Informing an Environmental Ethic in Future Leaders Through an Environmental Engineering Sequence

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Informing an Environmental Ethic in Future Leaders through Environmental Engineering Education

Abstract

As a growing population makes increasing demands on Earth's limited resources, leaders across all disciplines must possess fundamental environmental knowledge to understand the interconnectedness of people and the global biosphere, as well as the attitudes which foster an environmental ethic. We examined the ability of a semester-long course in environmental engineering education to increase students' environmental knowledge and shape the attitudes which promote this ethic. We evaluated students' knowledge and attitudes from the start to the end of the course according to their gender identity**,** racial identity, parents' educational attainment, hometown population, and program of study. Students' overall scores on "knowledge surveys" increased from 81.14% ± 1.46% at the start of the course to 89.67% ± 2.03% at the end of the course. While we observed differences in baseline knowledge by gender and racial identity, neither of these affected how much students' knowledge increased throughout the course. Nor was students' hometown population a significant factor in either baseline knowledge or increased knowledge by the end of the course. Father's educational attainment was not a significant factor either. However, mother's educational attainment was a significant factor in how much students learned if their mother had less than a bachelor's degree or a graduate degree. Whether the student was enrolled in a STEM field of study or not was not a significant factor in students' baseline knowledge; however non-STEM students' scored higher on knowledge surveys than their peers enrolled in a STEM field. Students' attitudes were also surveyed at the start and end of the semester. Generally, their attitudes became more positive toward the environment, more confident in our ability to employ technologies to reduce our impact on the environment, and they felt more strongly about the need for continuing environmental education to promote environmental stewardship.

Introduction

The need for an environmental ethic became evident in the 20th century due to a number of high-profile environmental failures, including those documented in Silent Spring [1] and Thomas Hardin's paper on the tragedy of the commons [2]. The establishment of the Environmental Protection Agency (EPA) almost immediately following passage of the National Environmental Policy Act (NEPA) and the inaugural Earth Day of 1970 further increased public awareness of the relationship between human activity and environmental quality [3]. This link was discussed as early as the 16th century by Malthus [4]. At the heart of the matter is the Earth's capacity to sustain a burgeoning global population which makes increasing demands on limited resources [5]. Projections of resource exhaustion continually change based on improvements in technology and consumer behavior. In 2017, global resource consumption overshot the sustainable rate of use of a year's worth of the Earth's resources by early August. This day, observed as Earth Overshoot Day, occurs earlier each year [6]. At the present rate, the human population will consume two years' worth of the Earth's resources that can be sustainably replenished each year by 2034. Thus, ensuring a healthy environment in the future requires embracing environmental sustainability. We define environmental sustainability as the ability to harvest resources at the same rate for a specified time well into the future, enabling ecosystems to continue their primary functions during that same period [7]. Arguably, concepts of sustainability, environmental knowledge, and attitudes are a question of values [8]. Credible cost-benefit analysis is essential to enable public commitment to maintaining and improving environmental quality [9] with clarity of understanding that pitting economic prosperity against environmental quality is a false choice [10]. As such, leaders across all disciplines must possess fundamental environmental knowledge to understand the interconnectedness of people and the global biosphere, as well as the attitudes which foster environmental stewardship. Environmental engineering education provides a framework to promote this stewardship.

The impact of an education focused on environmental awareness has the potential to enhance environmental attitudes and behaviors [11], [12]. In fact, a variety of research over the past 20 years has explored how environmental attitudes and knowledge are shaped by students' education [10], [13]. Previous research includes high school students enrolled in a 10-day environmental science course [12] and undergraduate students in a variety of college settings [14], [15], [16]. Other characteristics that have the potential to influence both knowledge and attitudes have also been studied, including parents' education [16], gender [13], [14], [15], hometown population [13], [17], field of study [17], and age of students [14]. There is no consensus on the relationship between some of these parameters on environmental attitudes and knowledge. For example, a study by Müderrisoğlu and Altanlar [17] determined that the courses taken by students do not affect environmental behaviors and attitudes. However, Yazici and Babalik [21] found a statistically significant difference between students' college-level field of study and their attitude, awareness, and sensitivity towards the environment. One trend that appears common in these studies is an acknowledgement of the need for ongoing environmental learning at each level of students' education and into their workplace training to combat environmental illiteracy [10], [18], [21].

Although more recent studies investigate collegiate-level environmental education, none evaluates the ability of a dedicated, semester-long course to shape the environmental knowledge and attitudes of a diverse population of students based upon gender, race, parents' educational attainment, hometown population, and academic field of study. Here, we evaluate the ability of the first course of a 3-course environmental engineering curriculum at a military academy to shape environmental attitudes, increase knowledge, and develop an environmental ethic among future leaders. Rolston [22] defines environmental ethics as a systematic account of values carried by the natural world, coupled with an inquiry into duties toward animals, plants, species, and ecosystems. The potential to increase environmental sustainability by leaders across multiple disciplines derives from an environmental engineering education rooted in enhancing environmental knowledge and attitudes via an environmental ethic. Graduates are future leaders of the military and organizations across numerous global disciplines. The synergistic effect of an educational environment and culture founded in a clearly defined set of values enables the development of environmental ethics to permeate all aspects of life.

Methods

The military academy maintains a 4-year program from which every student graduates with a bachelor of science degree. All classes are taught in small sections of no more than 20 students. All students enrolled in a non-engineering program must complete a 3-course engineering curriculum during their third and fourth year. The first course of the environmental engineering curriculum introduces students to the global and local issues that affect public health and the environment. Students first study the Earth as a system. In this unit, students learn about the interconnectedness of the lithosphere, atmosphere, hydrosphere, and biosphere, and human interventions in each. They discuss the flow of energy and major biogeochemical cycles, the concept of mass balance, the global commons and strategies to pursue sustainable access to them. In the second unit, students study how human intervention strains Earth's limited resources. They discuss threats to global biodiversity and then study biodiversity in a field laboratory exercise. In the third unit, students learn about conventional, alternative and renewable sources of energy. In the fourth unit, students learn about the major types and sources of both indoor and outdoor air pollution, and learn to assess risk to human health from both. In the fifth unit, students discuss the sources and fates of waste generated by human activity. At the end of each unit, students debate current issues related to that unit's material. Each unit also has an assignment that requires students to apply their knowledge to understand an environmental problem (i.e., the carbon footprint of a coal fired plant vs. a natural gas plant). The second and third courses build upon these themes to teach engineering design and evaluate proposed sustainable solutions.

This study took place over one semester with 175 respondents in the first course of their environmental engineering education. The majority of the participants were third-year students, although some were second or fourth-year. The surveys were administered to students enrolled in two similar courses: one designed for students majoring in environmental science or environmental engineering, and the other for students enrolled in the 3-course environmental engineering curriculum only.

We assessed student environmental knowledge and attitudes using a 12-question knowledge survey and a 7-question attitude survey focused on the environmental subjects integrated into the first of the three courses in their environmental engineering education. Since the target population was within the same age group, the demographic factors we examined include: student's field of study, race, gender, hometown population, and parents' highest educational attainment. The environmental knowledge and attitudes surveys were adapted from the nationwide 2000 National Environmental Education and Training Foundation (NEETF)/Roper Survey [10]. To ensure we captured the students' baseline knowledge and attitudes at the start of the course, we administered surveys over the first two lessons. End-of-course surveys were administered during the last two lessons. The 12-question environmental "knowledge survey" was linked to themes covered in 5 units throughout the first course of their environmental engineering education. The 5 units are Earth as a system (ES), strained resources (SR), energy (EN), human health (HH), and pollution management (PM). The "attitudes survey" asked students to express their attitudes on the environmental policies by using a Likert-type scale for some responses.

