Factors Influencing Cooperative and Competitive Decisions in STEM Courses

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Abstract

To explore factors that may inform teaching and learning in STEM education, we investigate individual and situational factors influencing students' cooperative versus competitive responses in a classroom, extra-credit problem social dilemma in core biology and engineering courses. We were curious how our competitive academic environment coupled with our cooperative military training impacts student decision-making. Analysis variables included class year (proxy for maturity), gender, group size, and number of exposures to the dilemma. Our results (N=2654) reveal significant main effects and interactions, with the largest effects often seen in women. To achieve more cooperative decision-making, instructors could create multiple small-group experiences and explicitly engage in and discuss cooperative decision-making. In addition to enhancing learning experiences for students, these activities could help initiate a climate shift to stimulate retention of women in STEM fields and overall achieve more cooperative decision-making.

Keywords: social dilemma, competitive and cooperative decision-making, women in STEM

Overview

Cooperation is valued and necessary in society, but competitiveness is often rewarded more, especially in academic, scientific, business, and other professional contexts. Therefore, a tension exists between making personal choices that benefit the community versus just the individual. People may choose what immediately seems best for themselves, without regard to long-term or more shared consequences. For example, many academic institutions have teamwork as a learning outcome and incorporate cooperative learning experiences into their courses; however, grades are typically individualistic, and can influence scholarships, graduate school positions, and other competitively awarded recognitions. The tension between cooperative and competitive choices is especially apparent in the STEM fields. Although collaborative and interdisciplinary science and engineering research and projects have become the norm in most fields, recognition is still achieved through competition when applying for grants, patents, publishing, fellowships, employment, and promotion.

This project investigates what individual differences and situational factors might influence cooperative versus competitive decision-making in an academic setting. To do this, we used a social dilemma scenario for an extra credit exercise (task adopted from Peden et al., 1990) in both engineering and biology courses. A social dilemma occurs when an individual must make a decision between two choices, (1) choosing what is good for oneself or (2) choosing what is good for the group that includes the individual, specifically when these choices are in conflict. One of the strengths of our activity is that the social dilemma was real (Henry, 2000) rather than being a laboratory exercise. We hope, that by developing a better understanding of such factors, some of which might be managed by instructors, we can better design learning experiences that will foster cooperative decision-making both within and also beyond academic settings.

We believe that our institution, the U.S. Air Force Academy (USAFA), provides an especially useful context in which to examine this tension. Stratification of students, for which academics plays a key role, forms the basis of Air Force career path decisions. Competitiveness may be enhanced by the military environment, where confident assertion and individual accomplishment are often met with positive reinforcement or reward. At the same time, USAFA trains and coaches students to mature into Air Force officers who have the skills to work cooperatively together on teams. Through this training USAFA students are encouraged and inspired to "do what is right even when no one is looking" and adopt a "service before self" mindset. So, while we hope for teamwork, we often reward individual effort. We need to be mindful "on the folly of rewarding A, while hoping for B" (Kerr, 1995). If we determine factors that indicate an increased likelihood for cooperative decision-making in our extremely competitive environment, they might be even more influential in other, less competitive environments.

Background

In 1776 Adam Smith, the "father of modern economics," published the seminal work on free-market economic theory "The Wealth of Nations." A major theme in Smith's work is the idea that competition can lead to the good of society in terms of economic prosperity, since it is competition that drives producers to create the best product. However, Hardin (1968) described how rational self-interest decisions can also lead to negative societal outcomes, such as the demise of a commonly held resource. A "tragedy of the commons" dilemma is a situation where (1) an individual would receive a higher benefit than the group by making a socially defecting choice rather than making a cooperative choice that benefits the entire group, and (2)

