MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2023, 19(3), em2240
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/13000

Enhancing Indonesian college students' views of social responsibility of scientists and engineers: The enact model intervention

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Received 29 November 2022 ▪ Accepted 17 February 2023

Abstract

This study aimed to investigate the effects of the ENACT model on promoting Indonesian college students' views of social responsibility of scientists and engineers. The ENACT model emphasized the students' epistemological understanding of science and technology using socio-scientific issue (SSI) approaches to enhance the social responsibility, and their science/engineering practices and experiences of taking action to resolve the issues. A total of 80 college students enrolled in a chemistry course in a university in Indonesia participated in the study, 40 of which majored in chemistry education, and the other 40 majored in chemical engineering. An instructor taught and implemented the ENACT project over 10 weeks as a part of the course. Data was collected by a questionnaire called "views of social responsibility of scientists and engineers (VSRoSE)" to explore the changes in students' views on social responsibility. The participating students responded to the questionnaire before and after the intervention. In results, the effects of the ENACT project were notable in the chemical engineering (ENG) group. The chemistry education (EDU) group scored much higher than the ENG group in all the eight factors of VSRoSE in the pre-test. However, the score patterns changed after the intervention. The EDU group still exhibited high scores, but not much changed. The ENG group scores significantly increased in five factors and have presented similar score patterns with the ones of the EDU group.

Keywords: ENACT model, SSI, science education, social responsibility, VSRoSE

INTRODUCTION

Numerous social, ethical, and moral problems that we are facing in the contemporary society are closely related to the rapid development of science and technology (Beck, 1992). For example, dangerous chemicals in the industry leak into rivers or unexpected diseases caused by the chemicals frequently occur in various places around the globe. In the field of science education, such problems are called socio-scientific issues (SSIs) (Zeidler et al., 2005). With concerns for students who live in the risk and uncertain society, numerous science educators and researchers have insisted the importance of teaching SSIs in schools. They have implemented SSI instruction with various strategies to promote students' capabilities to deal with SSIs and achieved quite positive outcomes. For example, SSI instruction contributed to promote the students' understanding of the nature of science and technology (Bencze & Krstovic, 2017; Levinson, 2010), argumentation and communication skills to negotiate multiple perspectives (Kahn & Zeidler, 2016; Newton & Zeidler, 2020), and character and values as citizens (Choi & Lee, 2021; Kim & Lee, 2021; Lee et al., 2013).

We would like to focus on enhancing students' social responsibility through SSI instruction. Lee and her colleagues (Lee et al., 2012) proposed character and values as one of the dimensions of scientific literacy for students and citizens. Character and values comprised three elements, and one of them was socio-scientific

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Contribution to the literature

- This study presents that the view of the social responsibility of STEM professionals can be enhanced by systematic educational programs like the ENACT project.
- This study suggests that the ENACT model can be integrated with college curriculum for various fields of engineering and natural sciences.

accountability. Socio-scientific accountability meant that students should have a feeling of responsibility on SSIs (e.g., "I am responsible for causing the issues", "I am responsible for resolving the issues") and willingness to take socio-political actions to resolving the issues (e.g., "I am willing to be engaged in responsible actions", "I am willing to do something for reducing the issues"). The education for social responsibility will be crucial for professionals in STEM fields as well as students and citizens (Ko et al., 2021; Mejlgaard et al., 2019; Zandvoort et al., 2013). Numerous researchers (e.g., Hansen & Hammann, 2017; Harris Jr et al., 2013) have emphasized the importance of fostering social responsibility of STEM professionals because scientists and engineers are one of the major stakeholders, which have expertise to conduct cutting-edge research and innovation, to predict potential risks and harms on human beings, societies, and environment, and to use their knowledge and skills to resolve the issues to make our society better and safer. It does not intend to attribute all SSIs to scientists and engineers because, especially in the realm of new technologies such as nanoscience and biotechnology, a "regulatory vacuum" exists (Corley et al., 2015, p. 112) in which risks cannot be predicted or monitored even by scientists or engineers.

Nonetheless, social responsibility of scientists and engineers should be seriously discussed. Although no consensus exists on the definition of the social responsibility among scholars, several scholars (Bielefeldt, 2018; Godhade & Hundekari, 2018; Ko et al., 2021; Pimple, 2002; Wyndham et al., 2015) differentiated social responsibility from individual research ethics (e.g., rigorous process, honesty, integrity), and tended to emphasize the aspects of social activism for larger welfare and common goods of society and environment. They also indicated key elements of social responsibility such as consideration of social consequences of science and technology, efforts of protecting human welfare and safety, consideration of environmental sustainability and communication with the public to minimize risk (Ko et al., 2021).

