
Article:

Oerther, DB, Gautham, L and Folbre, N (2022) Environmental Engineering as Care for Human Welfare and Planetary Health. Journal of Environmental Engineering, 148 (6). ISSN 0733-9372

https://doi.org/10.1061/(ASCE)EE.1943-7870.0002013

Environmental Engineering as Care for Human Welfare and Planetary Health

Daniel B. Oerther, Ph.D., P.E., DEE, M.ASCE
President, American Academy of Environmental Engineers and Scientists, 147 Old Solomons Island Road, Suite 303, Annapolis, MD 21401, USA
(corresponding author). ORCID: https://orcid.org/0000-0002-6724-3205. Email: oertherd@mst.edu

Leila Gautham, Ph.D.
Department of Economics, University of Massachusetts, Amherst, MA 01002, USA

Nancy Folbre, Ph.D.
Professor Emeritus, Department of Economics, University of Massachusetts, Amherst, MA 01002, USA

Abstract

Among the sub-disciplines of engineering, environmental engineering is distinctive in three aspects. First, descriptions of the profession of environmental engineering emphasize that environmental engineers solve problems to prevent harm, which typically is an important motivation for taking a job in care work. Second, the percentage of degrees awarded to women is highest for environmental among all sub-disciplines of engineering (i.e., 53.3% of bachelor's degrees, 46.3% of master's degrees, and 43.6% of doctoral degrees in environmental

engineering conferred in 2020 were awarded to women). Third, median salaries for environmental engineers – controlling for other variables – are lowest among engineering sub-disciplines (i.e., $82,036 per year in 2019), despite high levels of educational attainment and training. Our analysis of environmental engineers working in the United States strongly suggests that the profession of environmental engineering is highly susceptible to what is known as the care penalty. The care penalty is a function of market dynamics, which tend to undervalue work that generates substantial unpriced benefits for others. The care penalty often is observed in jobs characterized by high levels of intrinsic motivation, such as concern for human welfare. Additional data would be useful to further evaluate the care penalty in environmental engineering in other countries. To address the care penalty, we do not suggest that environmental engineers should become less caring. Rather environmental engineers should be aware of this potential economic risk and seek to mitigate the care penalty in two specific ways. First environmental engineers should encourage life-cycle principles and environmental full-cost accounting in order to increase fungibility among different measures of the components of the triple bottom line of people (i.e., human welfare), planet (i.e., planetary health), and prosperity (i.e., financial gain). Second, environmental engineers should clearly demonstrate the unique contributions that technically skilled commitments to human welfare can generate. We suggest that a greater awareness of these issues could build on and strengthen growing public concerns regarding environmental sustainability. Finally, we suggest that distinctive attributes of environmental engineering may prove critical to unlocking growth in the engineering workforce as care for human welfare and planetary health.

Keywords

care penalty, full cost accounting, gender, pay gap

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

1. Introduction

The way in which engineers describe themselves and their sub-disciplines deserves careful attention. Recent research in the social sciences offers some important insights into the ways in which different engineering sub-disciplines are publicly perceived and economically renumerated. Historically, the formal integration of engineering professional training into higher education over the past one hundred and fifty years was a major contributor to the growth of global market share and the dominance of the United States (U.S.) economy during much of the 20th century (Rosenberg and Nelson, 1994). Looking towards the future, the National Academy of Engineering (NAE) has warned repeatedly that the significantly lower percentage of engineering degrees awarded in U.S. universities – as compared to European countries and key competitors in Asia – represents a concern for future economic success of the U.S. (NAE, 2014). To recruit additional students to study engineering – while retaining the current pipeline of engineering students – the NAE developed the “Changing the Conversation” campaign (NAE, 2002; NAE, 2008; NAE, 2013).

As part of an intentional effort to unify messaging both that explains and promotes engineering, the NAE developed and tested marketing taglines, including: “engineers make a world of difference”; “engineers are creative problem solvers”; “engineers help shape the future”; and “engineering is essential to our health, happiness, and safety,” (NAE, 2013). After five years of experience promoting these taglines to the public, the NAE concluded that, “the new messages cast engineering as inherently creative and concerned with human welfare, as well as an emotionally satisfying calling,” (NAE, 2013, p.1).

The campaign – Changing the Conversation – was grounded in the observation that inspirational messages are effective for recruiting. The efforts of the NAE noted that the way in which a profession describes itself influences the kind of people a profession attracts to its ranks. For example, “The medical profession does not market itself to young people by emphasizing the long, hard road to becoming a physician. The image of the physician is of a person who cures disease and relieves human suffering,” (NAE, 2008, p.12). In contrast to the description of physicians, the public often describes engineers as “driving trains” or “designing and building things”, and historical messaging about engineering focused on an “aptitude for and strong interest in mathematics and science” (NAE, 2002).

To understand distinctive aspects of environmental engineering as a sub-discipline, the three-fold purpose of this article includes: 1) identifying how environmental engineers describe themselves and their subdiscipline using thematic analysis of a selection of publications; 2) analyzing evidence of a potential care penalty in the profession of environmental engineering;

and 3) proposing how environmental engineers respond to the care penalty to leverage self-identity as a caring profession to unlock growth in the engineering workforce promoting human welfare and planetary health.