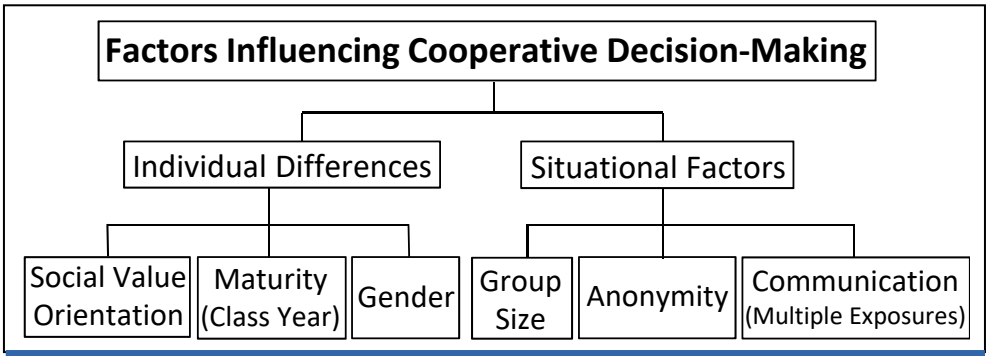

Figure 1. Factors influencing cooperative decisions.

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all individuals receive a much lower benefit if all or most individuals make the socially defecting choice (Dawes, 1980). Today, the phrase "tragedy of the commons" has been applied extensively to and is often associated with problems in economics, global ecological problems, environmental issues (Mosler, 1993), and game theory (reviewed in Ostrom et al., 2002). Research findings related to limited resources can also be applied to social situations where rewards are limited, such as often occurs in academic and STEM contexts (e.g. faculty positions and grants).

Prior research outside of academic contexts has shown that several factors may influence whether people make a socially cooperative or socially defective choice in the dilemma. These factors are organized in Figure 1 into individual differences and situational differences. Inherent individual differences include social value orientation, age, and gender. Environmental or situational factors include group size, anonymity, and communication.

Personal social value orientation is an individual's choice on how to allocate resources between the self and others. Individuals with a prosocial value orientation often intrinsically opt for the mutually beneficial outcome, whereas subjects with a pro-self orientation (individualistic or competitive) choose to maximize their own outcome (Emonds et al., 2011). That being said, competitive individuals, who seek to maximize their own outcomes and minimize others' outcomes, can be encouraged to cooperate when there are extrinsic incentives to make cooperation individually rewarding (Emonds et al., 2011).

According to Piaget (1932) and Kholberg's (1958) stages of moral development, age affects decisions. Younger individuals, ranging in age from children to young adults, are often egocentric with morality based on their own rules and immediate well-being, and thus, may be more likely to select the socially defective choice. The college years, or the path from adolescence into adulthood, mark the pivotal years where students move from a simplistic view of knowledge to a more complex, contextual view of the world and themselves (Perry, 1970). Older individuals, who have reached the age of full adult reasoning, may be concerned with immediate effects but are also cognizant of potential adverse consequences and long-term effects. Older individuals may also realize that their individual decisions can impact the larger group (Kopelman et al., 2002) and, consequently, may be more likely to make a cooperative choice in a social dilemma. Thus, a theoretical consensus supports a positive correlation between age and socially cooperative decision-making (Houser et al., 2012), but at least some research finds no difference across age groups (Nikoomaram et al., 2013).

Social-role theory, the theory that pertains to gender differences and similarities in social behavior, as well as evolutionary psychology, the theoretical approach that attempts to explain psychological traits as a function of natural selection, seem to imply that gender differences would exist in social dilemma decision-making. Some research favors the idea that women tend to be socialized to be more cooperative than men, who are socialized to be more competitive and independent (Goldsmith, 2013). Yet, there is very little definitive empirical support (Simpson, 2003), and the few studies that have investigated gender in a "commons" dilemma seem to draw contradictory conclusions. For example, Van Lange et al. (1997) showed significant main effects for social value orientation and gender with men being more pro-self, which is more consistent with the socially defective choice, while women are more prosocial and select the socially cooperative choice. In contrast, Brown-Kruse and Hummels (1993) found that men are more cooperative and community-minded than women when contributing to a group fund that was increased by a known multiplier and then divided among the group equally regardless of individual contributions. Overall, the existing body of literature seems to suggest that gender may have an influence on cooperation in social dilemmas, but its effect is unclear and may be small depending on the particular dilemma (Kopelman et al., 2002). Given the current attention to gender inequities in STEM fields (Blickenstaff, 2005), we are interested in whether or not we might find gender differences in our study.