The social responsibility of scientists and engineers is not naturally cultivated over their school years without systemic educational approaches (Bielefeldt & Canney, 2016; Hwang et al., 2023). Thus, many educators in engineering or natural sciences (Bielefeldt & Canney, 2016; Payne & Jesiek, 2018; Tassone et al., 2018; Zandvoort et al., 2013) tried to re-organize their curricula for fostering social responsibility. Some educators adopted inter- or trans-disciplinary approaches because research and innovation often comprise diverse stakeholders in and outside of academia and so they need to embrace diverse voices. Others have emphasized community involvement and volunteer activities, which provided opportunities to collaboratively work with others and to contribute to resolving community issues using their expert knowledge and skills.

However, few programs exist in Indonesia to develop social responsibility of science and engineering students. Most universities are limited to teaching individual research ethics as a part of a course. Thus, we have attempted to benchmark some foreign programs for fostering the social responsibility of Indonesian college students in STEM. Among the programs, we have decided to adapt the ENACT model developed by Lee et al. (2020). Similar other approaches, the ENACT model also includes inter- or trans-disciplinary approaches and community involvement to foster social responsibility. Besides, the ENACT model starts from exploring SSIs. As examining SSIs in their fields or interests, STEM students are able to obtain epistemological understanding of science and technology, to have opportunities to solve the issues using scientific and engineering practices and to share their solutions with the communities. Choi et al. (2021), Kim et al. (2021), and Lee et al. (2022) have reported positive outcomes with Korean college students after the ENACT interventions (we call the intervention "ENACT project"). The ENACT model provides specific guidelines for instructors to follow using various instructional scaffolds and so they can easily integrate with curriculum in Indonesian universities.

Therefore, we applied the ENACT model to basic science courses of a college located in Riau, Indonesia. The college students majoring chemical engineering and chemistry education conducted the ENACT project over 10 weeks. Then, we explored the effects of the ENACT project on promoting their view on the social responsibility of scientists and engineers. The guiding research question was summarized into 'to what extent does the social responsibility of Indonesian college students in STEM fields change over the course of the ENACT project?'