2. Environmental engineers self-identify as members of a caring profession

To describe the professional practice of environmental engineering and to inform the curriculum used to educate future environmental engineers, in 2009 the American Academy of Environmental Engineers and Scientists (AAEES) published the Environmental Engineering Body of Knowledge (EnvEngBoK) (AAEES, 2009). The EnvEngBoK describes the knowledge, skills, and attitudes (KSAs) of environmental engineers across the career-span. These are organized into 18 outcomes, and a modification of Bloom's taxonomy (i.e., knowledge, comprehension, application, analysis, synthesis, and evaluation) is used to map the levels of achievement in each outcome with education and continual professional training (Oerther et al, 2021a; Oerther et al, 2021b; Oerther et al, 2021c).

Within the EnvEngBoK, outcome 13 describes the "professional and ethical responsibilities" of environmental engineers. The text cites the importance of all engineers to abide by the Code of Ethics for Engineers (NSPE, 2019), including the importance of holding paramount the safety, health, and welfare of the public. The text notes, "however, environmental engineering is unique in that it is the engineering [sub-]discipline that as a whole **serves the public welfare, health, and safety directly** [emphasis added]. In addition, although other engineering [sub-] disciplines are becoming more aware of the need to understand the relationships between technology and environmental protection, environmental engineers are **directly responsible for preserving the natural environment** [emphasis added],” (AAEES, 2009, p.43).

In other words, since the founding of the profession in the mid twentieth century (Boyce, 1963), environmental engineers have developed an explicit professional and ethical responsibility to care directly for human welfare and planetary health (Hendricks and Baumann, 1990; Anderson, 2005; Hendricks, 2005). Based on the text of the EnvEngBoK, we speculate that caring for human welfare and planetary health may be the primary professional and ethical responsibility of environmental engineers (i.e., subordinating all other duties shared among environmental engineering and the other engineering sub-disciplines).

The theme of the caring nature of the profession of environmental engineering is reflected in the Standard Occupational Classifications (SOC) maintained by the U.S. Bureau of Labor Statistics (BLS, 2018). As emphasized in the highlighted text included in Table 1, the SOC entry for environmental engineers describes the use of engineering skills in the, “prevention, control, and remediation of environmental hazards.” In contrast, the SOC entries for many other engineering sub-disciplines emphasize “things” (i.e., aerospace engineers focus on “aircraft, missiles, and spacecraft,”; civil engineers focus on, “building structures and facilities,”; and industrial engineers focus on “systems”). As describes in the SOC for environmental engineering, preventing harm – especially harm related to the environment surrounding people – reflects concern for human welfare.

Similarly, the definitions of "what the profession does" included in the Occupational Outlook Handbook (OOH) also published by the BLS supports a differentiation between environmental engineering and other engineering sub-disciplines (BLS, 2021). For example, the OOH describes the work of environmental engineers as "develop[ing] solutions to environmental problems." This definition of environmental engineering contrasts significantly from the definitions of the work of civil engineers ("design, build, and supervise infrastructure projects and systems"), electrical engineers ("design, develop, test, and supervise the manufacture of electrical equipment"), or mechanical engineers ("design, develop, build, and test mechanical and thermal sensors and devices"). Phrases like, "solutions to problems," evoke social needs that are not necessarily expressed by market forces and that require some level of intrinsic concern for planetary health.

The theme of environmental engineering as a distinctive caring profession among the sub-disciplines of engineering may be found in the data available from the National Survey of College Graduates (NCSG) from 2010 to 2019, conducted by the National Science Foundation (NSF). For example, environmental engineers as well as civil engineers are the most likely to respond that when thinking about a job, the job's contribution to society is very important to them (i.e., as reported in Figure 1, the fraction of total environmental engineers offering this response (46%) is nearly twice the fraction of total computer engineers offering this response (27%)) (details on the data, sample, and variable construction are given in Appendix A).

Collectively, the language from the EnvEngBoK, SOC, and OOH as well as the data from the NCSG all suggest that environmental engineering may be characterized as a caring profession (Note: this conclusion does not suggest that other sub-disciplines of engineering are uncaring; rather the emphasis here is on the caring nature of environmental engineering). As a caring profession, the work of environmental engineers may involve a strong moral commitment, strong emotional attachment, or strong personal connection reflecting a distinct sense of right and wrong beliefs and behaviors shared among the group of workers that make up the profession of environmental engineers (Ellemers et al, 2019).

The peer reviewed literature on the education of environmental engineers further supports the theme of environmental engineering as a caring profession. For example, a survey of recent graduates of engineering asked about the desire to serve people or society through their jobs as well as their level of satisfaction in terms of meeting this desire through current employment (Bielefeldt and Canney, 2019). Results were binned into the sub-disciplines of "environmental engineering", "civil engineering", or "mechanical engineering". Many respondents expressed a strong desire for service, and many respondents expressed dissatisfaction with the ability to help people as part of their current job. Among the groups examined in the study, environmental engineers were the most likely to express a desire to serve and as well as the most likely to express dissatisfaction with the ability to serve as part of their current job (Bielefeldt and Canney, 2019). These results support the view that environmental engineers share a moral commitment and may point to environmental engineers pursuing jobs that allow for greater focus on human welfare.