Statistical analyses were completed using R Studio, version 1.1.414. Statistical differences between students' overall survey results were determined by a paired t-test. Statistical differences between males and females, and between white and non-white students were determined using a Student's t-test. Statistical differences between parents' highest level of education and students' hometown were determined by Analysis of Variance (ANOVA). Post-hoc testing to determine which contrasts were significant from ANOVA testing was conducted using Tukey's Test for Honest Significant Differences. Significance level for all analyses was $\alpha = 0.05$.

Results

Environmental Knowledge Survey

We surveyed 175 students at the start and end of the first course of their environmental engineering education. In terms of gender, males accounted for 74% of students, and females accounted for 26%. By field of study, students enrolled in a STEM field of study accounted for 31% of the course population, and with respect to race, students who identified as white accounted for 70%. In terms of the mothers' highest level of education, 29% of student's mothers attained less than a bachelor's degree, 33% attained a bachelor's degree, and 38% attained a graduate degree. In terms of the fathers' highest level of education, 26% of students' fathers attained less than a bachelor's degree, 29% attained a bachelor's degree, and 45% attained a graduate degree. In terms of the students' hometown, 67% classified themselves as living in a suburban area, 25% of respondents from a rural area, and 8% from an urbanized, major city location. In terms of geographic region, the highest number of respondents came from the state of California with 10%, Texas with 7%, and New York, New Jersey, Virginia, and Florida each with 5% of respondents.

In general, students' scores on the environmental knowledge survey increased from 81.14% ± 1.46% at the start of the course to 89.67% ± 2.03% at the end (Figure 1). Students' scores on questions linked to the five course themes increased across four of the five themes. Student scores increased on questions linked to the theme of strained resources, from 80.14% ± 2.38% to 86.96% ± 2.71%; energy, from 83.47% ± 3.65% to 93.94% ± 2.26%); human health, from 66% ± 4.99% to 77% ± 4.36%); and pollution management, from 86.86% ± 3.75% to 95.57% ± 1.89%. Students' scores on questions linked to the earth as a system theme were already quite high at the start of the course, 97.14% ± 2.49% and did not change significantly at the end of the course.

We also found survey scores for students enrolled in a STEM field of study were not significantly different than students enrolled in non-STEM fields at the start of the course ($p=8.01 \times 10^{-1}$, Figure 2). However, surveys administered at the end of the course showed that students who major in non-STEM fields of study scored higher than students enrolled in STEM field ($p=1.94 \times 10^{-2}$).

We found statistically significant differences between students who identify as male and those who identify as female at the start of the course ($p=6.06 \times 10^{-3}$). Students who identified as female scored 76.48% ± 3.79% and students who identified as male scored 82.76% ± 2.37% at the start of the course (Figure 6). At the end of the course, both groups scored significantly higher, but neither group was significantly different from the other ($p=5.05 \times 10^{-1}$).

We also found statistically significant differences between students who racially identified as white compared to those who racially identified as non-white at the start of the course ($p=2.92 \times 10^{-3}$). Students who identified as non-white scored 75.68% ± 4.45% and students who identified as white scored 83.40% ± 2.20% at the start of the course (Figure 3). At the end of the course, however, there were no significant differences between these two groups ($p=4.86 \times 10^{-1}$).

We found significant differences among students' scores at the start of the course based on the highest level of education attained by their mother ($p=4.71 \times 10^{-02}$, Figure 4). Students whose mother earned a graduate degree (master's or PhD) scored 82.34% ± 3.19% at the start of the course. Students whose mother earned a bachelor's degree scored 83.19% ± 3.49% at the start of the course. Students whose mother earned less than a bachelor's degree (associate's degree, high school diploma or GED) earned 77.17% ± 4.03% at the start of the course. There were significant differences between start and end survey scores among students whose mother earned less than a bachelor's degree ($p=2.21 \times 10^{-07}$) and start and end survey scores for students whose mother earned a graduate degree ($p=3.13 \times 10^{-05}$). However, survey scores for students whose mother earned a bachelor's degree did not significantly increase from start to the end of the course ($p=6.06 \times 10^{-02}$). There was no significant relationship between students' scores based upon father's highest level of education, either at the start or end of the course.

Environmental Attitudes Survey

The first two questions of the survey enabled understanding of students' motivation to take action regarding environmental sustainability. One of the questions asked, "Most of the time, do you think environmental protection and economic development can go hand in hand, or that we must choose between environmental protection and economic development?" At the start of the course about 60% of all males and females, all STEM and non-STEM majors, and students identified as white responded with, 'environmental protection and economic development can go hand in hand' (Figure 5). Between 3 and 6% of these same groups responded with, 'we must choose to pursue economic development or protection of the environment' and between 35 and 40% responded with, 'it depends.' The largest population that indicated, 'we must choose between economic development and environmental protection,' were those enrolled in a non-STEM field of study and whose mothers' highest level of education was a bachelor's degree. We also asked students, "When it is impossible to find a reasonable compromise between economic development and environmental protection, which do you usually believe is more important: economic development or environmental protection?" Responses from almost all demographic groups indicated that over 50% of respondents believed environmental protection is more important than economic development (Figure 6). The largest population that indicated, 'economic development is more important,' were those whose mothers' highest level of education was a bachelor's degree.

When asked for an opinion on the statement, "There are differing opinions about how far we've gone with environmental protection laws and regulations. At the present time, do you think environmental protection laws and regulations have gone too far, not far enough, or have struck about the right balance?" between 5 to 20% of all demographic groups at the start of the course responded, "I do not know" (Figure 7). At the end of the course, only about 3% of respondents still felt uninformed. Fewer students in almost all demographic groups indicated that current laws and regulations have gone too far at 5% of respondents. By the end of the course, nearly all groups increased their belief by 15% that current laws and regulations have not gone far enough. We observed a 12% increase in students of all demographic groups who 'strongly agree' or 'mostly agree' with the statement, "Technology will find a way of solving environmental problems" (Figure 8).

We observed a small decrease in agreeing with the statement, "The condition of the environment will play an increasingly important role in the nation's economic future" (Figure 9). Nearly all demographics had a small percentage, between 2-10% of respondents who 'mostly disagree' with the statement at the end of the course when compared to the beginning of the course where all respondents either 'mostly agreed' or 'strongly agreed' with the statement.

We also observed increased support at the end of the course among almost all demographics to the statement, "Private companies should train their employees to solve environmental problems" (Figure 10). Only a few students 'strongly disagreed' with the statement at the end of the course, and fewer numbers indicated that they 'mostly disagree.' Students identified as female increased from 43% 'strongly agree' at the start to 67% 'strongly agree' at the end of the course.

Finally, we asked students to indicate their support for the statement, "Government agencies should support environmental education programs for adults." There was greater than 80% of respondents who 'strongly agreed' or 'mostly agreed' with this statement from nearly every demographic at the start of the course (Figure 11). This statement also elicited the most 'strongly disagree' responses of any question, by many demographics. By the end of the course, however, most demographics increased their support by 3% for adult environmental education funded by government agencies.

Discussion

Environmental Knowledge

The 3 general findings for knowledge surveys were (1) that students started at significantly different knowledge levels based on most demographics, (2) their knowledge increased across all demographics, and (3) that at the end of the course there were no longer statistically significant differences in knowledge levels across nearly all demographics. Differences in initial knowledge levels across demographics support previous research [10], [16], and increases in knowledge due to education also support previous research [11], [12]. Statistically significant differences in baseline knowledge existed based on gender, race, and parents' educational attainment; however, differences at the end of the course were only statistically significant between STEM and non-STEM fields of study and between students with differing mother's educational attainment. We postulate that the social environment in our classrooms is inclusive and supportive of all of the demographics we studied, and this may have led to a general lack of statistically significant knowledge level differences at the end of the course across demographics. We must continue to use inclusive language in our communication, take neutral stances politically, and use examples in class that are positive toward all demographics.

