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Diversifying STEM Higher Education through Online Collaborative Instruction: The Case of an Engineering Ethics Course between an MSI and PWI

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Diversifying STEM Higher Education through Online Collaborative Instruction: The Case of an Engineering Ethics Course between an MSI and PWI

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Abstract

A collaboration between a Predominantly White Institution (PWI) in University of Virginia (UVA) and a Minority Serving Institution (MSI) in Hampton University (HU) for their respective Engineering Ethics courses formed part of a Mutual Benefit Approach (MBA) to increase diversity in research and education. HU undergraduate students and UVA graduate students engaged in a synchronous online classroom environment with shared lectures and seminars. The goal is to build relationships between faculty and students that could lead to other forms of collaboration, including joint research projects and opportunities for graduate study at UVA for students from HU, where there is no engineering graduate program. The current collaboration resulted in an internal grant from UVA to support one-day in-person student exchange visits to expose students to diverse environments, giving many students their first experience at a PWI/MSI campus. Through the MBA collaboration, students at both institutions will grow more fluent in operating in a real-world multicultural environment.

Keywords

Engineering Ethics, DEI in Engineering Education

Introduction

Summary of STEM Status for African Americans

Although job growth in STEM fields is projected to double in the next decade, bachelor's degrees in science to African American graduates was flat from 2001 to 2016 at 9% but has declined from 5% in engineering to only 4% in 2018, and for math from 7% to 4%.[1] Nationally, Blacks made up 3.9% of graduating undergraduate engineers in 2020.[2] In 2021, all Black enrollment in universities declined by 7% nationally.[1] Some of this can be considered the economic and social toll brought about by the pandemic. Yet since many public universities and colleges banned race-based affirmative action, enrollment by Black, Hispanic and Native American students has dropped by 12 percent.[1]

Furthermore, one may consider what happens when Black students are at the university and enrolled in a STEM field? In 2015, an in-depth study looked at students declaring for STEM fields and their retention rates over time.[4] Initially, the sub-population of students choosing a STEM major was the same for both Blacks and Whites at 18 to 19%.[4] The problem the study found was in overall retention to graduation. Though retention rates for all students was poor, the rate for White students was 43%, nearly double that for Black students at 22%.[4]

Overall, there are serious problems with African American students a) getting enrolled in increasing numbers in STEM fields and then b) making it to matriculation with a bachelor's degree. This situation highlights the need and relevance of Historically Black Colleges and Universities (HBCUs), which annually graduate roughly half of all Black engineers.[3]

Mutual Benefit Approach

The goal of the Mutual Benefit Approach (MBA) is to use a series of normalizing immersions from K-12 up through the PhD, in deliberately diverse STEM environments, to enable a natural transition to STEM Higher Education (SHE) for students, instructors, and other stakeholders from underrepresented groups in STEM (SUGS). This process also allows their peers at PWIs to have graduated experiences in engaging with SUGS in diverse STEM environments. Such long-term mutual engagement strategies for diversifying STEM are not well documented in the SHE literature, which tends to focus more on end-of pipe initiatives, such as affirmative action, Title IX and the multiple facets of diversity, equity, and inclusion at PWI. Though these initiatives are important, they do not address the supply problem that reduces the number or SUGS interested in and adequately prepared to succeed in SHE.