A second example from the peer reviewed literature on the education of environmental engineers notes that the rapid switch to on-line instruction during the spring semester of 2020 – due to COVID-19 – was associated with an “emotional disconnect” between faculty and students in environmental engineering (Oerther and Peters, 2020a; Oerther and Peters, 2020b). This result suggests that teaching in environmental engineering relies upon establishing strong personal connections as well as strong emotional attachment among students and faculty.

Finally, the caring nature of environmental engineering also has been described previously through a comparison of the sub-discipline of environmental engineering to the profession of nursing; in particular a growing body of evidence supports the view that the practice of environmental engineering benefits from a grounding in the theory of care developed by the profession of nursing (Oerther, 2017; Oerther et al, 2020; Oerther and Glasgow, 2021; Oerther and Oerther, 2022).

Nursing is widely recognized among the healthcare professions – including dentists, pharmacists, physicians and surgeons, veterinarians, and others – as among the most caring professions and the single most trusted profession (Saad, 2020). For example, the SOC entry for registered nurses describes the work of nurses as, “assess[ing] patient’s health **problems** [emphasis added] and needs, develop and implements nursing care plans, and maintain medical records. Administer nursing care to ill, injured, convalescent, or disabled patients. May advise patients on health maintenance and disease **prevention** [emphasis added] or provide case management," (BLS, 2018, p.104). Similar to the SOC entry for environmental engineers that describes the use of engineering skills in the, "prevention, control, and remediation of environmental hazards," the SOC entry for registered nurses emphasizes prevention. Furthermore, similar to the OOH entry for environmental engineers that describes the work of environmental engineers as "develop[ing] solutions to environmental problems," (BLS, 2021) the SOC entry for registered nurses emphasizes problem solving. The similarities between the occupational responsibilities of registered nurses and environmental engineers suggests that both professions may share distinctive aspects of caring (Oerther, 2021).

3. We hypothesize that environmental engineering is subject to the care penalty

As noted by the NAE in the Changing the Conversation campaign, the way in which a profession describes itself influences the kind of people a profession attracts to its ranks. Labor economists typically explain earnings differences as the result of differences in education, experience, and other measures of skill, often cumulatively referred to as "human capital". However, considerable research points to the additional impact of industry and job characteristics: individuals with very similar levels of human capital garner very different earnings, depending on who they are and where they are employed (Card et al., 2018). In particular, women tend to earn less than men with similar or even lower levels of education, partly as a result of past and current discrimination (Blau and Kahn, 2017).

Gender enters wage determination in another, more subtle way. Women tend to choose jobs that invite – and probably require – concern for human welfare. In the U.S. as well as other countries, women are disproportionately concentrated in jobs in health, education and social services, many of which are located in the public sector (Folbre et al., 2021). Women also are considerably more likely than men to be employed in non-profit or public-interest jobs. Both men and women pay a care penalty in these jobs, though proportionally more women are affected by it (England et al., 2002; Hirsch and Manzella, 2015; Hodges et al., 2018).

Explanations of the care penalty emphasize two related factors (Folbre, 2012; Folbre, 2018). The first concerns the supply side of the labor market – the behavior of job seekers. While intrinsic motivation – including concern for human welfare – can substantially improve work performance, it also lowers the bargaining power of workers, because it lowers their "reservation wage". When employers know that workers are willing to work for less, they typically offer employees lower starting salaries and lock them into a lower earnings trajectory. This might be interpreted as an illustration of the adage "nice guys (and gals) finish last" (Frank, 2004). While not all workers are equally motivated to do good, even a small number of workers who are willing to sacrifice pay can influence professional norms in ways that depress wages across a profession.

A second factor concerns the demand side of the labor market – the behavior of firms. Employers typically compare the wage they pay with the additional revenue that worker will generate. In many jobs, this additional revenue is directly linked to the workers' contributions to output. In many other jobs, however, a worker creates "positive spillovers" (i.e., promoting human welfare or planetary health) that are not captured easily by the firm and therefore do not directly contribute to financial gain. For instance, nurses and teachers are not paid on a per-unit-output basis, and neither hospitals or schools directly “sell” the improvements in health or education generated by nurses or teachers.

Similar to what has been observed previously for other occupations involving care, such as teaching, counseling, providing health services or supervising children (England et al, 2002), we hypothesize that – among the sub-disciplines of engineering – the profession of environmental engineering is highly susceptible to a care penalty – a reduction in pay attributable to the specific characteristics of care provision.

If our hypothesis is true, then we would expect to observe two patterns; one pattern in demographic data, and a second pattern in salary data. First, we would expect that environmental engineering would attract a larger fraction of women as compared to other sub-disciplines of engineering as a result of women being disproportionately represented in jobs performing care work (Folbre et al, 2022). Second, we would expect to observe lower salaries among environmental engineers as compared to other sub-disciplines of engineering as a result of paying a care penalty (regardless of gender) (Folbre, 2012; Folbre, 2018). To explore our hypothesis, we reviewed relevant and adjacent literature (i.e., Hunt, 2016; Blosser, 2017; Hess and Fore, 2018; Kuehn and Salzman, 2018; Cech, 2021), and we analyzed available demographic data from the Profiles of Engineering and Engineering Technology (Profiles) collected annually by the American Society for Engineering Education (ASEE) as well as the salary data from the NCSG conducted by the NSF.