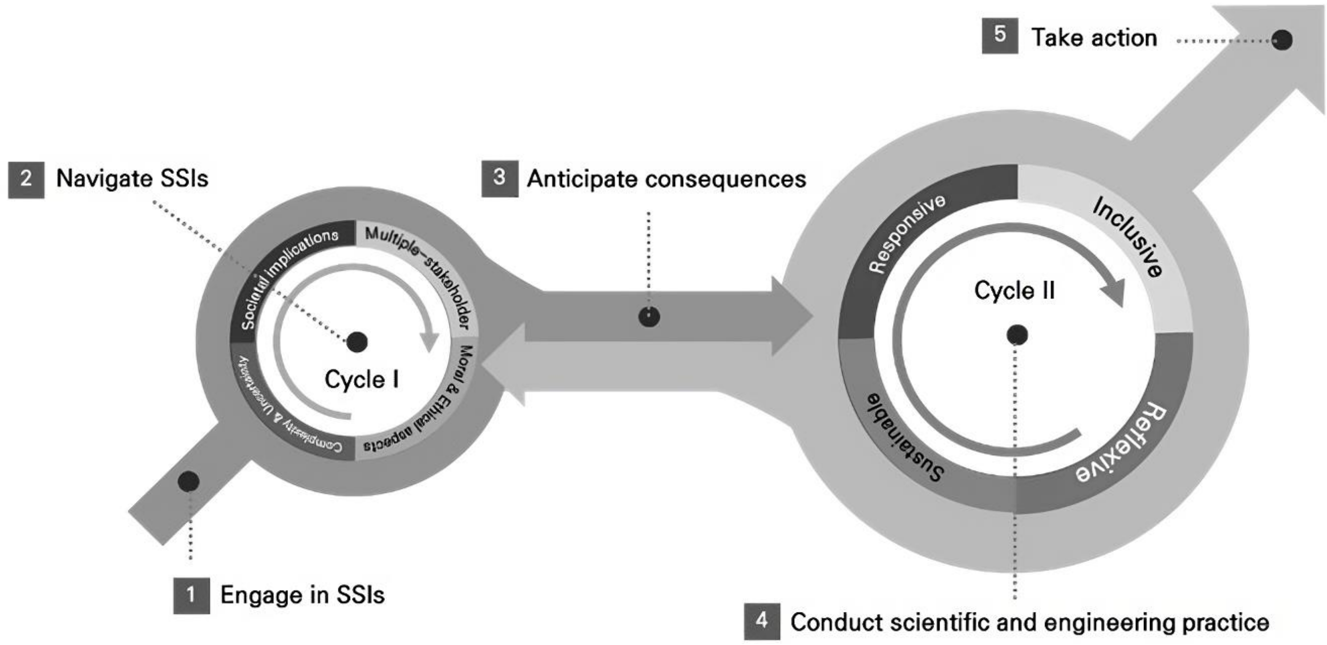


Figure 1. ENACT model (Lee et al., 2020, p. 10)

METHODS

Participants

A total of 80 college students enrolled in a chemistry course in a university in Riau, Indonesia participated in the study. 40 students majored in chemistry education, and the other 40 majored in chemical engineering. They were taught a same course but assigned to two separate classes. Out of 80, 20 were males, and the other 60 were females. Most students were seniors and planned to pursue their careers to be scientists, engineers, or teachers. An instructor taught and implemented the ENACT project for both groups as a part of the course. We could not arrange a comparison group and so compared their views of social responsibility before and after the intervention.

Enact Model Intervention: ENACT Project

We implemented the ENACT model over 10 weeks in the courses. The term, "ENACT" is an acronym of the five steps of investigation on SSIs. As shown in **Figure 1**, the steps include *e*ngage in SSIs, *n*avigate SSIs, *a*nticipate consequences, *c*onduct scientific and engineering practices, and *t*ake action.

In step 1, students select a topic of interest while freely exploring SSIs that are controversial in their major or field of interest. In step 2, they navigate the selected issue in earnest. They visualize with a map to present various stakeholders involved in the issue because it is an effective tool to identify various stakeholders and conflicts amongst them (Bencze & Krstovic, 2017). In step 3, students anticipate what could happen in the future if the issue persists. Then, they identify the gap between the possible future and the desirable future whilst writing the futures' wheel and future scenarios (Levrini et al., 2019; Oviawe et al., 2021; Tasquier et al., 2019), and think about what kind of efforts we must make to reduce this gap. In step 4, students construct a problem to solve and conduct science and engineering practices. They propose solutions through creative engineering design, scientific experiments, or real-data analysis. Lastly, students share their solutions with the local community (e.g., campaign, distribution of brochures) and try out even small practices and actions in step 5. Some students may seek community input to refine a solution or create a new problem to initiate a new process of inquiry.

As shown in **Figure 1**, the ENACT model comprises two cycles. The first cycle aims to promote the students' epistemological understanding of science and technology. Through steps 1-3, Lee et al. (2020) led students to understand four elements (see inside of cycle I); namely,

(a) social implications of science and technology,

(b) multiple stakeholders,

(c) moral and ethical aspects of science and technology, and

(d) complexity and uncertainty.

Once students understand the nature of science and technology, they move onto cycle II (steps 4-5). In cycle II, students are encouraged to do their practices, which are

(a) responsive,

(b) inclusive,

(c) reflexive, and

(d) sustainable.

Lee et al. (2020) intended to actualize the idea of RRI (responsible research and innovation) in cycle II.

Table 1. ENACT project

Steps	Instructional approaches	Students' activities
Engage in SSI	Web-based research, discussion	• Explored various SSIs regarding environmental pollution by web-surfing (e.g., articles, YouTube, news, & other media) or by sharing personal experiences • Chose an SSI that they wanted to explore (e.g., flying ash issue, coal burning, animal waste in slaughterhouse, organic waste (market waste), plastic straws)
Navigate SSI	Stakeholder mapping	• Identified various stakeholders (e.g., companies, government, & so on) involved in selected issues by drawing maps • Explored various perspectives & possible conflicts among stakeholders
Anticipate consequences	Futures wheel, future scenario	• Collaboratively drew a futures wheel to anticipate possible consequences of issues in future • Wrote future scenarios on plausible & desirable future scenarios • Discussed what we could do to reduce gap & decided a problem to solve
Conduct scientific & engineering practices	Experiments, prototyping, data analysis, etc.	• Conducted various scientific & engineering practices to propose solutions • Examples of solutions: Flying ash can be used as one ingredient in asphalt/concrete; making straws from rice flour; making lice eradication oil by using organic waste & so on.
Take action	Campaign, policy proposal	• Shared their solutions & took action (e.g., developing posters, videos, & so on)

