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Introducing Socioeconomic Determinants in Environmental Engineering and Chemistry Courses

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Abstract

Environmental justice research seeks to investigate and bring light to the disproportionate environmental burdens experienced by communities of low socioeconomic status. This paper presents the work done in two undergraduate courses to expand the scope of the environmental justice theme. We sought to encompass dimensions of social inequities by looking at government response times to environmental disasters in the United States as a function of location and socio-economic determinants in communities. Two courses in environmental engineering and chemistry were modified to include a module about natural and anthropogenic environmental disasters and their impact on the community as a function of government response time and the magnitude of resource allocations.

A survey was created to assess students' basic understanding of social justice associated with environmental disasters. A list of primary research articles were compiled covering a range of topics including environmental disasters (e.g., hurricanes Maria and Irma), hazardous spills (e.g., East Palestine), and poor decision-making (e.g., Flint water crisis). Students working in groups were asked to read different articles from the list, select one disaster, research the event further, and either give a PowerPoint presentation or write a report. A post-project survey and a reflection paper were administered at the end of the module. In both the engineering and chemistry courses, students' responses to Likert-scale questions on pre- and post-course surveys showed a notable increase in their interest and curiosity in how government responses and resource allocation can negatively impact remediation and recovery efforts of affected communities of low socio-economic status. Students in both courses recognized the value of learning about social justice implications of environmental disasters in STEM courses.

This work's first aim was to inform students of the environmental health risks resulting from exposure to hazardous chemicals or natural disasters. The second aim was to make them aware of the magnitude of social injustices that marginalized populations face in the aftermath of an environmental disaster. Initial findings demonstrate that our approach shows promise for achieving these objectives through the implemented coursework.

Introduction

The engineering profession has always aimed to serve society's needs. However, in some cases, engineering designs and products benefit some at the detriment of other groups [1], [2]. With justice issues affecting millions around the world, many engineering programs have started introducing modules and themes in their curriculum to educate students on such injustices and offer approaches to help them address these issues. The environmental engineering discipline is uniquely positioned to recognize environmental injustice, understand its adverse health and economic outcomes, and advance ethical approaches and solutions to mitigate the injustice issue.

As a result, integrating environmental justice themes into environmental engineering courses has become more prevalent in university programs over the years [3-5], which has helped shift the curriculum toward a justice-minded framework for the discipline. Even in chemical education, the incorporation of environmental justice themes in chemistry courses has increased and many articles describing its inclusion in the curriculum can be found in the chemical education literature [6-14]. It is worth noting that environmental justice is an integral part of social justice. Although the two are interconnected and overlap in their impact on marginalized communities, social justice encompasses fair and equal social and economic benefits in addition to environmental benefits.

Social justice education in professions such as medicine and law have been deemed necessary, prompting implementation of social justice courses and opportunities to facilitate students' understanding and practice, such as serving in free clinics or undertaking pro-bono law cases [1]. However, in engineering education, social justice themes have been less emphasized or ignored in curricular development [1], despite the inherent connection between social justice and environmental engineering. With engineering work significantly impacting society, inequality from social injustice can disproportionately affect vulnerable populations. Therefore, it is crucial to ensure engineering students are aware of both social and environmental issues when developing innovative solutions for the people affected by their projects.

One problem found that limits students' exposure to social justice is the decontextualization of problems within the engineering curriculum [1], [15], [16], [2]. While straightforward problems are helpful in allowing students to focus on concepts and principles, they do ignore the relevant social information affecting the situation that could inform a more comprehensive solution. Furthermore, this can suggest that engineering is a purely technical field and results in oversimplified engineering problems rather than focusing on the sociotechnical nature of issues students will come to face, wherein the social and technical dimensions of engineering affect each other [2]. Rather than detaching social justice from engineering, emphasizing the connection between the two will allow students to recognize multiple factors and seemingly invisible effects of social issues on developing effective, practical engineering solutions.

In a similar manner, social justice issues have been missing in chemical education [7]. However, addressing social justice within chemistry curricula has recently gained importance among instructors. More work has been published highlighting the importance and benefits of including social justice themes in chemistry courses: [17] incorporated the study of medical racism in an organic functional group chemistry lab, and Buckley and Fahrenkrug [6] used the Flint water crisis to introduce concepts of equity into an analytical chemistry course.