Another rationale for the MBA is the lack of mutuality in most partnership relationships between PWIs and MSIs. PWIs may view MSIs as targets for recruitment of students to diversify the PWI student body, particularly in graduate STEM programs. Furthermore, PWIs may engage with MSI as add-ons to proposals or projects to bolster the Broader Impacts merit review criteria of their projects. The Mutual Benefit Approach (MBA) stems from the belief that collaborations between PWI and MSI are likely to be more equitable and effective if they emerge from natural relationships between faculty, students, and administrators at partner institutions. MBA builds normalized trust relationships in which students, faculty, parents, and community partners are immersed in STEM educational experiences in richly diverse environments. It allows participants to transition through different STEM educational levels in different types of diverse environments. The MBA involves a four-point strategy for normalizing immersions that enable a transition to diversity in SHE. These four points are: i) Priming the pipeline, which engages SUG K-12 students, teachers, and other supporters in STEM activities facilitated by SHE academic stakeholders, community partners and STEM workforce partners. The activities include lab tour visits and campus tours to participating colleges and universities as well as mentoring and STEM tutorials provided by SHE students and faculty. ii) Continuous engagement, which involves SUGS from Community College (CC) to the PhD level in experiential and service learning activities that places their STEM education in the context of the communities that shape their identities. Thus, SUGS can retain their identity and connection to their home communities while pursuing higher education and subsequent careers in STEM. The partnership between HU and UVA, including student groups like the Collegiate 100 at UVA is an effort to provide this conscious continuous engagement. iii) Community engagement for social context (CESC), in which families and community organizations partner with the academic participants to support SUGS from K-12 through SHE in learning STEM in context. In this project, the 100 Black Men of Central Virginia, My Sisters Keeper, and the African American Pastors Council are some of the organizations that partner with UVA to offer lab tours, a summer academy, and STEM mentoring sessions on Monday evenings during the Fall, Spring, and Summer semesters to students from 6th to 10th grade in regional public schools. University students are also involved in facilitating these activities. iv) STEM Workforce Engagement, in which private sector companies, government agencies and NGOs like the Nature Conservancy, provide guest speakers, internships, and financial support to the MBA partnership programs. The four-point strategy is represented in Figure 1.

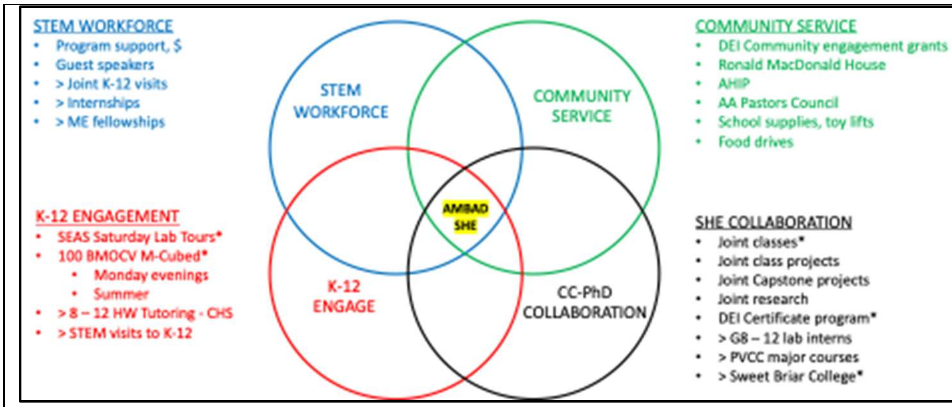

Figure 1: Four-point Strategy

This paper is devoted to one aspect of the MBA, which is a joint class in Engineering Ethics taught at HU and UVA. Thus, the paper focuses on the "Continuous Engagement" element of the four-point MBA strategy, though, as explained, this is integrated with the other three points of the strategy.

Ethics Instruction Engineering

An engineer is responsible for designing products and processes that are safe for the public, the local community, and the fellow workers at the company. Products and their contents, uses, and potential hazards must be properly disclosed and labeled. Engineers also have an ethical responsibility to credit intellectual property both within and without the company. To assist with ethical situations and legal compliance, many corporations have an Ethics/Compliance Officer.[5,6] It is such a critical component that Professional Engineers take an Ethics course every 2 years to maintain their licenses.[7] The National Society of Professional Engineers (NSPE) has a 24-hour licensure and ethics hotline.[7] Each engineering professional society has a code of ethics.[8,9,10]

In academia, ethics training has been lagging the professional engineering societies. It was only in 2000 that ABET formally had ethics as a criterion for accreditation.[11] Yet even now there is no mandate on the amount of ethics covered or if it merits a stand-alone course leaving it up to the individual educational programs to decide the manner of its instruction.[11,12] For many programs, the addition of ethics courses was primarily to meet ABET requirements.[11]

Still there are some outstanding resources available to academics and some good textbooks available.[13] National Society of Professional Engineers has a wealth of case studies online.[14] More academic ethics centers are starting to form nationally such as the Online Ethics Center for Engineering and Science.[15] It provides a repository of educational materials and an active chat for members to help one another.[15] In 2016, the National Academy of Engineering published a book on best practices in ethics education.[16] The practices outlined were mostly case studies with group discussions, but also included role playing and problem-based learning.[16] A survey of publications on ethics instruction from 2000 to 2015 found 80% of the papers involved case studies.[11]