Table 2. Reliability of VSRoSE construct

Factors	No of item	Cronbach's alpha
Concern for human welfare and safety (HUMAN)	5	0.819
Concern for environmental sustainability (ENVIR)	3	0.735
Consideration of societal risks and consequences (CONSEQ)	5	0.886
Consideration of societal needs and demands (NEEDS)	3	0.737
Pursuit of the common good (COMGOOD)	3	0.750
Civic engagement and services (CIVIC)	5	0.859
Communication with the public (COMMU)	3	0.790
Participation in policy decision-making (POLICY)	3	0.737
VSRoSE	30	0.944

The participating college students followed the ENACT model with guidance from the instructor. The summary of the ENACT model is as shown in **Table 1**. To help the instructor obtain a decent understanding on the ENACT model, we had workshops on the ENACT model. The second author of the study had worked with the ENACT group in Korea and so assisted the instructor. The instructor formed student groups (5-6 students in a group). She constructed the environment that the students could use computers and internet whilst engaging in the ENACT project. The students were encouraged to choose their topics regarding environmental pollutions that they were facing in their lives or communities because the instructor wanted students to be more personally engaged in the project.

Data Collection and Analysis

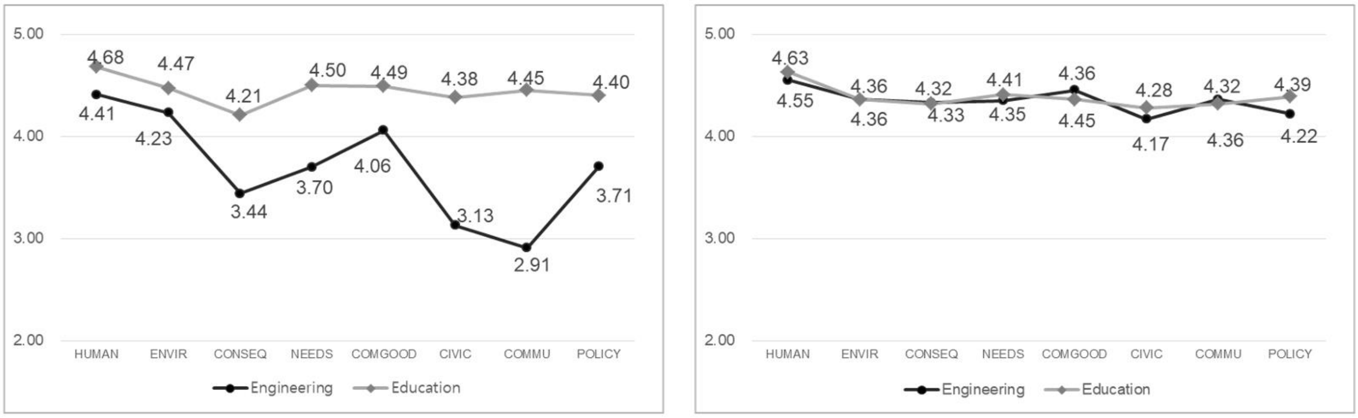
We used a measure called "views of social responsibility of scientists and engineers (VSRoSE)" (Ko et al., 2021) to explore the changes in the students' views on social responsibility. VSRoSE was developed based on the extensive literature reviews and statistically rigorous process. It comprises 30 items under eight factors of social responsibility of science and engineers (**Table 2**). The items are five-point Likert scale (1=strongly disagree, 5=strongly agree). We translated the English-version of VSRoSE into Indonesian one. To increase the clarity of the translated version of VSRoSE, three science educators who spoke English and Indonesian confirmed the translation (Gay & Airasian, 2003). The internal consistency reliability (Cronbach's alpha) was acceptable, as shown in **Table 2**.

The participants responded to VSRoSE before and after the ENACT project. Using SPSS 26.0 package, we conducted descriptive statistics and compared means between pre- and post-responses to confirm the effects of the intervention (paired t-test). When analyzing data, we divided the students into two groups; namely, chemical engineering and chemistry education students, because we assumed that the effects of the ENACT model may vary depending on their majors.