To promote diverse education that will foster socially aware engineers, the authors of this paper aimed to showcase unequal treatment of communities marginalized due to their social positionality along the lines of race and class. To encompass dimensions of social inequity, the topic of government response times to environmental disasters in the United States as a function of location and socio-economic determinants in communities was introduced. Although natural disasters can randomly affect places and devastate areas regardless of social factors, the path to recovery from one is not equal among all communities. Factors such as the response time, the amount of aid distributed, and the quantity of resources allocated can determine how long it will take for a region to rebuild from the event [18].

Two 1000-level courses in environmental engineering and chemistry were modified to include a module about natural and anthropogenic environmental disasters and their impact on the community as a function of government response time and the magnitude of resource allocation. Students were provided with a list of primary research articles covering a range of topics describing environmental disasters in the U.S. They also were asked to conduct their own research to further their understanding of the disaster.

Methods

The Pre and Post Survey

Prior to introduction of the module, students in both courses were given a survey with six questions to assess students' consideration of environmental disasters and the U.S. government's response. The survey included questions and response options listed in Table 1. The survey was delivered through an online link in the course learning management system. The first question was used to determine students' prior experience reading about disasters to demonstrate students' relevant prior knowledge. Other questions were used to measure students' interest in learning about disasters and government actions, how they valued learning about official responses to disasters, and finding solutions for social and environmental injustice. After the activity, students were given the same survey to assess any change in student opinions, interests, or perceptions.

Table 1. Engineering and chemistry pre and post survey questions

Q1. Have you watched a video, read an article, or seen in the news stories of environmental disasters (natural or man-caused) affecting communities in the United States ***and*** the government response afterwards? ***Response Options***: *Yes, No*
Q2. After hearing about an environmental disaster, how likely are you to look for government responses and actions after the disaster has occurred? ***Response Options***: *Very likely, likely, neither likely nor unlikely, not likely, very unlikely*
Response Options for Q3-Q6: *Strongly agree, agree, neutral, disagree, strongly disagree* **Q3**. I am curious to learn more about government response times to environmental disasters in the United States.
Q4. It is important to learn about social and environmental justice issues, in general.
Q5. It is important to learn about social and environmental justice in this class, to better recognize the connection between societal issues and STEM (science, technology, engineering, math) course content.
Q6. I feel I have a responsibility to help find solutions to social and environmental injustice.

The Reading, Writing, and Reflection Assignment

The general topic for the activity was the government response to natural or anthropogenic disasters in the U.S., taking into consideration the location of the event and the socioeconomic status of the affected community. The response was defined as the time it took the government to respond to the catastrophe and the resources that were deployed to help the afflicted population. Six disaster events since the year 2000 were explored by students and are listed in Table 2. The articles were chosen for this module because they not only explained the occurrences of the disasters, but also addressed the responses by the federal and local governments within the community. Samples of the assigned articles can be found in the references [18-20]. We chose to build a pool of primary research articles for students to ensure that the articles met our criteria of content coverage (environmental disaster, environmental and social justice, government response).

Students in both engineering and chemistry self-selected their own groups of four people. In the engineering course, students chose which disaster to read about, research further, and present as a group to the class in a slideshow presentation. In the chemistry course, student groups were assigned a disaster article to read and then to submit a group electronic report. An alternative approach would have been to allow student groups in the chemistry class to select a topic on their own in order to encourage more ownership by students of the work submitted.

The instructors permitted students to self-select group because they believed that the ability to choose group members would lead students to form teams with classmates whose abilities and academic aims are matched, or with friends who share similar commonalities or interests. In mixed-ability groups, there exists a concern for unequal contributions to a group project, as some students will be inclined to put forward more effort than others to achieve a higher grade. This therefore allows other students to assume less responsibility and not participate equally to the group effort. By allowing students to choose groups, they are more likely to work with others of similar academic goals and reduce the likelihood of unequal contributions.

Lejk et al. [21] found that higher-ability students attain lower grades in mixed-ability groups compared to student-chosen groups, although lower-ability students benefit from mixed-ability groups and achieve higher scores when working in mixed groups. In a situation significantly affecting their class grades, it is unfair for hard-working students to risk receiving lower grades due to randomly-assigned groups with students less inclined to put equal effort. Furthermore, students may know each other’s schedules and allow for better planning to work on the project outside of class. For example, athletes would need to work around sports events, so choosing to partner with other athletes may help ensure that group members are available to meet at the same times.