4. Analysis of demographic trends and salaries in environmental engineering

During the past decade (2009 to 2019), the U.S. witnessed a doubling in the number of baccalaureate degrees awarded in the total of all sub-disciplines of engineering plus computer science (i.e., from a total of 74,387 in 2009 (ASEE, 2010) to a total of 144,818 in 2019 (ASEE, 2020)). Over a similar period, the number of baccalaureate degrees awarded in the sub-discipline of environmental engineering also increased substantially (i.e., from 496 in 2004 (Jones et al, 2005) to 1,231 in 2019 (ASEE, 2020)), and the most recent data show that environmental engineering is the fastest growing sub-discipline of engineering when comparing the total change in undergraduate enrollment from Fall 2019 to Fall 2020 (ASEE, 2021).

The first reported census of environmental engineers was published in 2005 (Jones et al, 2005). This census was updated in 2016 (Blaney et al, 2016) and again in 2018 (Blaney et al, 2018). From these three reports, three key messages include: 1) enrollment of students pursuing degrees in environmental engineering has seen a steady increase over the past fifteen years; 2) the proportion of women is high as compared to other sub-disciplines of engineering (i.e., women earned 53.3% of the baccalaureate degrees in environmental engineering conferred in 2020 as compared to 23% of total baccalaureate graduates, and women earned 46.3% of the master's degrees and 43.6% of the doctoral degrees in environmental engineering conferred in 2020 (ASEE, 2021)); and 3) the proportion of other historically underrepresented groups (i.e., Black, Indigenous, and People of Color (BIPOC)) is not substantially different than other sub-disciplines of engineering (i.e., historically underrepresented groups earned 14.9% of the baccalaureate degrees in environmental engineering conferred in 2020 as compared to 15.5% of total baccalaureate graduates (ASEE, 2021)).

As reported in Table 2, the sub-discipline of environmental engineering awarded the largest percentage of bachelor's degrees to women (43.7%) in 2009. This percentage was more than twice that of civil engineering (20.1%) and approximately three- to five-times larger than aerospace (14.2%), electrical (11.5%), mechanical (11.4%), or computer engineering (7.9%). Among degrees awarded in 2009, only 17.8% of all baccalaureate degrees were awarded to women (ASEE, 2010); whereas in 2019, the percentage had risen to 22.5% (ASEE, 2020). Over the same decade (2009 to 2019), environmental engineering consistently awarded the largest percentage of baccalaureate degrees to women, and environmental engineering is the only sub-discipline where more than half of all baccalaureate degrees are awarded to women (Table 1, data for 2019). We hypothesize the caring nature of the work of environmental engineers – including the invitation or perhaps the requirement of concern for human welfare – disproportionately attracts women to environmental engineering in much the same way the caring nature of nursing disproportionately attracts women to become registered nurses (Folbre et al., 2021).

To begin to estimate the cost of the care penalty in the sub-discipline of environmental engineering, we pooled five waves of the NSCG: 2010, 2013, 2015, 2017, and 2019, and limited our sample to individuals currently employed in engineering occupations, with a total of 50,213 observations (see Appendix A for more details). When reporting statistics disaggregated by occupation, we considered eight occupations with sample sizes greater than 1,500 observations; these eight occupations were environmental, aerospace, chemical, civil, computer, electrical, industrial, and mechanical engineering. These eight occupations constitute more than 80 percent of all individuals employed in engineering occupations in our sample (Note: while additional occupations included in the SOC would be interesting to include for comparison – such as agricultural, biological, biomedical, as well as health and safety engineer – these additional occupations lacked sufficient number of observations in the NSCG to be included in the current analysis at this time).

Among these eight representative engineering occupations, environmental engineers have the lowest median salary, and it is approximately 17% lower than the median salary for all engineers (Table 3). This low salary for environmental engineers exists despite the fact that compared to the average for all engineering occupations, environmental engineers are more likely to have a master's degree and are as likely to have a PhD (Appendix A, Table A1).

While environmental engineering has the highest fraction of women (Appendix A, Table A1), and women in engineering occupations earn less than men, low salaries in the sub-discipline of environmental engineering persist *within* gender groups: among both women and men, environmental engineers earn the lowest median salaries (Table 3).

We also conducted a more systematic assessment of salary differences across engineering occupations using ordinary least-squares (OLS) regressions to estimate salary differences controlling for available potential confounders, including: education, experience, race and ethnicity, characteristics of highest degree awarded (year, whether outside the US, and institution quality using 1994 Carnegie codes), and job characteristics (including part-time status, employer sector, employer region, and employer size). Table 4 shows our estimates of occupational coefficients from the OLS regression of the natural log of salaries on occupational dummies (with environmental engineers as the reference occupation) and these individual and job controls (the first specification includes only individual controls, while the second specification adds controls for job characteristics). The OLS coefficient on a particular occupation can be interpreted as the log point difference in salaries between that occupation and environmental engineers. On average, salaries in every engineering occupation are higher than salaries for environmental engineers, for both women and men, controlling for the full set of comprehensive individual and job characteristics. Some of these pay differences are considerable: for example, among men, electrical engineers have earnings that are 21 log points higher than for environmental engineers. With the exception of civil and industrial engineering among women (where differences are too small to be statistically significant), difference in pay between environmental engineers and engineers in other sub-disciplines are statistically significant at the 1 percent level for both women and men.

