in science and technology.

The results with preservice teachers' age revealed significant differences in seven sub-factors, except for the COMMU area. The average scores in all age groups showed slight differences. However, the students over the age of 22 had significant differences in the three areas, including NEEDS, CIVIC, and POLICY areas, while 20-21 age students had significant differences in

the four areas, including Concern for human welfare and safety (HUMAN), Concern for environmental sustainability (ENVIR), Consideration of societal risks and consequences (CONSEQ), and pursuit of the common good **(**COMGOOD). The students aged 18-19 had only the highest mean scores significantly in the COMMU area. These results are not very similar to those of Ko et al. (2022), who found no statistical differences among grade levels among science and engineering majors. From these results, we can conclude the existence of a change in the perceptions of preservice science teachers along with age or grade level. This result may also be interpreted that studying science and technology education may be resulted in gaining an awareness of the social responsibility of scientists and engineers.

CONCLUSION

In this study, we investigated pre-service teachers' views on the social responsibility of scientists and engineers. The results of this study show that pre-service science teachers' views on the social responsibility of scientists and engineers in society and research provide a sound basis for assessing social responsibility. This study provides researchers and teachers with a starting point for understanding preservice science teachers' views of the social responsibility of scientists and engineers. In addition, this study allows researchers to understand the role of scientists and engineers in solving humanity's major problems from the perspective of preservice science teachers. From this perspective, this study provides insightful information for literature and fills a research gap. We hope that future researchers will focus on helping pre-service teachers better understand the social responsibility of scientists and engineers and train more socially responsible teachers who understand the importance of the impact of science and engineering research on society.

RECOMMENDATIONS

This quantitative study examined preservice science teachers' views on social responsibility. The study's main limitation is that the participants were from a public research university. Most PSTs had more positive attitudes toward social responsibility but less favorable attitudes toward science and technology research participation. This study provides important and valuable insights into preservice science teachers' attitudes toward social responsibility. Still, more than the present study is needed to draw a general conclusion about preservice science teachers and social responsibility. Therefore, further research is required to obtain a public opinion about social responsibility views and identify the specific factors that led to preservice science teachers' views on social responsibility. This research also indicates that PSTS were less concerned about the role of social responsibility in engaging and promoting scientific research in science and engineering. This finding suggests the need to emphasize the positive impact of science and engineering research on society and the importance of considering social impact in teacher education. Such emphasis on the importance of social responsibility will help to understand the effects of science and engineering in a social context for professional responsibility. The results of this study show that views on participation in community service activities are not robust in the views of preservice teacher education. In summary, examples need to be used to emphasize socially responsible factors in teacher education.

LIMITATIONS

We should note some limitations for future research. We conducted the present study at a public research college and included a limited number of participants. We made every effort to have pre-service teachers in the three enrolled subjects in this study. The data in this study was collected from one country. For this reason, attention should be paid to generalizing the results. The researchers believe that this study will be helpful for educators to understand better the views of pre-service teachers about the social responsibility of scientists and engineers. Further studies should consist of a more extensive data set from different disciplines in STEM. They may provide more results to inform researchers about the social responsibility of preservice science teachers. Another limitation is that we used a scale to collect data to determine the social responsibility of PSTs for scientists and engineers. Further studies should consider other data collection instruments and qualitative methods to contribute to the literature. In addition, scientists' and engineers' views on social responsibility may vary by context, discipline, and type of faculty. Because this study is the first to examine PSTs' views of social responsibility, scientists and educators should conduct further studies in different contexts and with preservice science teachers.

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