Both classes were given a writing assignment designed to engage students through reading, writing, and reflecting on what they read about a topic. This writing-to-learn methodology activates background knowledge and extends the thinking about what the student read. Gupte et. al. described the use of writing-to-learn (WTL) assignments where students gained understanding of organic chemistry concepts through use of a draft writing, peer review, and revision process [22]. In the work described here, the pre-survey was used to measure prior awareness, as well as student attitudes before completing the writing assignment. In the writing assignment, students were asked to summarize the essential information and to reflect on the consequences and government responses to the disasters. Specific assignment prompts are shown in Table 3.

Table 2. Topics of environmental disasters for engineering and chemistry student module

- Flint, MI water contamination
- East Palestine, OH train derailment
- Maui, HI wildfires
- Texas, Florida, and Puerto Rico hurricanes
- Kentucky coal slurry spill
- Gulf of Mexico Deepwater Horizon oil leak

Table 3. Engineering and chemistry assignment prompts

- What happened, where, when, to who, by whom?
- What chemical contaminants were people exposed to?
- Consequences of the disaster?
- What is the government response?
- Findings by the article authors?
- Reflection on consequences and responses

Results and Discussion

Of 38 chemistry students, 32 responded to both the pre and post survey giving a response rate of 84%. 57 out of 58 students in the environmental engineering course took the pre and post survey, accounting for a 98% response rate.

Prior knowledge

Question 1 of the survey demonstrated that the majority of students in both classes had gained some knowledge of environmental disasters and government response prior to the course (81% of engineering students and 97% of chemistry students). This fact could be due to the common pedagogical efforts K-12 and secondary education to intertwine environmental topics into science course material in order to make it more relevant. Alternatively, one might hypothesize that students may have greater exposure to these kinds of topics given that the Flint Water Crisis occurred within their lifetime.

Interest in reading about government response

Question 2 gauged the likelihood of students looking for government actions after a disaster occurs. In general, the event and immediate aftermath are well publicized, but many people lose interest in and overlook the government response and resource allocation following the disaster. Although the information is often available, students are not usually motivated to seek out the details on their own.

Similar to an approach by Crisp et.al. we grouped the response options into three categories: LIKELY which describes a broad likelihood (BL) combining very likely and likely, UNLIKELY which describes a broad unlikelihood (BU), encompassing very unlikely and not likely, and NEUTRAL [23]. Table 4 shows the percentage change in engineering and chemistry student responses for each of the categories. The broad likelihood of being interested in finding out about the government response increased by 21% and 16% for engineering and chemistry students respectively, whereas the unlikelihood and neutral interest decreased after the activity.

Table 4. Engineering and Chemistry responses to Question 2 in the pre and post survey

	ENGINEERING		**CHEMISTRY**	
	Pre-Activity	**Post-Activity**	**Pre-Activity**	**Post-Activity**
LIKELY (BL)	67%	88%	78%	94%
NEUTRAL	21%	10%	13%	6%
UNLIKELY (BU)	12%	2%	9%	0%

Curiosity to learn more about government response time

Question 3 assessed how motivated students are to learn more about government response to disasters. This indicated their willingness to conduct their own research into the subject rather than passively rely on news sources to learn about the situation. Similar to Question 2, the survey responses for this question were analyzed into three outcomes: AGREE which describes a broad agreement (BA), combining strongly agree and agree, and DISAGREE which describes broad disagreement (BD) compiling disagree and strongly disagree, and NEUTRAL. Table 5 shows the percentage change in engineering and chemistry student responses for each of the categories.

Table 5. Engineering and Chemistry responses to Question 3 in the pre and post survey

	ENGINEERING		**CHEMISTRY**	
	Pre-Activity	**Post-Activity**	**Pre-Activity**	**Post-Activity**
AGREE (BA)	63%	79%	84%	90%
NEUTRAL	37%	21%	16%	9%
DISAGREE (BD)	0%	0%	0%	0%

Students in both courses reported an increase in their curiosity to learn more about how the government reacts and helps communities after a disaster. It is noteworthy to mention that no student disagreed with the statement on being curious to learn more about government responses in both the pre and post activity survey.