Moving beyond the individual, cooperation in social dilemmas has been shown to be inversely correlated to group size (Dawes et al., 1980). When an individual is a member of a large group, the perceived risk associated with the self-interest choice is less because of an assumed lower impact of their individual choice on the group outcome (Brewer and Kramer, 1986). Larger groups, relative to smaller groups, also promote the diffusion of responsibility (De Cremer and Bakker, 2003) and anonymity, which increases socially defective choices (Kerr, 1999; Houser et al., 2012). In contrast, when an individual is in a small group, the personal sense of contribution and responsibility is greater because subjects likely know each other better. Further, when decisions are publicly disclosed, people may be more likely to choose the socially cooperative choice (Hardy, 2006) because it may be "more shameful" to choose the socially defective choice in public (Houser et al., 2012). These patterns of behavior suggest that an incentive to make socially cooperative decisions for individuals in groups, especially large groups, is to ensure decisions are public.

Loosely related to group size and anonymity, an individual's sense of community and the presence of honest communication within a group can influence an individual's choice in a social dilemma decision. Members of a group can create a feeling of community and group identity when individuals in the group know each other, communicate, and share common goals. Within such group communities, increased communication has been shown to substantially increase the number of individuals making the socially cooperative choice (Dawes et al., 1980, Orbell et al., 1988).

The results summarized here uncover conclusions that seem inconsistent, and few studies investigate the combined impact of variables with large numbers of participants. The objective of the current work is to identify the effects of the factors influencing decisions in a social dilemma in a competitive academic environment that also focuses on teamwork, cooperation, and social responsibility. This combination naturally cultivates a social dilemma, which exists between individual competitive (and potentially socially defective) choices and cooperative choices that also impact the group.

Given the individual differences and situational factors that can influence a cooperative or competitive decision, this study examined maturity (class year), gender, group size, and number of exposures (a manipulation of level of communication). Student social value orientation data were not gathered, and all individual choices were anonymous to the participants. Based on the literature reviewed, we formulated four research questions and hypotheses, one each grounded in class year, gender, group size, and exposure. The impact of various combinations of variables was exploratory.

The first research question was whether class year, as a measure of maturity, would influence decisions in a social dilemma. Because prior research supports a positive correlation with age and socially cooperative decision-making (Houser et al., 2012), we predicted more upperclass students than first-year students would select the socially cooperative choice. Though this study looks at a very narrow age range, it represents the transition years between late adolescence and adulthood (Kohlberg, 1958) as well as two years' experience in the USAFA officer training programs. As students progress through these programs, the hope is for more social cooperation and sense of responsibility for the welfare of the larger group.

The second research question was if gender would affect decision-making in a social dilemma. Because some research indicated a weak link between men choosing the socially defective choice and women choosing the socially cooperative choice (Van Lange et al., 1997), we predicted a higher percentage of women than men would select the socially cooperative choice.

The third research question was related to group size, which prior research indicates is inversely related to cooperation in social dilemmas (Dawes et al., 1980). We predict when part of a smaller group, more students would choose the socially cooperative choice due to the sense of community within the smaller group.

Finally, we were curious if communication between group members regarding the outcome of prior choices would affect decision-making in later opportunities to engage in the same social dilemma. When engaged in decision-making, people use both prior personal experience and knowledge obtained through communication with others. Further, the literature revealed that a subject's sense of community and honest communication within

a group can influence a subject's choice in a social dilemma decision (Orbell et al., 1988). If given multiple exposures during a single semester to respond to the dilemma, individuals would have time to reflect on their choices and communicate with other individuals. Therefore, when students are given additional opportunities to respond to the same social dilemma within the same course in the same semester, we predicted a higher percentage of students would choose the socially cooperative choice than did the first time.

Method

Participants

A total of 2,657 first-year and upper-class students participated in this study. First-year student participants (n=1,115, 42%) were enrolled in a general education, required introductory engineering course. Upper-class student participants (n=1,539, 58%) were enrolled in a general education, required biology course and/or a general education, required introductory aeronautics course. As is standard at our institution, student assignment to course sections was random and is performed by the Registrar's Office, which uses a method with constraints (e.g., student intercollegiate athletes cannot enroll in late afternoon courses due to team practice schedules). Table 1 summarizes class year and gender of the participants. The gender distributions of the participants reflect the overall student population at the institution.