While differences in knowledge levels based on mother's educational attainment were not statistically significant either at the beginning or end of the course, an interesting observation was made. Students whose mother earned less than a bachelor's degree scored an average of 77.17% at the start of the course, whereas students whose mother earned a bachelor's degree or a graduate degree scored within 1% of each other and scored an average of 82.73%. However at the end of the course, students whose mother earned less than a bachelor's degree or earned a graduate degree scored within 0.1% of each other and scored an average of 90.88%. Students whose mother earned a bachelor's degree scored an average of 87.21% at the end of the course and were the only one of the three groups whose scores did not show statistically significant improvement. Students whose mother earned a bachelor's degree had the highest mean scores at the start of the course and the lowest scores at the end of the course. Further investigation into the reason for the lack of statistically significant improvement among students whose mother attained a bachelor's degree may help improve education for this population.

Environmental Attitudes

The key finding for environmental attitudes was that student attitudes changed to become more positive toward the environment and humanity's ability to solve environmental problems. Of the 7 questions asked in the attitudes survey, 3 illustrate these differences most clearly. These questions asked students if they (1) thought environmental protection laws and regulations had gone far enough, (2) thought technology would find a way of solving environmental problems, and (3) thought private companies should train their employees to solve environmental problems. Comparisons of student responses to these questions at the beginning and end of the course indicated that students think we need more environmental protection, that technology can indeed solve environmental problems, and that private companies should take a more active role in environmental protection.

Nearly all demographics became more positive toward the environment and our ability to protect it, and different demographics showed stronger trends in responses to different questions. This indicates that across demographics, increased knowledge about the environment may lead to more positive attitudes toward the environment.

These changes in attitudes were expected as previous studies have documented them [11], [12]. Increased awareness of environmental problems may very well be the cause. Other reasons for the more positive attitudes toward the environment may include pedagogy. Our courses were taught in classes with student to teacher ratios of no more than 18 to 1. Students were frequently encouraged to participate in class, and classes were not traditional lectures where students may have been discouraged from asking questions or sharing personal examples. Also, 2 separate hour-long videos about environmental issues were shown in class, a field trip to a recycling facility occurred, and all students had to participate in 3 hour-long debates about environmental problems. These pedagogical tools may have made environmental problems more meaningful for students.

Conclusion

Environmental Knowledge

The 3 general findings for knowledge surveys were that (1) students started at significantly different knowledge levels based on many demographics, (2) their knowledge increased across all demographics, and (3) that at the end of the course there were no longer statistically significant differences in knowledge levels across nearly all demographics. We intend to sustain our inclusive educational environment, and we expect this will continue to lead to decreased knowledge level differences among demographics. Further, our study can be used as an example for two key points. First, statistically significant differences in environmental knowledge do indeed exist across demographics in society as indicated in our study and previous research. Second, our study serves as a positive example of how education can eliminate statistically significant differences in knowledge across demographics.

Environmental Attitudes

The key finding for environmental attitudes was that student attitudes changed to be more positive toward the environment and our ability to solve environmental issues. Three questions in our survey illustrate these differences most clearly between attitudes at the beginning and at the end of the course. Nearly all demographics became more positive toward the environment and our ability to protect it, and a lack of trends among demographics indicates that different demographics were not more or less susceptible to changes in environmental attitudes. Increased knowledge about environmental issues may lead to attitudes developing to become more positive toward the environment and enable the development of an environmental ethic to inform future actions and decisions.

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Appendix 1 - Figures

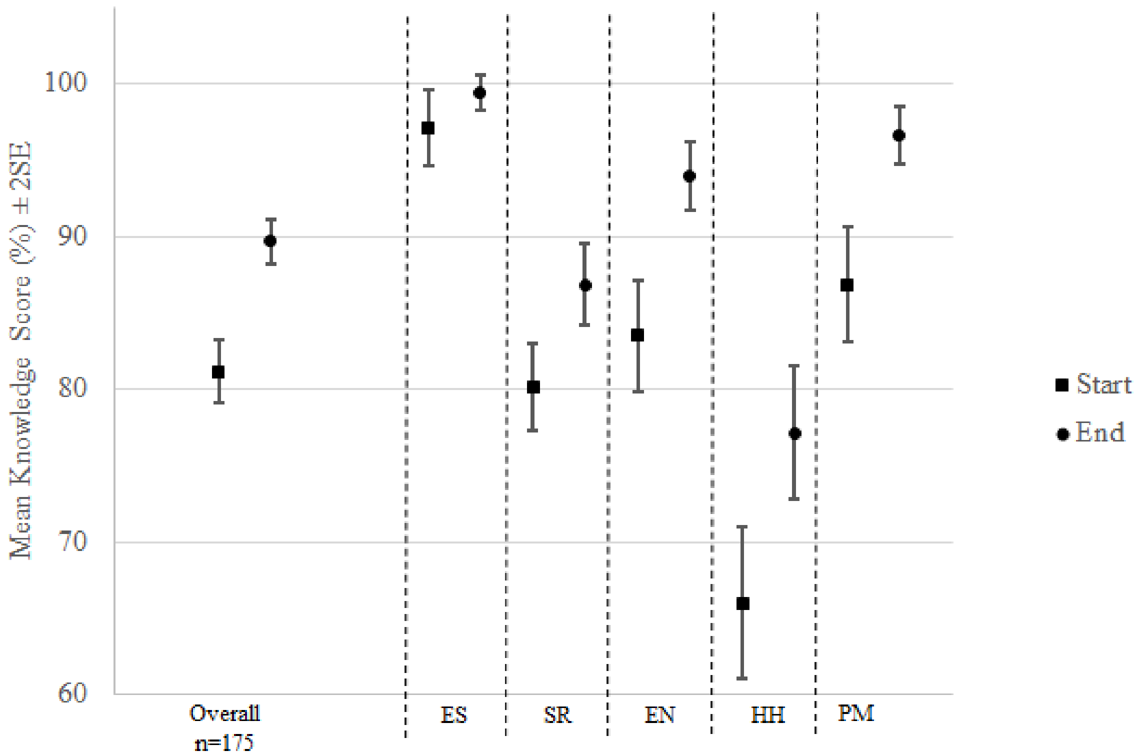

Figure 1. Mean score on environmental knowledge surveys (overall and by course theme) at the start and end of a semester-long course. Students' overall scores increased from 81.14% ± 1.46% at the start of the course to 89.67% ± 2.03% at the end of the course (t = -7.4901, df = 174, p = 3.81 x 10^{-12}). Among the course's five units, student scores increased in SR, from 80.14% ± 2.38% to 86.96% ± 2.71% (t = -3.90, df = 174, p-value = 1.37 x 10^{-4}); EN, from 83.47% ± 3.65% to 93.94% ± 2.26% (t = -5.37, df = 174, p-value = 2.46 x 10^{-7}); HH, from 66% ± 4.99% to 77% ± 4.36% (t = -3.5455, df = 174, p-value = 5.04 x 10^{-4}); and PM, from 86.86% ± 3.75% to 95.57% ± 1.89% (t = -4.72, df = 174, p-value = 4.64 x 10^{-6}).