Importance of learning about social and environmental justice

When asked Question 4 (Figure 1) about their opinion of whether it "is important to learn about social and environmental justice issues, in general," 44% and 31% of engineering and chemistry students respectively strongly agreed, 49% and 63% agreed, and 7% and 6% were neutral before the modular activity. After the group work activity, this dramatically inverted to 63% strongly agreed and 37% agreed for both classes with no other responses reported. For this question and the following two others (Questions 4-6), the 5-response categories are included to explicitly show a differentiation between" agree" and "strongly agree" which represents the changes in students' attitudes.

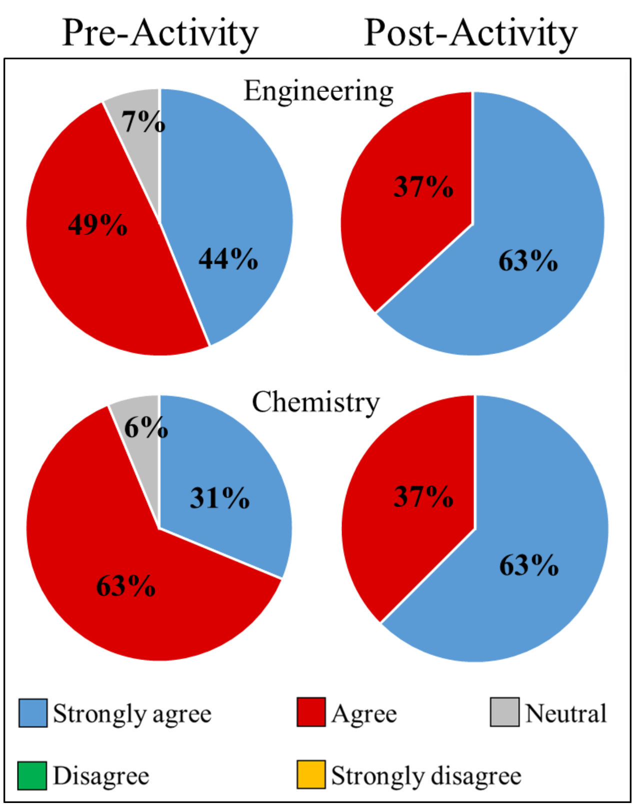

Figure 1. Results of student responses to Question 5 before and after the module assignment in both engineering and chemistry courses.

Importance of learning about social and environmental justice in STEM courses

Another significant response was observed for Question 5 (Figure 2) when students responded to whether "It is important to learn about social and environmental justice in this class, to better recognize the connection between societal issues and STEM course content." The response rate prior to the activity was 34% strongly agreeing to this question for chemistry, with 63% agreeing, and 3% strongly disagreeing in the chemistry class. After the activity, the responses inverted to 47% strongly agreed, 50% agreed, and 3% disagreed. In the environmental engineering course, 14% of the students strongly agreed in the pre-survey and this percentage increased to 47% after the activity. The increase in this category was due to students changing their responses from agree and neutral to strongly agree. These changes in thinking about the importance of learning about environmental disasters in STEM courses demonstrate that the activity was beneficial for students.