Self-reported levels of job satisfaction also show that environmental engineers report low levels of satisfaction with their job's salary and opportunities for advancement. For example, the fractions of individuals who report that they are at least somewhat satisfied with their salary – or with their opportunities for advancement – are the smallest for environmental engineering as compared to the other eight sub-disciplines of engineering (Appendix A, Figures A1 and A2 and Table A2).

To sum up, we note that the average salaries are lowest among environmental engineering as compared to other sub-disciplines of engineering, controlling for a comprehensive set of individual and job characteristics. We further note that this trend is consistent when salary data are disaggregated by gender; both women and men earn significantly less in environmental engineering. Collectively, these results support our suspicion that professionals employed as environmental engineers earn much less than similar individuals in other engineering occupations, consistent with the possibility of the care penalty.

Caveats to our analysis of salaries include the fact that we could not control for many unobserved individual or employer characteristics, and therefore represent only associations between occupations and earnings. However, the striking pay penalties observed for environmental engineers are consistent with the hypothesis that environmental engineering is highly susceptible to the care penalty. Our preliminary results invite further study – with or without the collection of additional data – to evaluate the nature of earnings differentials across engineering occupations.

5. Implications for the future of caring in environmental engineering

If, as we have described above, there is a high probability that a care penalty exists in the profession of environmental engineering, then what should we do next? Certainly, environmental engineers should not be encouraged to be “less caring”, and we should be cautious in waving a warning flag that discourages caring individuals from engaging in the important work of environmental engineering. Therefore, we propose that the first reaction to this discovery should be confirmation.

Presuming confirmation further supports the presence of a care penalty in environmental engineering, we suggest that a broad approach to solutions should be pursued; looking to the literature to explain how short-run market forces can lead to undervaluation (i.e., recently in the “essential workers” of the COVID-19 pandemic (Folbre et al, 2021)). As a starting point for discussion of possible solutions in the sub-discipline of environmental engineering, we suggest the consideration of two parallel responses.

Each proposed response focuses on one of the two factors in the labor market that contribute to the care penalty, namely the behavior of firms or the behavior of job seekers. To be consistent with the historical development of the field (i.e., Boyce, 1963; Hendricks and Baumann, 1990; Anderson, 2005; Hendricks, 2005) as well as the modern practice of environmental engineering (i.e., AAEES, 2009), each of these two parallel responses should utilize the comprehensive view of sustainable development prevalent within the profession of environmental engineering. This view includes the model of the triple bottom line accounting of people (i.e., human welfare), planet (i.e. planetary health), and prosperity (i.e., financial gain) (Brown and Rasmussen, 2019; EPA, 2021). To be consistent with the future practice of environmental engineering, each of these two parallel responses should carefully consider the five specific ways that environmental engineers propose to help solve societal grand challenges during the first-half of the 21st century, namely: 1) sustainably supplying food, water, and energy; 2) curbing climate change and its impacts; 3) designing a future without pollution or waste; 4) creating efficient, healthy, resilience cities; and 5) fostering informed decisions and actions (NAE, 2019).

As a first approach – targeting the demand side of the labor market represented by firms – we propose that environmental engineers should encourage both life-cycle principles (i.e., Oerther, 2022) as well as environmental full-cost accounting (i.e., ISO 26000:2010 Guidance on Social Responsibility) in order to increase fungibility among different measures of the components of the triple bottom line of people, planet, and prosperity. While we note that this may be viewed as a "long-term" goal, one important aspect of the care penalty is that the positive spillovers in value created in human welfare and planetary health often are poorly captured in financial gains on the quarterly balance sheet of firms.

Our suggestion is supported by the observation that industry leading firms specializing in the sub-discipline of environmental engineering (i.e., AECOM) enjoy slimmer profit margins as compared to industry leading firms specializing in the sub-discipline of computer engineering (i.e., Intel). For example, the EBITDA margin (earnings before interest, taxes, depreciation, and amortization as a Percentage of revenue) of AECOM varied between 1.71% and 7.32% over the period 2010-2020 (https://www.macrotrends.net/stocks/charts/ACM/aecom/ebitda-margin); whereas the EBITDA margin for Intel varied between 35.10% and 47.73% between 2010 and

2020 (https://www.macrotrends.net/stocks/charts/INTC/intel/ebitda-margin). The trend of a slimmer profit margin observed for AECOM holds for other large firms in environmental engineering (i.e., EBITDA margins in March, 2020 included: 5.12% for Jacobs; 7.32% for Stantec; and 7.81% for Tetra Tech Inc). Whereas, the trend of a sizeable profit margin for Intel holds for other large firms in computer engineering (i.e., EBITDA margins in March, 2020, included: 14.85% for AMD; 38.12% for Qualcomm; and 46.96% for Texas Instruments Inc).

One of the contributing factors to this observation of slimmer profits margins could be related to the commodification of engineering services. Consolidation of local firms as well as buy-outs and mergers among larger firms specializing in environmental engineering (i.e., the 2017 acquisition of CH2M by Jacobs Engineering Groups Inc.) (Jacobs, 2017) have occurred alongside the emergence of severe disruptions coming from machine learning and generative design algorithms. What is now commonly known as the "Fourth Industrial Revolution" is contributing to a race to the bottom for low cost, fast delivery of design (Crawford, 2018).