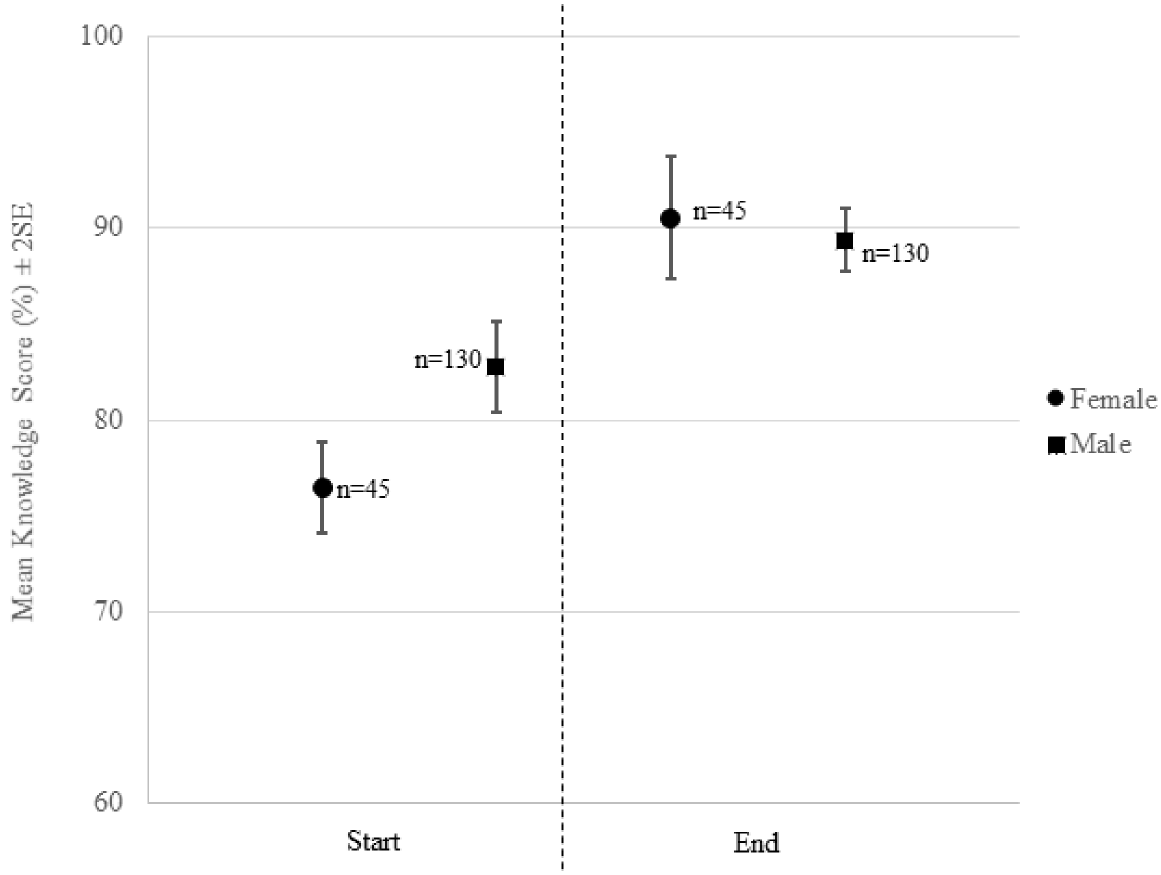

Figure 2. Mean score on environmental knowledge surveys by gender identity at the start and end of a semester-long course. Students who identified as female scored 76.48% ± 3.79% and students who identify as male scored 82.76% ± 2.37% at the start of the course ($t = -2.81$, $df = 82.41$, p-value = 6.06×10^{-3}). Scores of both groups were significantly higher on the end-of-course survey, but neither group was significantly different from the other at the end ($t = 0.66$, $df = 70.08$, p-value = 5.05×10^{-1}).

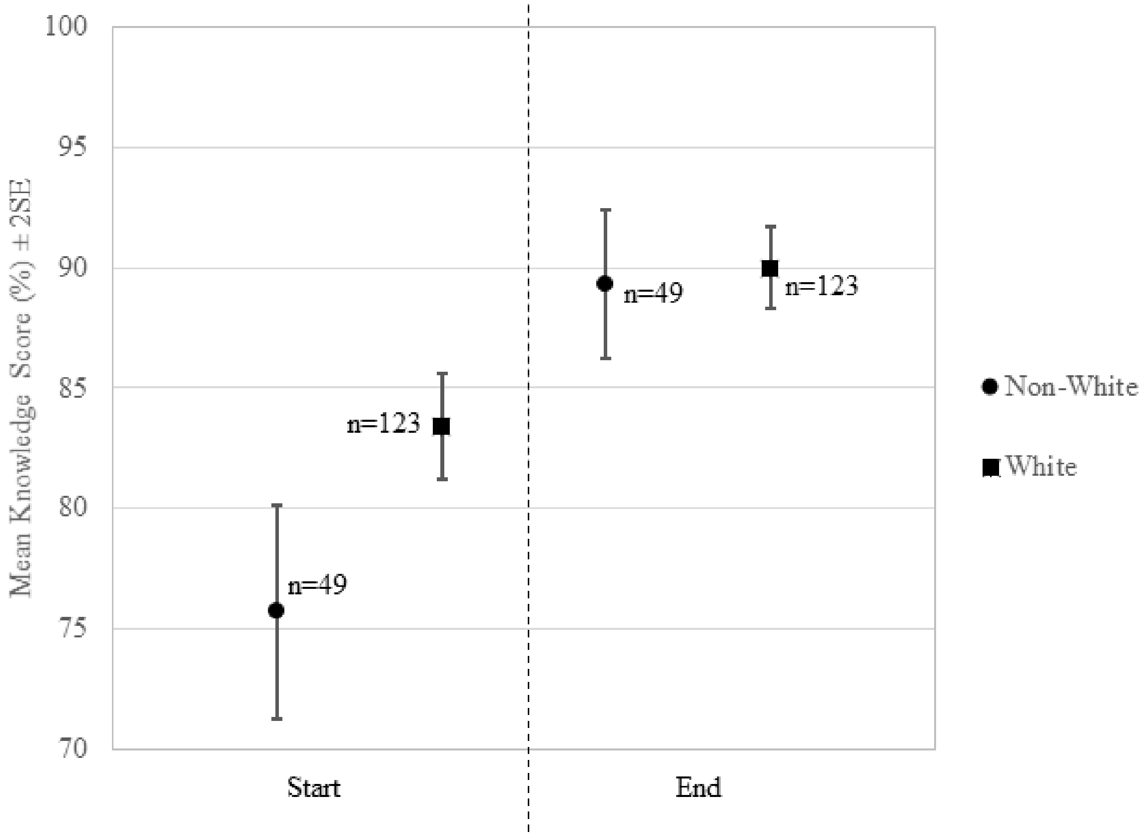

Figure 3. Mean score on environmental knowledge surveys by racial identity at the start and end of a semester-long course. Students who identified as non-white scored 75.68% ± 4.45% and students who identified as white scored 83.40% ± 2.20% at the start of the course (F value = 6.04, df = 2, p-value = 2.92×10^{-3}). At the end of the course, there were no significant differences (F value = 0.72, df = 2, p-value = 4.86×10^{-1}).