Graduate Ethics at PWI

Engineering Ethics at University of Virginia is a graduate course developed from an NSF CCLI grant in 2006. It is taught in the Spring semester as “Ethics in Science and Engineering Research and Practice.” The class size varies between 6 to 12 students per year taking the course as a graduate elective in Systems Engineering. In 2022 the class had 16 students, including 2 African Americans and 1 undergraduate student admitted by special permission. In most years the students in the class are White and Asian, reflecting the composition of the graduate student body in Engineering at UVA. The class covers the professional codes of ethics, ethical theories, ethical dilemmas, and issues in applied ethics supported by case studies from the National Society of Professional Engineers and the Online Ethics Center at UVA[15]. Students also create and lead case studies based on the booklet, “On Becoming a Scientist,” by the National Academies.[17] The course includes invited speakers from industry, government, and NGOs who talk about ethical issues in their professional practices as scientists and engineers.

Undergraduate Ethics at MSI

Engineering ethics and safety course at HU, is a team-taught class developed for undergraduate chemical, computer, and electrical engineering students. All 17 students were African Americans. Ethical theory is delivered primarily using case studies, with the inclusion of guest speakers. The objective is to not only give the students proper tools and ethical theory so that they can properly argue and solve an ethical dilemma; the additional focus is to provide them useful professional tools.[18] The professional skills included teamwork with 360 peer evaluations and group contracts, design safety with fault tree analysis and calculations of risk priority numbers, and quality control calculating moving average and range charts process capabilities.[18]

Methodology of Course Delivery

From the pains of the pandemic, where classes were taught online for both programs for over one year, tools like Zoom, Blackboard Ultra Collaborator, Canvas, etc. were used and relied on like never before. Delivering material online and still involving students interactively using breakout virtual rooms, has opened the doors to teaching courses between campuses in a manner not previously considered. The objective was to teach the classes concurrently so that when material of interest is being delivered in one class the other class can link into it virtually. Hampton University changed its class to match the time for University of Virginia. In addition, instructors had access to materials and were able to upload seminar and lecture videos as well as other course materials to each other’s classes. Four seminars were shared between the two institutions, with three coming from HU guest speakers, and one from UVA’s Andres Clarens on Environmental

Ethics. The seminar by Andres Clarens inspired Brian Aufderheide to develop an Excel worksheet for calculating carbon tax for any given process.

Outcomes

Professional Engineering Code of Ethics

The basis of the Ethics course delves into the conduct of engineers in their profession and endeavors to prepare engineers to be ready for their profession. An external presenter on professional standards was Mr. William A. Brown Sr., P.E. He currently serves as Chairman of the Engineering Advisory Board at HU, and retired as the highest ranking civilian engineer in the Army Corps of Engineers. A consummate professional with the highest integrity, Mr. Brown, Sr., P.E. delivered the professional standards using the NSPE code of ethics[10] as the baseline of the lecture module. He emphasized ethics as the core of every aspect of his work and as such it should be how every engineer conducts their business. The explanation of fundamental canons, the rules of engineering practice and the professional standards engineers are obligated to abide by. The ancient concept of the litmus test was explained as a way to help engineers stay grounded in the ethical standards. For example, once the engineers complete their project, the litmus test for the engineer: “Would you okay what you produce for use by people you love most in this world?” should be a starting point on checking on professional ethical standards. The speaker provided 4 questions that can serve as a litmus test guide for every engineer.

1. Would my choice violate a law or company policy?
2. Do the benefits outweigh the harms (short or long term)?
3. What would my professional colleagues say?
4. Do I want people to know what I am doing?

These litmus test questions help engineers to stay away from common ethical violations such as certifying work done be others, receiving bribes to obtain or falsify work, avoiding delivering bad news to client, falsifying contract documents, and complying with discriminatory practices. The talk was delivered by zoom with presentation material made available to all students across the institutions. Both groups of students engaged with the speaker live during the talk. The presentation lecture included a follow up quiz developed by the presenter for the class. The quiz was presented as a 25-question ethics exam that challenged the students on their understanding of professional code of ethics as well as highlight the key elements of ethics.