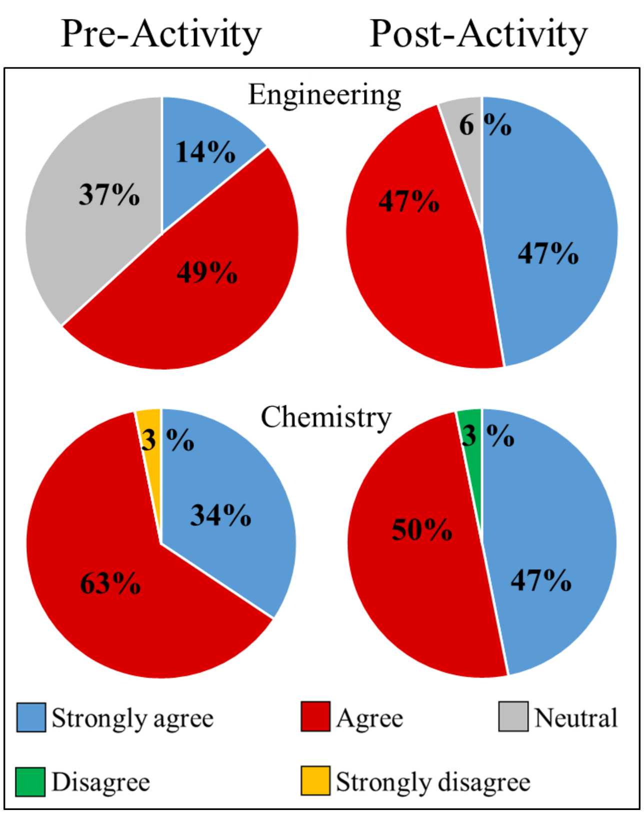

Figure 2. Results of student responses to Question 5 before and after the module assignment in both engineering and chemistry courses.

Responsibility to find solutions to social and environmental justice

Question 6 queried students' ownership of responsibility to solve environmental problems (Figure 3). For chemistry, the number of students who strongly agreed on their responsibility to solve environmental problems increased from 19% to 34%. However, the data suggested that there was a decrease in the overall number of students who felt a responsibility to find solutions (85% strongly agree and agree changed to 79% strongly agree and agree). For environmental engineering students, the percentage of strongly agree and agree decreased by 14% and 3% respectively after the activity, and the neutral category increased from 7% to 24% in the post survey.

One possible explanation for this result is that the general chemistry class was made up of 100% science major students, who are heading toward primarily health-related fields. Perhaps these students feel their responsibility for problem solving goes towards health problems rather than environmental ones. The authors were surprised to see a similar trend among environmental engineering students. These students are freshmen and one explanation of the percent decrease in feeling responsible to help solve social injustice is that they see their responsibility as technical experts, designing engineering solutions, not solutions for social injustice.

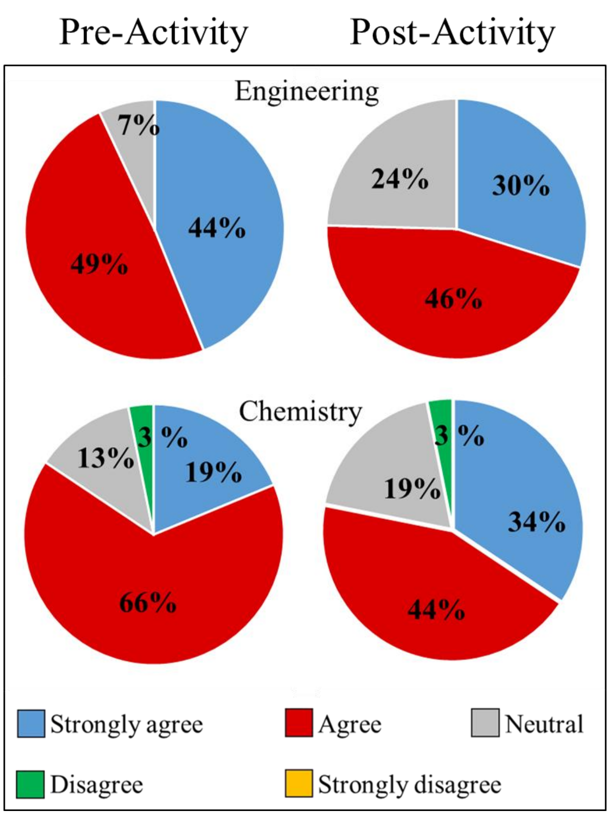

Figure 3. Results of student responses to Question 6 before and after the module assignment in both engineering and chemistry courses.

The Reading, Writing, and Reflection Assignment

All students had to submit a writing report on their reading. The writing prompts are listed in Table 3. In this assignment, students reported the basic facts of what, where, when, affected communities, the chemical contaminant, and a reflection on the consequences and government response. The purpose of asking students about the chemical pollutants was two-fold, to evaluate if students could identify the pollutants and their health risks from reading the articles and describe the information in their report. It was hypothesized that students in general chemistry and environmental engineering would be comfortable reporting chemical compounds listed in the articles as their prior exposure to science courses prepares these students with basic nomenclature. All students reported the government response to the disasters. Some reports included mention of relief efforts made by the community in addition to the government. Common themes arising from the student presentations and reflections were the importance of government assistance for communities after a disaster, the necessity of regulations to protect communities, inadequate responses by government that seemed to be more prevalent in economically depressed communities, and the need for people to speak up to notify the public of insufficient aid after catastrophes. A few examples of reflections by engineering and chemistry students respectively are included in Table 6.