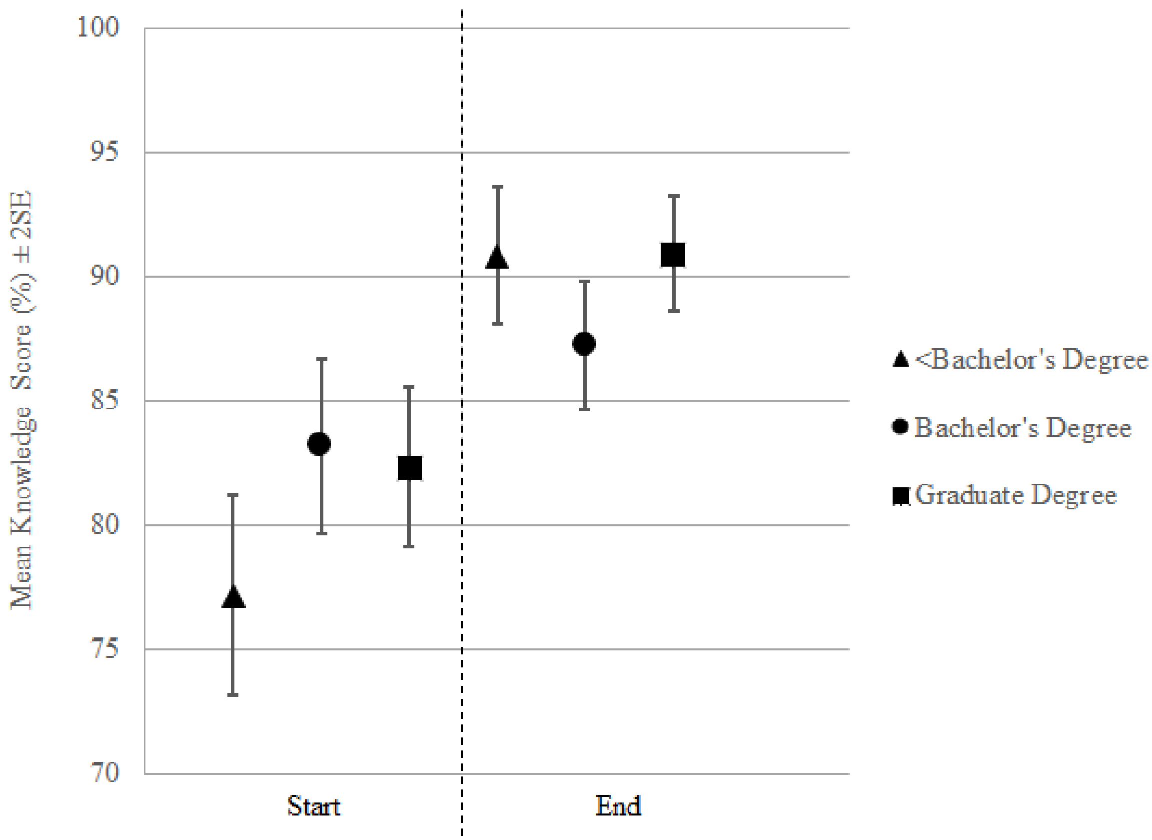

Figure 4. Mean score on Environmental Knowledge Survey by mother's educational attainment at the start and end of a semester-long course. Students whose mother earned a graduate degree (master's or PhD) scored 82.34% ± 3.19% at the start of the course and 90.92% ± 2.34% at the end. Students whose mother earned a bachelor's degree scored 83.19% ± 3.49% at the start of the course and 87.21% ± 2.57% at the end. Students whose mother earned less than a bachelor's degree (associate degree, high school diploma or GED certificate) earned 77.17% ± 4.03% at the start of the course and 90.83% ± 2.76% at the end. There were significant differences between start and end survey scores among students whose mother earned less than a bachelor's degree ($t = -5.62$, $df = 86.70$, p-value = 2.21×10^{-07}) and students whose mother earned a graduate degree ($t = -4.32$, $df = 120.99$, p-value = 3.13×10^{-05}). Students whose mother earned a bachelor's degree did not significantly improve ($t = -1.85$, $df = 104.71$, p-value = 6.61×10^{-2}).

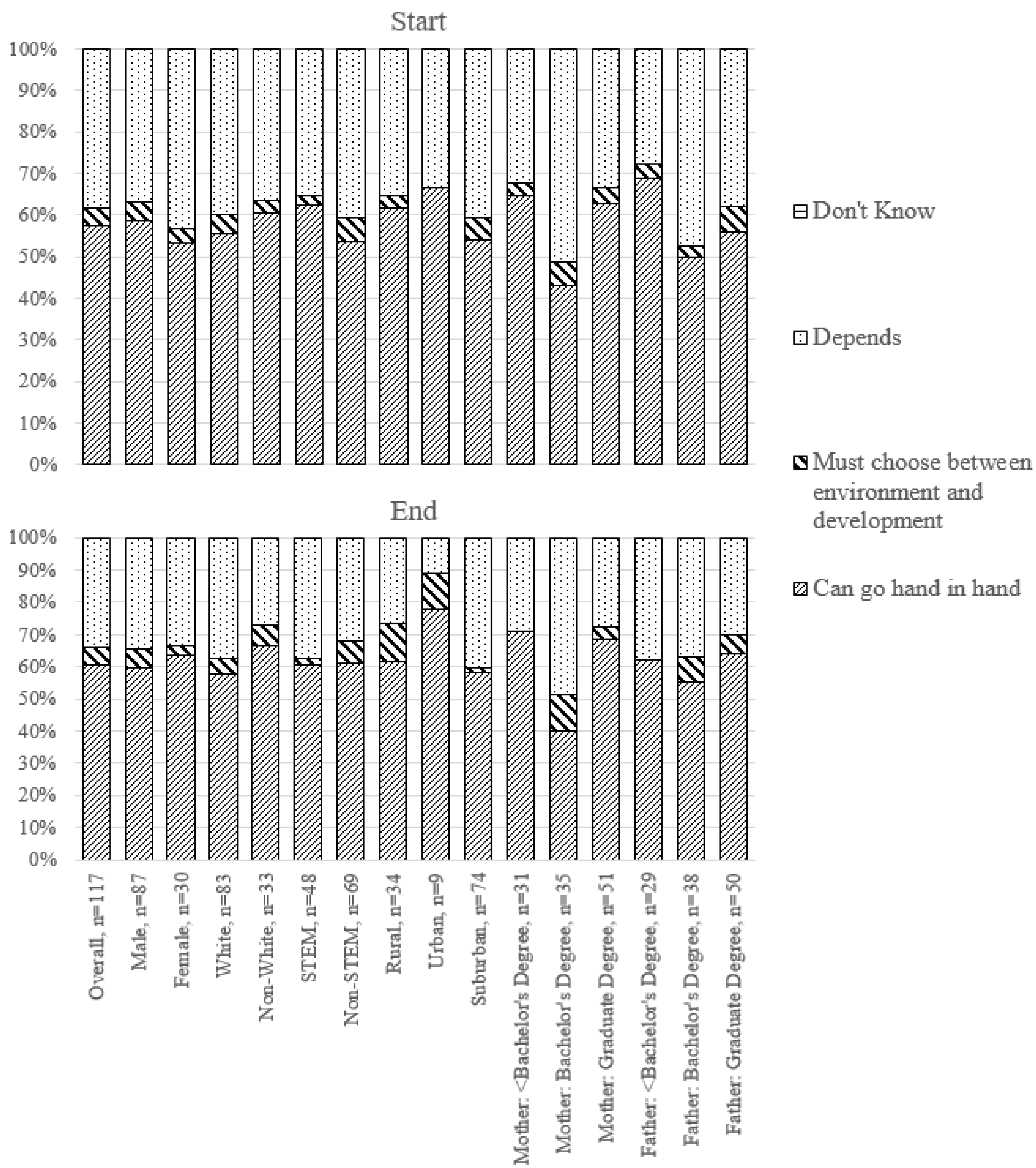

Figure 5. Student response to the question, "Most of the time, do you think environmental protection and economic development can go hand in hand, or that we must choose between environmental protection and economic development?" at the start (top) and end (bottom) of the course.