RESULTS

Overall Effects of the ENACT Project

The effects of the ENACT project were more noteworthy in the chemical engineering (ENG) group. As shown in **Figure 2**, in the pre-test the chemistry education (EDU) group scored much higher than ENG group in all eight factors. EDU group showed a little lower score in CONSEQ (M=4.21) and higher score in



(a) Pre-test scores (b) Post-test scores

Note. HUMAN: Concern for human welfare and safety
CONSEQ: Consideration of societal risks and consequences
COMGOOD: Pursuit of the common good
COMMU: Communication with the public
ENVIR: Concern for environmental sustainability
NEEDS: Consideration of societal needs and demands
CIVIC: Civic engagement and services
POLICY: Participation in policy decision making

Figure 2. Mean scores of pre- and post-tests over the VSRoSE factors

Table 3. Changes in the VSRoSE scores of chemical engineering (ENG) and chemistry education students (EDU)

Factors	Group	Pre-test		Post-test		t	p
		M	SD	M	SD		
Concern for human welfare and safety (HUMAN)	ENG	4.41	0.506	4.55	0.505	1.694	.098
	EDU	4.68	0.372	4.63	0.424	-0.285	.777
Concern for environmental sustainability (ENVIR)	ENG	4.23	0.585	4.36	0.573	1.599	.118
	EDU	4.47	0.543	4.36	0.612	-.680	.501
Consideration of societal risks and consequences (CONSEQ)	ENG	3.44	1.126	4.33	0.536	8.273	.004
	EDU	4.21	0.538	4.32	0.680	1.292	.204
Consideration of societal needs and demands (NEEDS)	ENG	3.70	0.682	4.35	0.544	4.757	.000
	EDU	4.50	0.489	4.41	0.546	-0.805	.426
Pursuit of the common good (COMGOOD)	ENG	4.06	0.529	4.45	0.547	1.461	.152
	EDU	4.49	0.506	4.36	0.626	-1.275	.210
Civic engagement and services (CIVIC)	ENG	3.13	0.925	4.17	0.640	6.544	.003
	EDU	4.38	0.461	4.28	0.595	-0.721	.475
Communication with the public (COMMU)	ENG	2.91	1.064	4.36	0.527	8.130	.009
	EDU	4.45	0.558	4.32	0.601	-1.595	.119
Participation in policy decision making (POLICY)	ENG	3.71	0.913	4.22	0.651	3.302	.002
	EDU	4.40	0.636	4.39	0.559	-0.187	.853
VSRoSE total	ENG	3.69	0.496	4.35	0.431	8.538	.000
	EDU	4.44	0.394	4.39	0.493	-0.360	.721

HUMAN (M=4.68), but the rest of the factors their mean scores ranged from 4.38 to 4.50. However, the mean scores of ENG group varied over the factors. They relatively scored high in HUMAN, ENVIR, and COMGOOD (M=4.41, 4.23, 4.06, respectively), but scored very low in COMMU (M=2.91) and CIVIC (M=3.13). The gap between EDU and ENG groups were quite significant in CONSEQ, CIVIC, and COMMU. However, the score patterns changed after the intervention. The EDU group still showed high scores, but not much changed, in every single factor in VSRoSE. However, the ENG group scores significantly increased in most factors and presented a similar score pattern with the scores of the EDU group.

The statistical analysis in **Table 3** presented that the scores of VSRoSE significantly increased after the ENACT intervention, but only in the ENG group ($t=8.538$, $p<.000$). The ENG students showed statistically significant improvement in CONSEQ, NEEDS, CIVIC, COMMU and POLICY ($p<.05$).

Concern for Human Welfare and Safety (HUMAN)

Concern for human welfare and safety (HUMAN) has been emphasized as a major social responsibility of scientists and engineers (Bielefeldt, 2018; Godhade & Hundekari, 2018; Wyndham et al., 2015; Zandvroot et al., 2013).

HUMAN indicates that STEM professionals should make a certain effort to predict potential risks to human welfare, safety and health in advance and strive to minimize them whilst conducting research and innovations. Five items are included in HUMAN and

Table 4. Responses to the items of HUMAN items

*I believe scientists and engineers **should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
1. Not harm human health at the least	4.43	4.28	4.63	4.60	4.46	4.44
2. Place utmost importance on human health	4.72	4.63	4.73	4.68	4.72	4.65
3. Be vigilant whether his/her research risks human safety	4.43	4.60	4.65	4.65	4.54	4.63
4. Consider the possible adverse effects on human health	4.67	4.63	4.63	4.65	4.65	4.64
5. Prevent humans from the risks at the least	3.93	4.65	4.78	4.73	4.35	4.69
Total	4.41	4.55	4.68	4.63	4.54	4.60