Nonetheless, engineering design is inherently related to the user experience, and as a caring profession the sub-discipline of environmental engineering may include strong personal connections, strong emotional attachment, and a shared moral commitment to human welfare and planetary health. Firms specializing in environmental engineering may leverage the prior efforts of the NAE's Changing the Conversation campaign and market themselves to employees and clients using care to deliver a better product. The importance of caring, including empathy – or the ability to understand and share the feelings of another – has been described as a hallmark trait of jobs in the emerging space of "STEMpathy" – where science, technology, engineering, and math skills are coupled to human empathy (Friedman, 2016). Friedman predicts that STEMpathy jobs are less susceptible to outsourcing as well as less susceptible to the Fourth Industrial Revolution (Friedman, 2017).

As a second approach – targeting the supply side of the labor market represented by job seekers – we propose that environmental engineers should clearly demonstrate the unique contributions that technically skilled commitments to human welfare can generate. For example, the literature suggests that there are significant gender gaps with women in the U.S. more likely to be interested in environmental concerns, especially climate change, as compared to men (Saad, 2021). The literature further suggests that diversity among teams performing engineering design is a benefit – both to the process of design as well as to the quality of the final design as measured by utility among the breadth of potential customers (Wulf, 2002). While issues of gender and diversity are nuanced and require careful consideration of causes, effects, and solutions, we offer the preliminary suggestion that these two trends could be coupled with the upswing in appreciation for climate finance to help capture a portion of the spillover benefits of environmental engineering.

For example, understanding the true value of environmental services is important for all of humanity. Local development projects (Piggott-McKellar et al, 2019), investment portfolios and multinational corporations, as well as central banks and governments (D'Orazio and Popoyan, 2019) all are exploring innovative approaches to price planetary health as part of a financial position in light of a changing climate. These efforts include insurance products developed specifically by environmental engineers (i.e., the Caribbean Ocean and Aquaculture Sustainability faciliTy or COAST (Oerther, 2022)) as well as the use of finance to mitigate the impacts of disasters and return to sustainable development through collaborations of nurses, engineers, and other caring professions (i.e., Dion et al, 2022).

Environmental engineers – who have a documented commitment to human welfare and planetary health as well as a distinctive demographic among the engineering sub-disciplines – may be uniquely positioned to emerge as leaders who demonstrate both technical knowledge and skills as well as professional attitudes consistent with future needs. As the profession of environmental engineering continues to grow and as the role of climate change continues to impact both the local and the global economy, there will be an increasing competitive advantage for caring environmental engineers to rise to top leadership positions across the wide-range of firms that rely upon any engineering sub-discipline. Environmental engineers may benefit by borrowing from similar efforts to penetrate leadership positions such as the campaign to "Get Nurses on Boards" (Oerther, 2018). While future work should explore the nuanced issues of justice, diversity, equity, and inclusion, we suggest that efforts borrowed from other caring professions, such as nursing, have the potential to change the culture within firms as more diverse leaders helps to open up opportunities to capture value created in caring for human welfare and planetary health on the quarterly balance sheet.

6. Conclusions

Based upon a review of the literature as well as the analysis of available data, we observe that environmental engineering may be susceptible to a care penalty. Rather than suggest that environmental engineers should become less caring, we propose that environmental engineers should be aware of this economic risk and seek to mitigate the care penalty in advantageous ways. We suggest that a greater awareness of these issues could build on and strengthen growing public concerns regarding environmental sustainability. Finally, we suggest that distinctive attributes of environmental engineering may prove critical to unlocking growth in the engineering workforce in the U.S. as care for human and planetary health.

References

AAEES. 2009. *Environmental Engineering Body of Knowledge*. Annapolis, MD: American Academy of Environmental Engineers and Scientists.

Anderson, W.C. 2005. "A History of the American Academy of Environmental Engineers: Part 1: 1955 to 1984." *Environmental Engineer, 41*(1), 10-18.

ASEE. 2011. *Engineering by the Numbers 2009*. Washington, DC: American Society for Engineering Education.

ASEE. 2020. *Engineering and Engineering Technology by the Numbers 2019.* Washington, DC: American Society for Engineering Education.

ASEE. 2021. *Engineering and Engineering Technology by the Numbers 2020*. Washington, DC: American Society for Engineering Education.

Bielefeld, AR, and Canney, NE. 2019. "Working engineers' satisfaction with helping people and society through their jobs." *European Journal of Engineering Education, 44*, 939-953.

Blaney, L., Kandiah, R., Ducoste, J.J., Perlinger, J.A., Bartelt-Hunt, S.L. 2016. "Trends in population and demographics of U.S. environmental engineering students and faculty from 2005 to 2013." *Environmental Engineering Science, 33*(8), 578-590.

Blaney, L., Perlinger, J.A., Bartelt-Hunt, S.L. Kandiah, R., Ducoste, J.J. 2018. "Another grand challenge: Diversity in environmental engineering." *Environmental Engineering Science, 35*(6), 568-572.