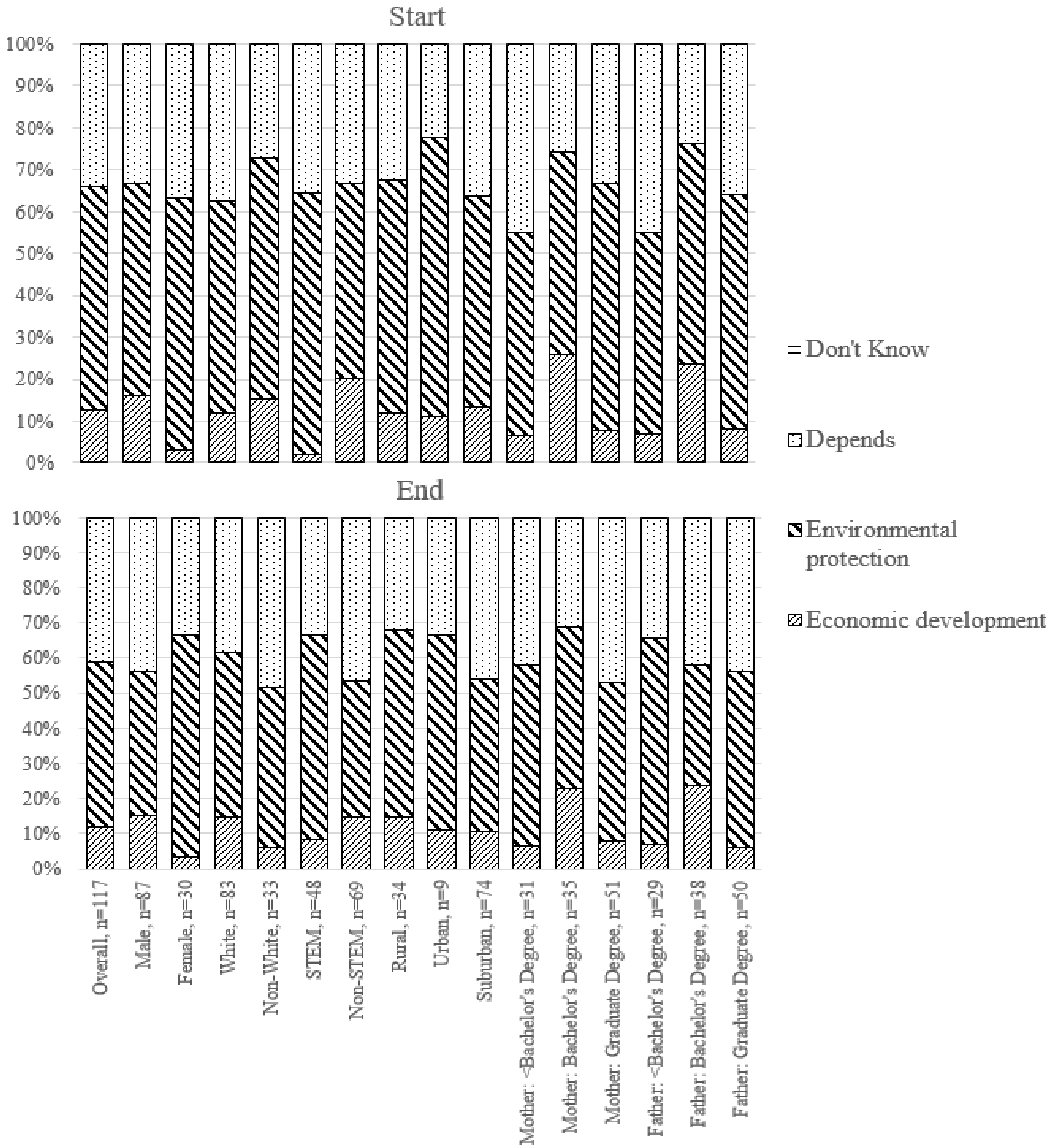

Figure 6. Student response to the question, “When it is impossible to find a reasonable compromise between economic development and environmental protection, which do you usually believe is more important: economic development or environmental protection?” at the start (top) and end (bottom) of the course.

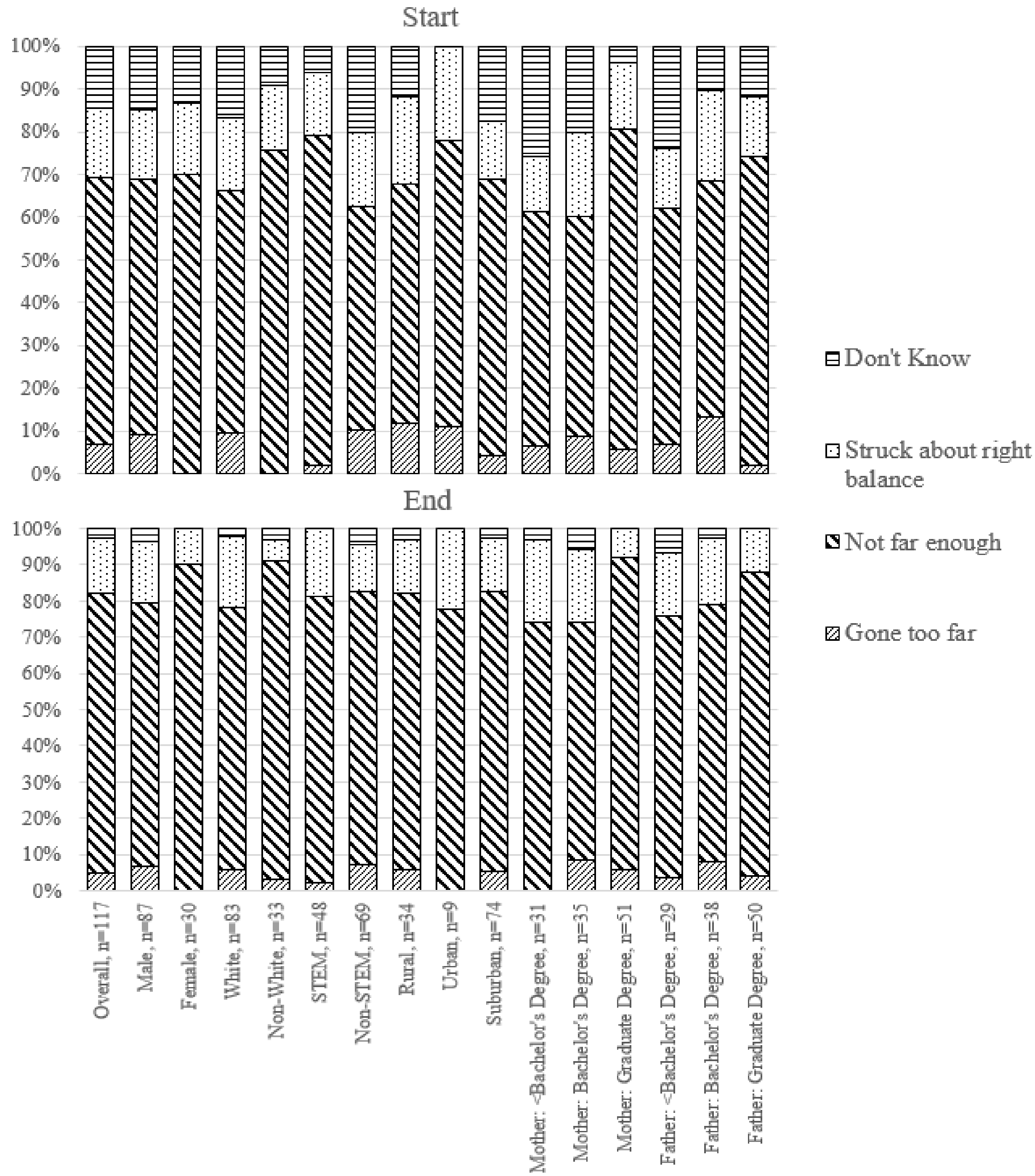

Figure 7. Student responses to the question, "There are differing opinions about how far we've gone with environmental protection laws and regulations. At the present time, do you think environmental protection laws and regulations have gone too far, or not far enough, or have struck about the right balance?" at the start (top) and end (bottom) of the course.