Table 5. Responses to the items of ENVIR items

*I believe scientists and engineers **should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
6. Protect the environment during the research process	4.45	4.43	4.63	4.47	4.54	4.45
7. Minimize the effects on the ecosystem	4.55	4.47	4.50	4.47	4.52	4.47
8. Promote sustainable development in the environment	3.70	4.20	4.30	4.25	4.00	4.23
Total	4.23	4.36	4.47	4.36	4.35	4.38

Table 6. Responses to the items of CONSEQ items

*I believe scientists and engineers **should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
9. Recognize the potential social problems in one's area of expertise	3.67	4.43	4.30	4.35	3.99	4.34
10. Be able to identify social problems inherent in modern science and technology	3.65	4.47	4.25	4.45	3.95	4.40
11. Be cognizant of contribution that one's work can make to advancement of field	3.42	4.20	4.27	4.30	3.85	4.31
12. Be able to identify pressing social problems in one's area	3.05	4.43	4.00	4.32	3.53	4.31
13. Carefully examine the conflicting values of multiple stakeholders	3.40	4.47	4.25	4.30	3.82	4.34
Total	3.44	4.33	4.21	4.32	3.82	4.34

mean scores of ENG and EDU groups are shown in **Table 4**.

ENG and EDU groups presented the highest mean scores in HUMAN over other factors. The ENG group highly agreed on placing utmost importance on human health (item 2) and on considering the possible adverse effects on human health (item 4). On the other hand, they scored lower to item 5. However, they responded to the items evenly after the intervention. The EDU groups showed very similar score patterns to the items in pre- and post-test. The scores ranged from 4.60 to 4.73 in the post-test. Both groups strongly believed that protecting human welfare and safety should be their responsibility.

Concern for Environmental Sustainability (ENVIR)

Similar to HUMAN, concern for environmental sustainability (ENVIR) have been frequently listed as a major social responsibility of scientists and engineers (Bielefeldt, 2018; Vanasupa et al., 2006). It means that STEM professionals should pay attention to whether their practices are exacerbating the destruction of environment and they are pursuing sustainable development.

As shown in **Table 5**, three items in ENVIR exist. Both groups showed high scores in pre- and post-tests. However, interestingly, the students in ENG group obtained low mean scores in item 8. It indicates that they believed the importance of sustainable development, but there could be some disagreement as to whether promoting sustainable development should be the responsibility of engineers. However, the mean score of the item increased.

Consideration of Societal Risks and Consequences (CONSEQ)

Consideration of social risks and impacts (CONSEQ) indicates that STEM professionals should sensitively recognize social consequences of science and technology, such as conflicts of interests and unequal distribution of values (Bielefeldt, 2018; Wyndham et al., 2015; Zandvroot et al., 2013).

As shown in **Table 6**, five items represent CONSEQ. In the pre-test, the mean scores of the items were quite different between the groups. The ENG group less agreed that recognizing and identifying social consequences would be the social responsibility of STEM professionals (M=3.44). They scored lowest in item 12 (M=3.05). On the contrary, the mean scores of the EDU group ranged between 4.30 and 4.45, showing no difference among the items. However, after the intervention, the ENG group became more aware of the importance of considering societal risks and consequences and took it as their social responsibility.

Table 7. Responses to the items of NEEDS items

I believe scientists and engineers ***should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
14. Consider whether one's research generates knowledge needed by the society	3.65	4.43	4.60	4.47	4.12	4.45
15. Conduct research consistent with the values and expectations of the society	3.65	4.35	4.45	4.42	4.05	4.39
16. Identify societal needs & expectation for scientific & engineering research	3.80	4.27	4.45	4.40	4.13	4.34
Total	3.70	4.35	4.50	4.41	4.10	4.39

Table 8. Responses to the items of COMGOOD items

I believe scientists and engineers ***should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
17. Conduct research that can enhance the quality of human life	4.38	4.60	4.70	4.47	4.54	4.54
18. View promotion of human welfare & safety as a primary goal of one's research	4.62	4.42	4.45	4.40	4.54	4.41
19. View reducing the challenge that people experience in their daily life as an important goal of one's research	3.20	4.35	4.32	4.30	3.76	4.33
Total	4.06	4.45	4.49	4.36	4.27	4.42