Blau, F.D., Kahn, L.M. 2017. "The gender wage gap: extent, trends, and explanations." *Journal of Economic Literature, 55*(3), 789-865.

Blosser, E. 2017. "Gender segregation across engineering majors: How engineering professors understand women's underrepresentation in undergraduate engineering." *Engineering Studies, 9*(1), 24-44.

BLS. 2018. *Standard occupational classification manual*. Washington, DC: United States Bureau of Labor Statistics.

BLS. 2021. *Occupational outlook handbook*. Washington, DC: United States Bureau of Labor Statistics.

Brown, K., and Rasmussen, K. 2019, July 9. “The Sustainable Development Goals in 2019: People, Planet, Prosperity in Focus.” *United Nations Foundation* blog. Accessed December 9, 2021. https://unfoundation.org/blog/post/the-sustainable-development-goals-in-2019-people-planet-prosperity-in-focus/

Boyce, E. 1963. “The American Sanitary Engineering Intersociety Board.” *American Journal of Public Health, 53*(7), 1127-1131.

Card, D. Cardoso, A.R., Heining, J., Kline, P. 2018. “Firms and labor market inequality: evidence and some theory.” *Journal of Labor Economics, 36*(S1), S13-S70.

Cech, E. 2021. “*The trouble with passion: How searching for fulfillment at work fosters inequality*.” Berkeley, CA: University of California Press.

Crawford, M. 2018, July 11. “How industry 4.0 impacts engineering design.” *American Society of Mechanical Engineers* blog. Accessed December 9, 2021. https://www.asme.org/topics-resources/content/industry-40-impacts-engineering-design

Dion. K.W., Oerther, D.B., Lavin, R.P. 2022. “Promoting climate change resilience.” *Nursing Economic$,* (in press).

D’Orazio, P., Popoyan, L. 2019. “Fostering green investments and tackling climate-related financial risks: Which role for macroprudential policies?” *Ecological Economics, 160*, 25-37.

Ellemers, N., van der Toorn, J., Paunov, Y., van Leeuwen, T. 2019. “The psychology of morality. A review and analysis of empirical studies published from 1940 through 2017.” *Personality and Social Psychology Review, 23,* 332-366.

England, P., Michelle B., Folbre, N. 2002. “Wages of virtue: the relative pay of care work.” *Social Problems, 49*(4), 455-473.

EPA. 2021. “People, Prosperity and the Planet (P3) Student Design Competition.” *United States Environmental Protection Agency* blog. Accessed December 9, 2021. https://www.epa.gov/P3.

Folbre, N. 2012. “Should women care less? Intrinsic motivation and gender inequality.” *British Journal of Industrial Relations, 50*(4), 597-619.

Folbre, N. 2018. Gender and the Care Penalty. In L. Arguys, S. Averett & S. Hoffman (Eds), *Oxford Handbook of Women in the Economy*. New York: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190628963.013.24

Folbre, N., Gautham, L., Smith, K. 2021. “Essential workers and care penalties in the United States.” *Feminist Economics, 27*(1-2), 173-187.

Folbre, N., Gautham, L., Smith, K. 2022. “Gender inequality, bargaining, and pay in care services in the U.S.” *Industrial and Labor Relations Review*, (in press).

Frank, R. H. 2004. “*What Price the Moral High Ground? Ethical Dilemmas in Competitive Environments*.” Princeton, NJ: Princeton University Press.

Friedman, T. 2016. “*Thank you for being late: An optimist’s guide to thriving in the age of accelerations.*” New York, NY: Farrar, Straus, and Giroux.

Friedman, T. 2017, January 4. “From Hands to Heads to Hearts.” *The New York Times* blog. Accessed December 9, 2021. https://www.nytimes.com/2017/01/04/opinion/from-hands-to-heads-to-hearts.html.

Hendricks, D.W., and Baumann, E.R. 1990. "*AEEP – 25 Years*." Washington, DC: Association of Environmental Engineering Professors.

Hendricks, D.W. 2005. "A History of the American Academy of Environmental Engineers: Part 2: 1985 to 2005." *Environmental Engineer, 41*(2), 26-38.

Hess, J.L., Fore, G. 2018. "A systematic literature review of US engineering ethics interventions." *Science and Engineering Ethics, 24*, 551-583.

Hirsch, B.T., Manzella, J. 2015. "Who cares - and does it matter? Measuring the wage penalty for caring work." In S.W. Polachek, K. Tatsiramos, & K.F. Zimmerman (Eds), *Gender Convergence in the Labor Market* (213-275). New York: Emerald Insight Publishing Limited.

Hodges, M., Budig, M., England, P. 2018. "Wages of nurturant and reproductive care workers: Adjudicating individual and structural mechanisms producing the care pay penalty." *Social Problems, 66*(2), 294-319.

Hunt, J. 2016. "Why do women leave science and engineering?" *ILR Review, 69*(1), 199-226.

Jacobs. 2017, December 18. "Jacobs completes CH2M acquisition, creating $15 billion professional services leader focused on delivering innovative solutions for a more connected, sustainable world." *Jacobs Engineering Group Inc* blog. Accessed December 9, 2021. https://invest.jacobs.com/investors/Press-Release-Details/2017/Jacobs-Completes-CH2M-Acquisition-Creating-15-Billion-Professional-Services-Leader-Focused-on-Delivering-Innovative-Solutions-for-a-More-Connected-Sustainable-World/default.aspx

Jones, S.A., Barnett, M.O., Bhandari, A., LaPara, T. 2005. "An initial effort to count environmental engineers in the USA." *Environmental Engineering Science, 22*, 772-782.