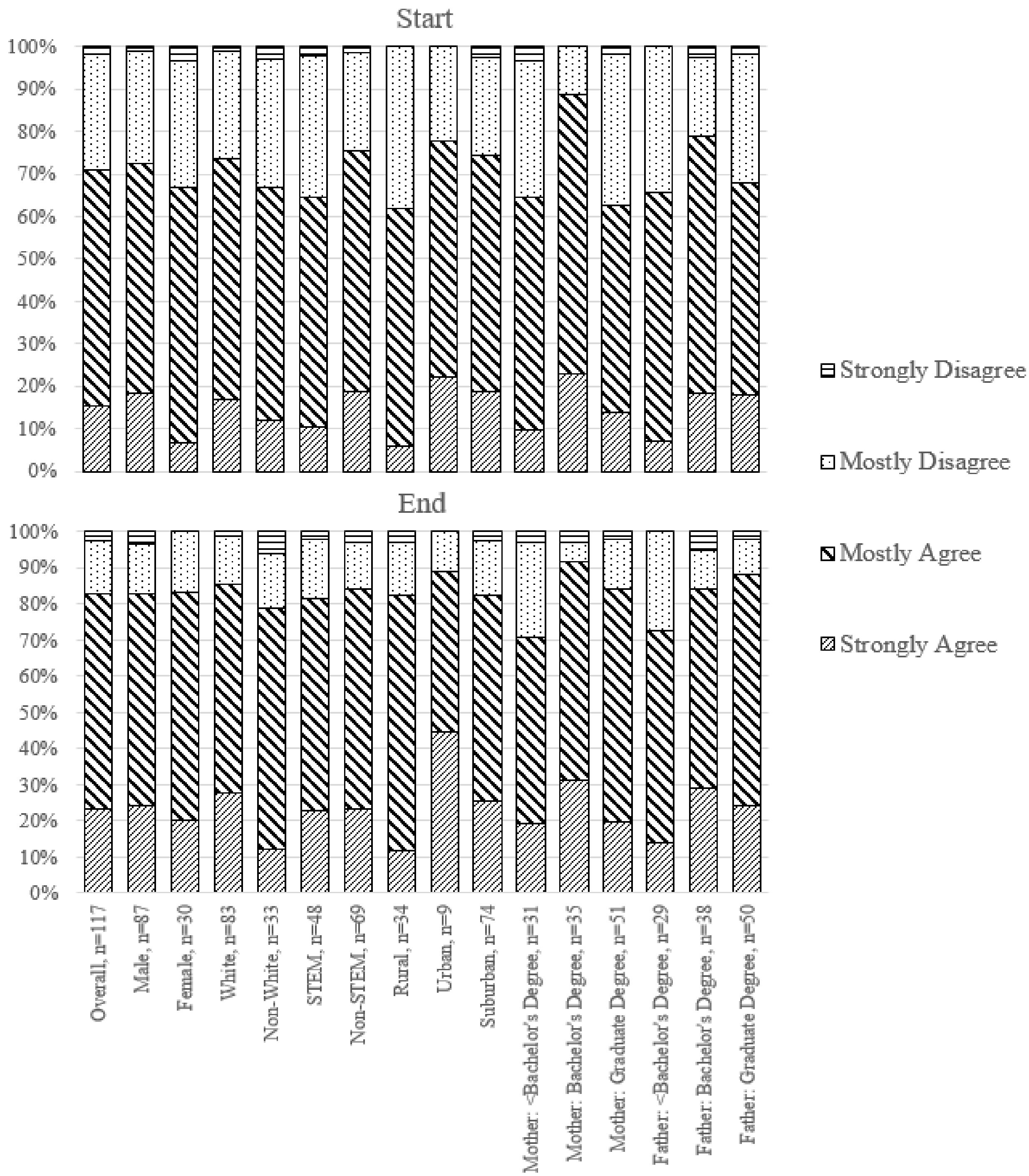

Figure 8. Student responses to the statement, "Technology will find a way of solving environmental problems," whether you strongly agree, mostly agree, mostly disagree, or strongly disagree." at the start (top) and end (bottom) of the course.

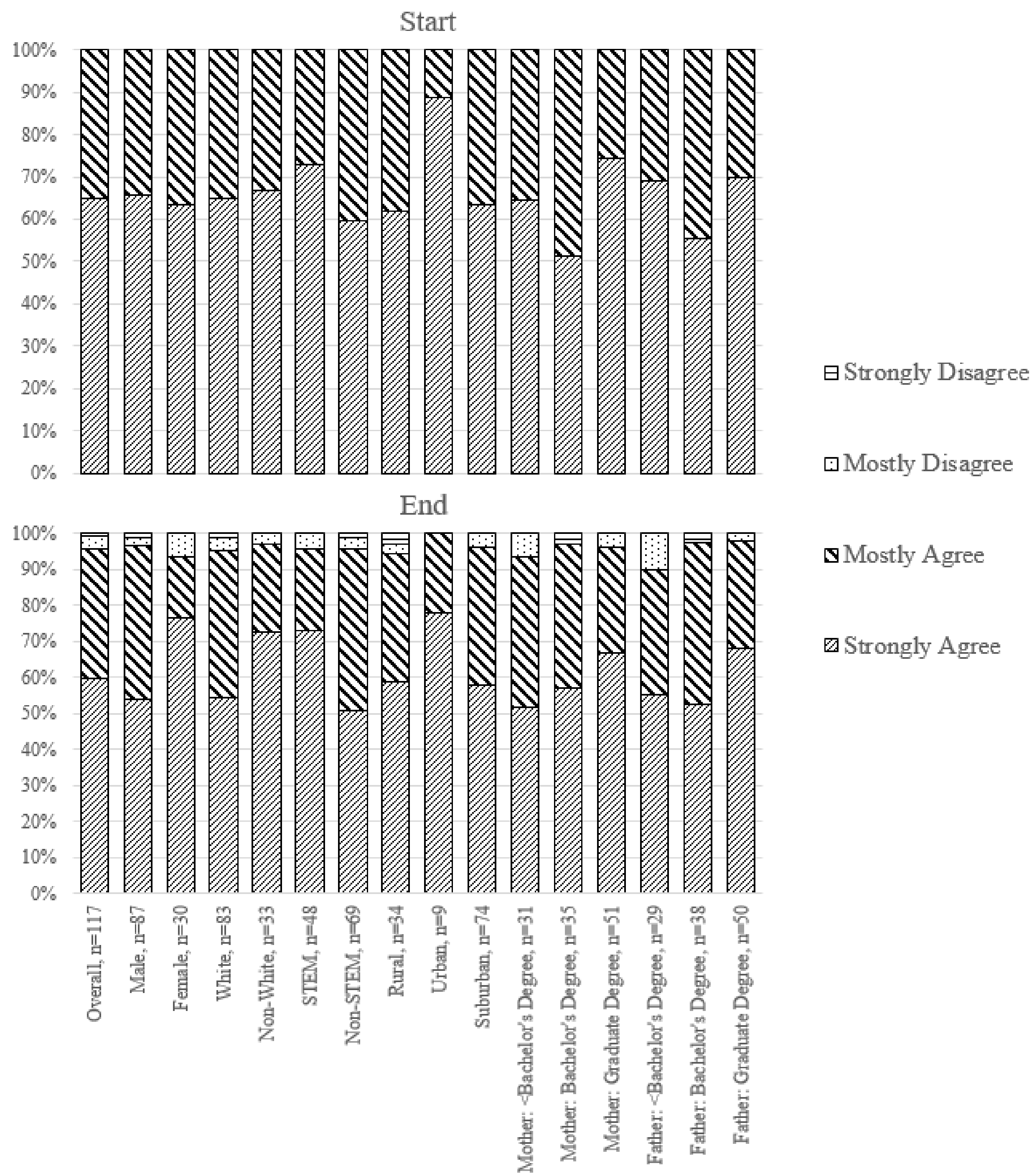

Figure 9. Student responses to the statement, "The condition of the environment will play an increasingly important role in the nation's economic future," whether you strongly agree, mostly agree, mostly disagree, or strongly disagree." at the start (top) and end (bottom) of the course.