Table 9. Responses to the items of CIVIC items

I believe scientists and engineers ***should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
20. Be willing to participate in civic affairs if the goal of the affair is to solve the problems related to science and technology	3.70	4.25	4.53	4.32	4.11	4.29
21. Collaborate with general public & citizens to solve problems related to science & technology	3.75	4.22	4.43	4.32	4.09	4.27
22. Actively encourage others to participate in solving problems related to science & technology	2.90	4.13	4.40	4.32	3.65	4.23
23. Collaborate with knowledgeable and interested citizens to solve problems related to science and technology	2.80	4.25	4.53	4.40	3.63	4.32
24. Serve an advisory role for the public in their area of expertise	2.60	4.03	4.03	4.20	3.31	4.11
Total	3.13	4.17	4.38	4.28	3.75	4.24

Consideration of Societal Needs and Demands (NEEDS)

The consideration of societal needs and demands (NEEDS) indicates the recognition of broad range of stakeholders, including marginalized groups, and the effects to work to communicate and reflect their needs and expectations (Stilgoe et al., 2014; Tassone et al., 2018). There are three items in NEEDS. Like CONSEQ, in the pre-test, the mean scores of the ENG group were much lower than the ones in the EDU group. The mean scores of the ENG group in NEEDS ranged from 3.65 to 3.80. It indicates that the ENG group presented lower agreement in that they should conduct their research to meet the needs of society (M=3.70). However, after participating in the ENACT project, their view on NEEDS had changed and were likely to accept it as a part of their roles (**Table 7**).

Pursuit of the Common Good (COMGOOD)

The pursuit of the common good (COMGOOD) means that STEM professionals need to conduct scientific and technological research and innovation in a way that benefits can be distributed to more people, not in the direction of pursuing individual or organizational interests (Pimple, 2002). COMGOOD contains three items. The variation of the mean scores among the items was quite large in both groups. They presented the lowest mean scores for item 19 (M=3.20 for ENG, M=4.32 for EDU), they agreed that they should contribute to enhance the quality of human life and welfare, but they dissent that reducing the challenge that people experience in their daily life would be their important goal. However, the mean scores for item 19 in the ENG group largely increased after the intervention (**Table 8**).

Civic Engagement and Services (CIVIC)

Civic engagement and services (CIVIC) indicate the STEM professionals' volunteering, consulting, and pro bono activities to share their expertise, and collaborating with the public to solve community problems related to science and technology (Bielefeldt, 2018; Glerup & Horst, 2014). Five items are included in CIVIC. The ENG group showed low mean scores for CIVIC. It has been controversial among scholars if social participation and service are the social responsibilities of scientists and engineers (Schlossberger, 2016).

The scores in **Table 9** resonated with the previous studies. The ENG group showed the second lowest scores among the eight factors, which was quite different from the ones of the EDU group. Especially, they scored very low in items 22, 23, and 24. It seems that there was no great resistance to participating in civic affairs, but

Table 10. Responses to the items of COMMU items

*I believe scientists and engineers **should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
25. Make public familiar with science using media such as books, articles, blog, & lectures	2.75	4.20	4.38	4.33	3.56	4.26
26. Explain knowledge & research necessary for solving social problems to public	2.45	4.25	4.32	4.30	3.39	4.28
27. Knowledge or research regarding science & technology should be explained in a way that is easy for general public to understand	3.55	4.65	4.68	4.43	4.11	4.54
Total	2.91	4.36	4.45	4.32	3.68	4.35

Table 11. Responses to the items of POLICY items

*I believe scientists and engineers **should***	ENG		EDU		Total	
	Pre	Post	Pre	Post	Pre	Post
28. As a member of a professional organization of scholars, one must influence the policy-making process related to science and technology	3.72	4.33	4.47	4.45	4.10	4.39
29. Actively participate in policymaking processes related to science & technology	3.43	4.35	4.40	4.45	3.91	4.40
30. Emphasize its importance and must attract investment for science and	4.00	4.00	4.32	4.35	4.16	4.17
Total	3.71	4.22	4.40	4.39	4.05	4.32

they were not willing to collaborate with knowledgeable and interested citizens to resolve local issues (M=2.80) and to serve an advisory role for the public (M=2.60). However, their experiences of the ENACT project contributed to changing their views positively.