Corporate Ethics, Quality, and Compliance

The application of the engineering code of ethics were also highlighted through a guest lecture by Ms. Britta Brown Whitehead who works as a Compliance Officer at HII Newport News Shipbuilding. In her presentation, she covered a myriad of ethical issues that included military design flaws to new legal landscape for ethical violations by corporations, and discussed how management can be held criminally accountable for gross ethical violations at any company level.

The foundational definition of ethics contrasted with feelings, religion, law, and societal norms. The presenter reiterated approaching ethics using core approaches (utilitarian, rights, justice, common good, and virtue). She focused on the triangular approach to ethics, quality, and compliance leading to the concept of the fraud triangle. Compliance was defined in reference to detection, prevention, and remediation of misconduct of ethical risks. The approach looks at ethical risk based on perceived pressure, rationalization and perceived opportunity as the elements of a fraud triangle. Case studies highlighted the rise of ethical risks leading to lowered quality of standard and failure in compliance, hence violation of ethics. Complexity of compliance requirements was identified as a key element in precipitation of ethics failures. The concept of ethical drift was also defined to the students as a situation when complexity or compliance requirements force the engineers to make their own judgements about what rules to follow. Finally, the realization and awareness of ethical failure of successful leaders termed the Bathsheba Syndrome[19] was highlighted as a reference for young engineers to take action on responsive ethics within the corporate structures. The understanding of why those in leadership end up violating ethics can help engineers in lowering the ethical risks or countering the ethical drift. This lecture was also interactive via zoom with the recording made available for student reference.

Intellectual Property

Engineers operate in a creative space where there is continual development and/or enhancement of products and processes. In the realm of ethics, there is a need for engineers to learn how to protect their creativity as well as avoid violating other engineers' creativity. A patent law firm team led by Edward J. Brooks III, of Brooks, Cameron & Huebsch, PLLC law firm provided a guest lecture on the ethics of Intellectual Property and Patent Law. The lecture focused on the areas of intellectual property (i.e. utility patent, design patent, trademarks, copyright, trade secret) and processes for filing patents. Discussions on what is patentable laid the foundation to understand when a patent can be filed leading to domestic and international protections provided through filing of patents. The lecture also delved into the valuation and monetization of patents. As a way to enhance the discussion on the ethics of intellectual property, a series of topics were proposed to the students in advance of the lecture to allow their input in prioritizing the discussion points. Topics such as patenting algorithms and software were featured along with emerging technology. The case on *KCI v. Alice Holdings* was discussed in reference to patenting software. Other topics on the ethics of Intellectual Property dealt with the subject of patent trolls. The students also had the access to submit written questions post lecture to receive opinion feedbacks.

Environmental Ethics

There is a growing realization that environmental change will have disproportionate impacts on different communities. Extreme weather events, supply chain disruptions, and responses to these stressors embodied by the energy transition will all impact those people least able to respond to these stressors. But members of these communities are also largely underrepresented in the workforce, which limits our collective ability to identify culturally appropriate and resonant strategies to build more resilient communities. Of the many tools used by environmental resilience community, one tool that is approachable for undergraduate students is life cycle assessment (LCA). LCA is a quantitative tool for assessing the environmental burdens of a process or a product. It is the foundation for important tools like greenhouse gas inventories (also known as carbon footprint analysis). It can also be used by engineers to inform design and process decisions. For this effort, an online module was developed and offered via Zoom to students at UVA and at HU. The module involved interactive activities as well as lectures for the students to gain hands-on experience with the material.

Carbon Tax Financial Operational Model

Almost all of the HU students had learned how to build a Financial Operational Model (FOM) in their Engineering Economy class, where engineering design calculations are coupled with labor, utilities, and capital costs to develop total fixed capital calculations for project construction[21] and profit loss sheet that covers yearly operating expenditures.[20] A resulting economic summary sheet determines the Net Present Value, Interest Rate of Return, and Payback Time for the life of the project.[20] The objective was to expand the FOM to include a Carbon Tax worksheet. The evaluation for the Carbon Tax includes the total electricity used by the process and how it was generated, the total steam for heating and what fuel the boilers consumed, and any greenhouse emissions to the atmosphere. A direct cost line for the Carbon Tax would be included on the Profit Loss sheet. Included in the spreadsheet are following tables: Electrical Power Plants and Their Carbon Footprints[21], Process Emissions and CO_2 Equivalents[22], Calculate Energy for Steam Heating[23], CO_2 Generated by Heating with Fossil Fuels[24]. The exercise for the students was to add the Carbon Tax sheet into an existing FOM, link all the process and utility values calculated from the engineering design, and choose various electrical plants and/or Carbon Tax rates to see how it affected the overall project's Net Present Value and Interest Rate of Return for the proposed engineering design.