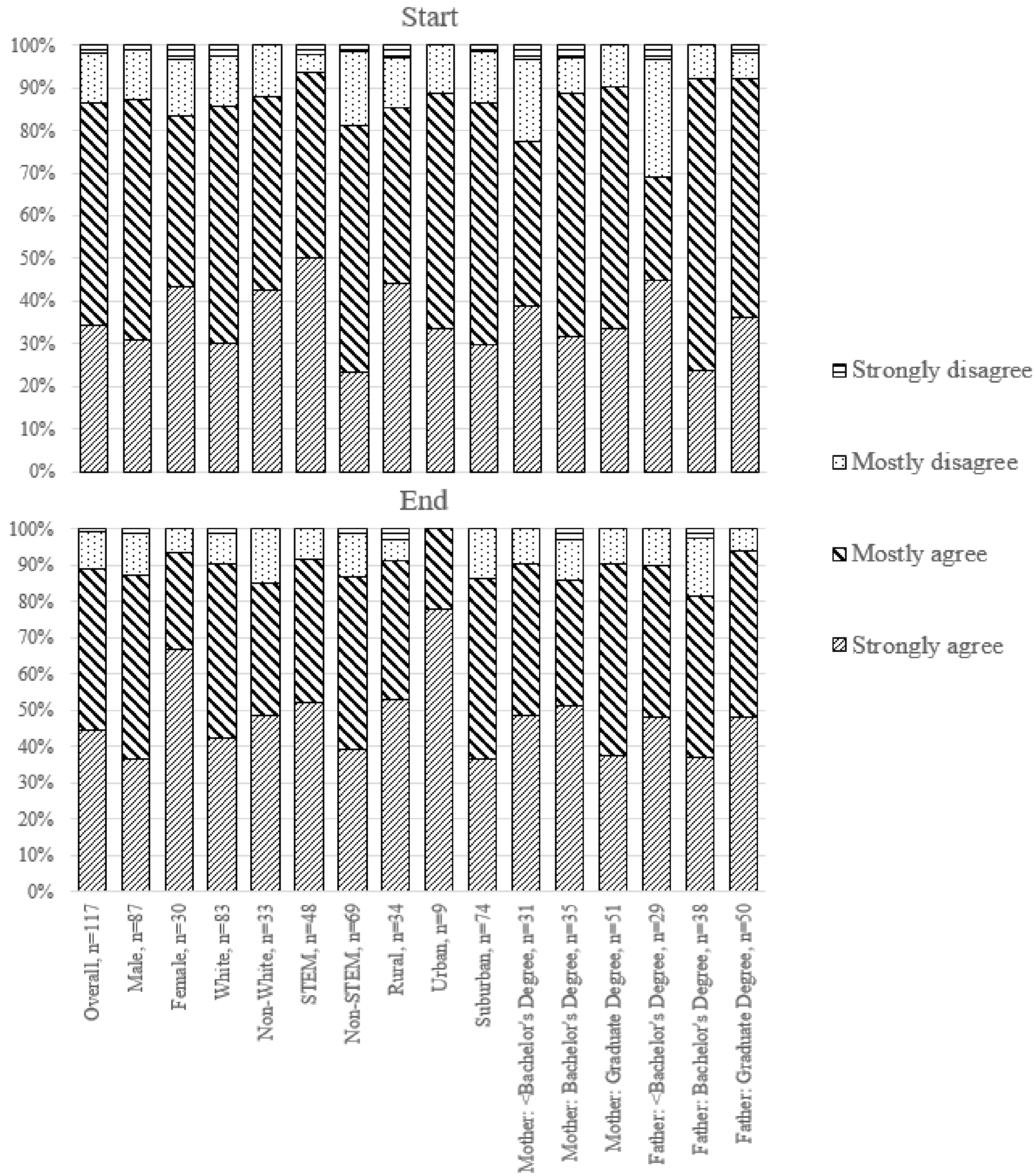

Figure 10. Student responses to the statement, "Please indicate for the following statement, "Private companies should train their employees to solve environmental problems," whether you strongly agree, mostly agree, mostly disagree, or strongly disagree." at the start (top) and end (bottom) of the course.

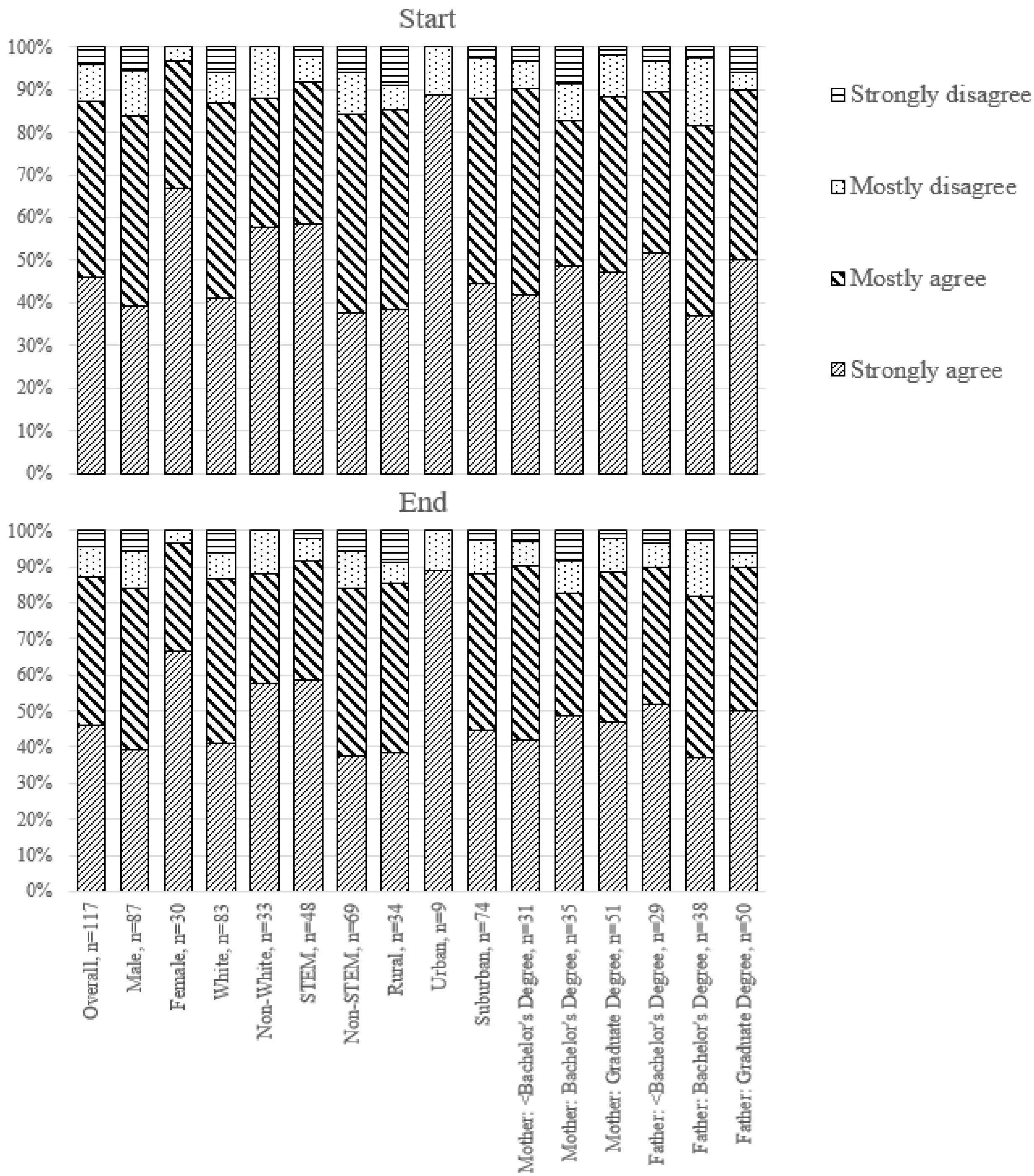

Figure 11. Student responses to the statement, "Please indicate for the following statement, "Government agencies should support environmental education programs for adults," whether you strongly agree, mostly agree, mostly disagree, or strongly disagree." at the start (top) and end (bottom) of the course.