Class Year	Gender	n	% of total
First-year	Men	827	31%
	Women	288	11%
Upper-class	Men	1193	45%
	Women	346	13%
	TOTAL participants	2654	

Table 1. Summary of participants.

Materials and Procedure

Our study used a social dilemma originally posed by Peden et al., (1990) and modified by Selterman (2015). In our investigation, the social dilemma was presented on each exam and/or final exam. A sample of our verbiage was as follows:

> *You have the opportunity to earn extra credit points on your exam. Select whether you want 2 points or 6 points added to your grade if your answer to the extra credit problem is correct. However, if more than 10% of the section/class enrollment chooses 6 points (regardless of whether he/she is correct), then no one will earn any extra credit points. All responses will remain anonymous to the rest of the class, although your instructor will know so that points can be allotted.*

The exact extra-credit question and point allotments were different for first-year and upper-class students because the dilemma was posed on exams in different subject areas. However, the percentage of extra-credit points was kept constant across all sections and courses. The group size for "small" groups was a single section of a course (on the order of twenty-five students or less), whereas the "large" group consisted a collection of multiple sections of the same course (approximately 250 students). Participants were informed of how many course sections were included in their group for the dilemma. Permission to conduct the study was obtained through our institutional ethics board.

Results

Responses across all sections of courses for all semesters were tallied based on the variables of interest (class year, gender, group size, and exposure). Each possible social commons dilemma response was counted as a separate event (i.e. if a student responded to a dilemma on the first exam and on the final exam, then those responses would count as two tally counts). Chi-square (χ^2) analyses were used to examine the four main hypotheses as well as the multi-factor exploratory questions.

Figure 2 shows the percentage of participants responding in a cooperative versus a competitive manner across all their exposures for each of the two-group comparisons for the four main hypotheses, Class year, Gender, Group size, and Exposure, respectively. Upper–class students made the cooperative decision significantly more often than First-year students, $\chi^2(1)=60.63$, $p<0.001$. There was no significant difference in the response choices made by Women compared to Men, $\chi^2(1)=0.08$, $p>.05$. Small-group students made cooperative decisions significantly more often than students in the Large groups, $\chi^2(1)=15.94$, $p<0.001$. Finally, students made significantly more cooperative choices on their second exposure than their first exposure, $\chi^2(1)=18.54$, $p<0.001$.

We were also curious how multiple factors might interact to influence the decision-making of cooperative or competitive responses. First, we examined how Class Year and Gender interacted. Figure 3 shows the percentage of cooperative and competitive responses for Men and Women overall and individually for First-year students and for Upper-class students. There was no significant gender difference overall (shown in Figure 2), or for First-year students, $\chi^2(1)=1.63$, $p>.05$. However, for Upper-class students, Women made significantly more coopera-

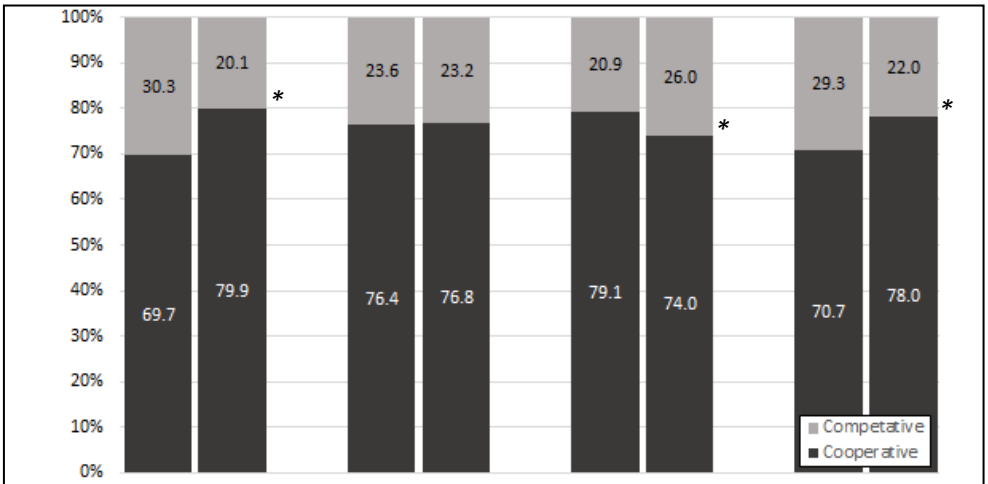

Figure 2. Cooperative and competitive responses for each two-group comparison. *$p<0.05$

Figure 2. Cooperative versus Competitive Responses for each of the two-group comparisons for the four main hypotheses.