The assignment was a group project: Life Cycle Analysis for Production of Monoclonal Antibodies (MABs). The students were provided with the FOM where the MABs are made using the *Pichia pastoris* gene expression system. The simplified design covered the bioreactor for cell growth and MAB production, then cells separated from a stacked disk centrifuge, followed by a protein A chromatography column. Electricity for bioreactor agitator, pump, and the centrifuge was calculated. Amount of steam required to sterilize all equipment was determined. Carbon dioxide from the yeast growth during the process, and the disposed waste cells made up the process greenhouse emissions. Students generated a pie chart comparing the Carbon Tax by electricity, steam, and emissions. They then did a histogram of carbon dioxide emissions by various electrical plants. A final sensitivity analysis was done by varying from no Carbon Tax up to $100 per metric ton on the project's Net Present Value, Interest Rate on Return, and Payback Time. The Carbon Tax sensitivity range was based on Canada's Carbon Tax policy.[25]

Discussion

The content of the guest lectures was included in written assignments and case study presentations on applied ethics to the students at UVA. In the discussion of these works the class probed the issues raised in the lectures deeply for their relevance to ethical theory and the NSPE engineering code of ethics. The HU students also followed up the guest lectures by competing relevant quizzes and assignments.

Intellectual Property Interaction

The students were quite engaged on the subject of intellectual property. They were provided with 17 topics prior to the lecture and 7 of the 17 topics were selected as first choice for prioritization while 5 of the remaining 10 topics were selected as second choice prioritization for discussion. In post-lecture question submission, the questions of interest were varied but covered most of the 17 topics. The students received written feedback to their questions that were aligned to one of the 17 initial questions and beyond.

Results Carbon Tax Group Project

Overall, the students did quite well on the assignment getting marks from 80 to 100 with an average of 92.2 and standard deviation of 6.9%. Almost all were disheartened by the fact that although the process produced nearly two thousand metric tons of carbon dioxide a year, even at the $100 per metric ton charge, this was a mere pittance compared to the high value of MABs, and had little effect on the profitability of the proposed biopharmaceutical plant (see Figs. 2, 3). An interesting discussion ensued on whether or not all Carbon Tax sources should be treated economically the same. In future classes, it would be a great learning tool to redo the exercise with a traditional chemical or steel plant for comparison.