Communication With the Public (COMMU)

Communication with the public (COMMU) indicates that STEM professionals need to encourage the public to be interested in and familiar with science and science-related problems by explaining their research and sharing their scientific knowledge in a manner that the public can understand (Canney & Bielefeldt, 2015). It includes three items. For the ENG group, the mean scores of COMMU were lowest among the factors in the pre-test (M=2.91). They presented negative responses to items 26 (M=2.45) and 25 (M=2.75), which means that they could explain their research for the public (M=3.55), but they hesitated to say that making the public familiar with science using media or explaining knowledge and research necessary for solving social problems to the public should be their social responsibility. However, they also exhibited improvement after engaging in the ENACT project (**Table 10**).

Participation in the Policy Decision-Making (POLICY)

Participation in the policy decision-making (POLICY) indicates the efforts of STEM professionals to participate in proposing or establishing policies for science and technology to develop in the right direction and distribute its benefits evenly, as well as to induce investment in related fields (Lathem et al., 2011; Vanasupa et al., 2006). It contains three items. In the pre-test, the mean scores of the items were also quite different between the groups. The ENG group more agreed in item 30, but less agreed with items 28 and 29. It means that they were aware of the importance of participating in policymaking to recruit more funds to conduct better research and innovation but were less interested in participating in general policy-making processes. However, after the intervention, the ENG group became more aware of the importance of participating in the policy decision-making with their expert knowledge and skills (**Table 11**).

DISCUSSIONS AND CONCLUSION

We applied the ENACT model to foster the view of Indonesian STEM undergraduates on the social responsibility of scientists and engineers and obtained positive results. Whereas Bielefeldt and Canney (2014) mentioned that STEM students' social responsibility remained almost same without any systematic education over the college years, the chemical engineering (ENG) group in the study had shown a great improvement after engaging in the ENACT project in five factors of VSRoSE (i.e., CONSEQ, NEEDS, CIVIC, COMMU, and POLICY). However, the chemistry education (EDU) group did not show any changes in the VSRoSE scores. We believe that several factors could contribute to such positive changes. One reason could be the instructional approaches. The ENACT model emphasize on students' autonomous engagement. To facilitate this, we allowed the students to select their own topics out of their interests or experiences because relevant topics often increases students' motivation for learning (Masnaini et al., 2018) and the motivation also contributes to facilitating their engagement in learning (Niemiec & Ryan, 2009). Another reason may be that students were guided by the five steps of the ENACT model. They understood the nature of science and technology by examining the issues in steps 1, 2, and 3, and then moved onto steps 4 and 5. It means that students could engage in various scientific and engineering practice only after they obtained thee decent understanding of the issues and the nature of science and technology (Bencze & Krstovic, 2017; Choi & Lee, 2021).

However, the effects of the ENACT project occurred only in the chemical engineering (ENG) group. In other previous studies of the ENACT project (e.g., Hwang et al., 2023; Ko et al., 2022), engineering students did not show high scores in NEED, COMGOOD, or CIVIC. It is partly because there is a debates on whether such elements should be a part of the social responsibility of STEM professionals (Schlossberger, 2016). The ENG group, which has to fulfil their social responsibility as STEM professionals in the future, may have been more difficult to say that these elements should be the social responsibility of STEM professionals than the pre-service chemistry teachers. Nonetheless, the fact that the mean scores of the ENG group increased in five factors may be regarded as an extremely significant achievement. This study also confirmed that the systematic approach like the ENACT model is necessary to foster the view of social responsibility.

Based on the results of the study, we believe that we can expand the implementation of the ENACT model to college education for engineering or natural sciences. In Indonesia, we are teaching research ethics as a part of the college course, but most courses are likely to focus on normative principles as researchers. Experiences of seeing the nature of science and technology through SSIs and of enacting their own projects to resolve the issues can make a significant difference in their learning (Payne & Jesiek, 2018; Tassone et al., 2018).

The effects of the ENACT model can vary across the fields of science and engineering. STEM professionals in some fields may be more sensitive to the environmental consequences, while others may be more concerned about human safety and welfare. Other fields are used to communicating with people, even with the people not in the fields or the general public, but some fields mostly work within their own community. We believe that the ENACT model can be applied to any field of science and engineering because all fields have their own societal issues to be solved and SSIs naturally formulate the atmosphere where STEM professionals and other stakeholders should collaborate to resolve the issues. We expect that these positive effects may occur in many fields of science and engineering.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: This study was funded by LPPM in Universitas Riau 1336/UN19.5.1.3/PT.01.03/2022.

Ethical statement: Authors stated that the study was approved by Universitas Riau (Approval code: B/188/UN19.5.1.3/PT.01.05/2022). Data collected from this paper has obtained the necessary clearance from the college students involved in the study.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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