Kuehn, D., Salzman, H. 2018. "The Engineering Labor Market: An Overview of Recent Trends." In R.B. Freeman, & H. Salzman (Eds), *U.S. Engineering in a Global Economy*. Chicago, IL: The University of Chicago Press.

NAE. 2002. *Raising Public Awareness of Engineering.* Washington, DC: National Academy of Engineering. https://doi.org/10.17226/10573.

NAE. 2008. *Changing the Conversation: Messages for Improving Public Understanding of Engineering.* Washington, DC: National Academy of Engineering. https://doi.org/10.17226/12187.

NAE. 2013. *Messaging for Engineering: From Research to Action*. Washington, DC: National Academy of Engineering. https://doi.org/10.17226/13463.

NAE. 2014. *The importance of engineering talent to the prosperity and security of the nation: Summary of a forum*. Washington, DC: National Academies Press. https://doi.org/10.17226/18626.

NAE. 2019. *Environmental Engineering for the 21st Century: Addressing Grand Challenges.* Washington, DC: National Academies Press. https://doi.org/10.17226/25121.

NSPE. 2019. *Code of ethics for engineers*. Alexandria, VA: National Society of Professional Engineers.

Oerther, D.B. 2017. “Using nursing theory to improve the teaching of engineering practice.” Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, OH. https://doi.org/10.18260/1-2--29084

Oerther, D.B. 2018. “Leveraging NAM’s Getting Nurses on Boards Coalition to Promote NAE’s Changing the Conversation Campaign.” Paper presented at the 2018 ASEE Annual Conference & Exposition, Salt Lake City, UT. https://doi.org/10.18260/1-2--30771.

Oerther, D.B., Peters, C.A. 2020a. “Educating heads, hands, and hearts in the COVID-19 classroom.” *Environmental Engineering Science, 37*(5), 303.

Oerther, D.B., Peters, C. 2020b. "Think-pair-listen in the online COVID-19 classroom." *Environmental Engineering Science, 37*(10), 647-648.

Oerther, D.B., Yoder-Wise, P., Malone, B. 2020. "Identifying opportunities for educators to pursue collaboration at the interface of nursing and engineering – and a word of caution." *Journal of Advanced Nursing, 76*(4), 920-923.

Oerther, D.B. 2021. "Environmental health professionals: Local interprofessional collaborations require global thinking to meet shared ethical obligations." *Journal of Environmental Health, 84*(5), 26-28.

Oerther, D.B., Chin, D.A., Gude, V.G., Haas, C.N, MacKay, A.A., Ozis, F., Marincel Payne, M.K., and Vaccari, D.A. 2021a. "The Academy, the Association, and the Society Advancing Environmental Engineering Training and Credentialing." *Environmental Engineering Science, 38*(10), 923-926.

Oerther, D.B., Chin, D.A., Shaw, A., Vaccari, D.A. Wert, W. 2021b. "Dear WEF, the Academy needs your input to update the Environmental Engineering Body of Knowledge." *Water Environment Research*. https://doi.org/10.1002/wer.1647

Oerther, D.B., Chin, D.A., Vaccari, D.A. 2021c. “Updating the environmental engineering body of knowledge.” *Journal of Environmental Engineering*. https://doi.org/10.1061/(ASCE)EE.1943-7870.0001973

Oerther, D.B. 2022a. “Using modified mastery learning to teach sustainability and life-cycle principles as part of modeling and design.” *Environmental Engineering Science,* (in press).

Oerther, D.B. 2022b. “A case study of community engaged design: Creating parametric insurance to meet the safety needs of fisherfolk in the Caribbean.” *Journal of Environmental Engineering, 148*(3), 05021008.

Oerther, D.B., Oerther, S. 2022. “Comparing oranges versus grapes as a metaphor of the nurse+engineer.” *Journal of Clinical Nursing*. https://doi.org/10.1111/jocn.16209.

Piggott-McKellar, A.E., McNamara, K.E., Nunn, P.D., Watson, J.E.M. 2019. “What are the barriers to successful community-based climate change adaptation? A review of grey literature.” *Local Environment, 24*(4), 374-390.

Rosenberg, N., and Nelson, R.R. 1994. “American universities and technical advance in industry.” *Research Policy, 23*(3), 323-348. https://doi.org/10.1016/0048-7333(94)90042-6.

Saad, L. 2020, December 22. “U.S. Ethics Ratings Rise for Medical Workers and Teachers.” *Gallup* blog. Accessed December 9, 2021. https://news.gallup.com/poll/328136/ethics-ratings-rise-medical-workers-teachers.aspx.

Saad, L. 2021, April 5. “Global warming attitudes frozen since 2016.” *Gallup* blog. Accessed December 9, 2021. https://news.gallup.com/poll/343025/global-warming-attitudes-frozen-2016.aspx.

Wulf, W.A. 2002. “The Importance of Diversity in Engineering.” In *Diversity in Engineering: Managing the Workforce*. Washington, DC: The National Academies Press.