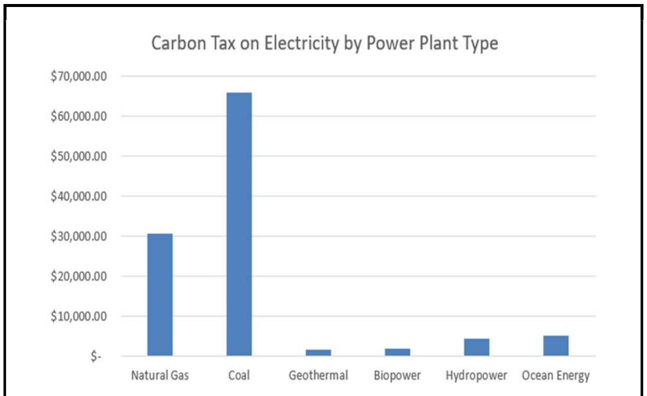

Fig. 2 Amount of Carbon Tax for Production of MABs by Power Plant Type

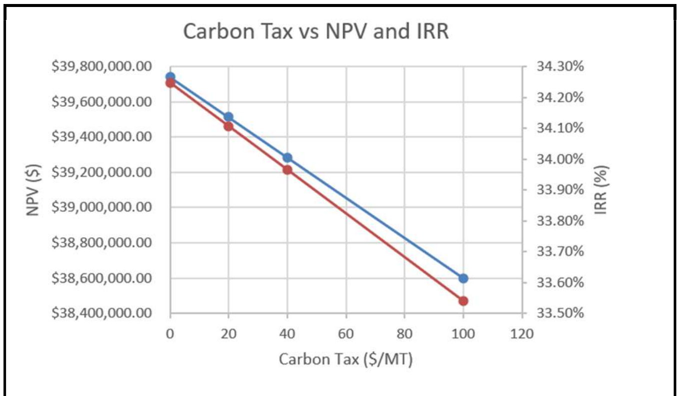

Fig. 3 Sensitivity Analysis by Carbon Tax Amount to Project Profitability

Future Work

Joint Project and Field Trips

Garrick Louis has obtained an internal grant which provides funding for students and faculty of both UVA and HU to visit each other's respective schools in the next offering of the course. The grant also funds select high school students to visit the institutions. The objective is to increase interaction of high school, undergraduate, and graduate students in a meaningful project that deals with Social or Environmental Justice. Mixed groups of HU and UVA students will tackle a case study with an ethical dilemma and produce a presentation and a written report. The high school students will have the opportunity to participate in this project. The proposed structure of the exercise is as follows:

1. Faculty from both classes will share their rules of engagement on group discussions, and will generate a proposed set for joint discussions between the two classes. Students from both classes will vote and/or modify them if necessary.
2. One week prior to the team project all students will be informed about group contracts. All contracts will specify expectations for the group, meeting objectives and times, and possible conflict resolution strategies.
3. UVA students and high school students will take a field trip to HU. A tour of the university will be given. Student teams will be formed. Different case studies and team projects will be outlined. Student teams will have their first meeting face to face during this visit. If time permits, preliminary short presentations from each team on initial thoughts and issues for their case study will be given at the end of the visit day.
4. Student teams will develop and sign group contracts.
5. Faculty will present oral presentation rubrics to students. Students will discuss and suggest changes leading to final rubrics.
6. One month later HU students and high school students travel to UVA. A tour of the university will be given. Teams will present to each other. Oral presentation rubrics will be filled out by both faculty and students for each presentation. Full participation of all student members from high school to graduate students is expected. Grades and comments will be given to each group so that suggestions can be acted upon for the final written report.
7. All participating students, High-school teachers, and faculty will complete a survey on their perceptions on the organization, structure, logistics, strengths, weaknesses, and suggestions for improvement of the exchange experience. These will be used to help document the impact of the course.

It is anticipated that students will learn from each other through the multiple case studies, the research and presenting as peers. The plan is to consult with professionals from the Center for Teaching Excellence at HU and UVA to design case studies that are sufficiently broad to allow high school students untrained in ethics to share informed opinions, while having sufficient depth for undergraduate and graduate students to dig deep enough as a research topic.

Conclusions

The Mutual Benefit Approach is a broad institutional endeavor to increase diversity in STEM Higher Education through long-term normalizing immersions in diverse STEM environments for students, instructors, community members, and members of the STEM workforce from K-12 through the PhD. The MBA uses a four-point strategy that includes K-12, Community College through to the PhD, Community Engagement, and STEM workforce engagement. These four elements overlap and reinforce each other through all stages of the immersion experiences. This paper reports on a joint Engineering Ethics Course taught between University of Virginia, and Hampton University. It represents the second leg of the four-point strategy and aims to provide an opportunity for students, faculty, and speakers to experience a diverse STEM learning environment while at their respective institutions (that are not significantly diverse). The joint course takes advantage of online learning applications like Zoom and Blackboard, to facilitate rich exchanges between the students, faculty, and speakers as the co-learn elements of Engineering Ethics. Including physical interactions between the classes in the next version of the class by allowing students from UVA to be hosted by the peers at HU for one day. In this way the UVA students get to experience being the "minority" on campus then participating in a diverse STEM learning environment during the actual Ethics class session. The exchange visit is repeated later in the semester when the UVA students host their peers from HU. The experience for participants is enriched by the participation of High School students interested in STEM Higher Education and in visiting and participating in a sample engineering education experience. More joint assignments involving mixed teams of the HU and UVA students are planned for the next offering of the class. This collaboration motivated the instructors to develop new tools, projects, and assessments. For this iteration, the authors shared four outstanding seminars and inspired one additional tool that can be used to evaluate environmental impact and an economic measure to help correct it in the future.

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