Table 6. Sample environmental engineering and chemistry student reflections

- Maui wildfires: "The convergence of natural disasters with human-induced climate change accentuates the intricacy of disaster scenarios. It underscores the necessity for comprehensive approaches to environmental management to alleviate the social and economic impacts of impending disaster."
- Puerto Rico Hurricane Maria: "I have learned how the government treats regions of lower socioeconomic levels and residents of US territory, which is worse and slower aid than US states have received."
- "This assignment has made me realize that environmental disasters not only affect the environment, but they are disasters that have complex social consequences as well."
- East Palestine train derailment: "The community now live in fear of the long-term health effects that the chemicals will have on those living in the area."
- Flint water crisis: "I have also learned that the economic standing of the community also plays a role in how the disaster is handled. In Flint, large portion of the community falls below the poverty line, which was a key reason why it took around 18 months for the state and federal government. There is a stark inequity when it comes to how these disasters are handled between the wealthy and poor communities, which must be addressed."
- "I have learned that many of the environmental disasters we see in the news raise so many more concerns that are broader than the environmental impact, it is a real social justice issue."
- "This assignment has really opened my eyes to the struggles that people endure after natural disasters, especially low socioeconomic communities."

- “This assignment evoked a deep reflection on the broader social impact of environmental disasters on communities. It made me realize how connected natural disasters, socio-economic disparities, and the vulnerability of marginalized populations are.”
- “Environmental disasters disproportionately affect marginalized communities, exacerbating pre-existing inequalities and leaving them with limited resources to rebuild and recover.”
- “This activity has made me think about the profound social impact of environmental disasters on communities. It highlights the interconnectedness of social, economic, and environmental factors.”
- Flint water crisis - “[I] learned how residents who are living in economically depressed areas with high rates of racial minorities are more likely to be exposed to unsafe drinking water.”
- Flint water crisis - "The government response to this crisis was inadequate and the residents' health was blatantly disregarded, mainly due to the racial and economic characteristics of Flint.”
- East Palestine train derailment – "many aspects of [the citizens of East Palestine] current life qualities remain undetermined and under reconstruction."
- East Palestine train derailment - "lack of communication between the government and the train companies. The chemicals were not considered dangerous; therefore, the company didn't feel the need to tell the state about its transportation."
- East Palestine train derailment - "during evacuation of the population, it's important to make sure everyone is taken care of. This includes the homeless, the elderly, the sick, the disabled, the ones who cannot drive, etc."
- Kentucky coal slurry pill - "It is important that citizens call out these companies that are creating these negative effects."

A word cloud generator was used for the reflections that students submitted [24]. The results are shown in Figure 4. Since the aim of the project was to have students learn about the government response to communities after an environmental disaster, after removing the words “environmental, disasters, government, response, and communities” and the names of the regions affected and types of disasters from the reflections, the most common words used by students were:

Nouns: injustice, impact, disparity, inequity, poverty
Adjectives: social, marginalized, socioeconomic, economic
Verbs: realize, learned

These recurring words illustrate the students’ connection of social determinants to their environmental engineering and chemistry education. It also shows that students became aware of the magnitude of social injustices that marginalized populations face in the aftermath of an environmental disaster.

Figure 4. Results from the word cloud generator: word size corresponds to frequency of appearance in student reflection responses.

Conclusion

Environmental engineering and chemistry courses, which are highly technical and content driven, may not provide students with exposure to the significance of social injustice in these fields of study. This work sought to introduce dimensions of social inequities into two courses in environmental engineering and chemistry. The courses were modified to include a module about natural and anthropogenic environmental disasters and their impact on the community as a function of government response time and the magnitude of resource allocations. Our study showed that after reading about and researching the environmental disasters and their implications, students showed an increase in their interest, curiosity, and awareness of the magnitude of resource disparity allocated to communities based on their affluence and social status. Incorporating such topics into their courses is essential to guiding students in responsibly using the core principles of their fields for real-world applications. Such an addition to standard curricula will produce future scientists and engineers who are better equipped to address societal issues through their work.

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