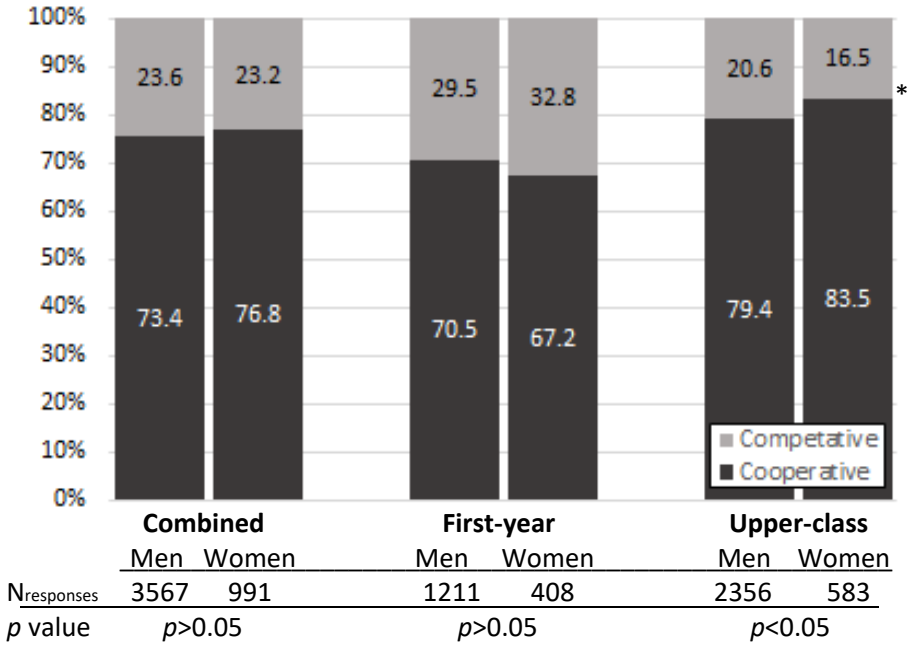

Figure 3. Cooperative versus Competitive Responses for Gender and Class year.

tive choices then Men, $\chi^2(1)=5.10$, $p<0.05$.

Next, we examined how Class Year and Gender interacted with Exposure. Figure 4 shows the percentage of cooperative and competitive responses for each combination: comparing Overall Men's and Women's First and Second Exposures ($\chi^2(1)=7.80$, $p<0.01$ and $\chi^2(1)=15.57$, $p<0.001$, respectively), First-year Men's and Women's First and Second Exposures ($\chi^2(1)=2.12$, $p>.05$ and $\chi^2(1)=5.02$, $p<0.025$, respectively), and then Upper-class Men's and Women's First and Second Exposures ($\chi^2(1)=6.34$, $p<0.02$ and $\chi^2(1)=13.22$, $p<0.001$, respectively). In every case except First-year Men, there were significantly more cooperative responses for the second exposure. Also of interest is that First-year Women's First Exposure led to the lowest level of cooperative responses, but Women's likelihood to respond cooperatively steadily climbed with Exposure and Class year, leading to the highest rate of cooperative responses made by Upper-class Women's in their Second Exposure.

Next, we examined how Group Size interacted with Class Year and Gender. Figure 5 shows the percentage of cooperative and competitive responses for each combination. For the First-year students there was no difference in the choices made by the Small and Large groups ($\chi^2(1)=0.62$, $p>0.05$). However, Upper-class students in the Small groups made significantly more cooperative choices than those in the Large groups ($\chi^2(1)=8.42$, $p<0.01$). Both men and women showed a greater likelihood of making a cooperative response when part of a Small group than a Large group ($\chi^2(1)=7.53$, $p<0.01$ and $\chi^2(1)=12.26$, $p<0.001$, respectively), although the magnitude of the difference was greater for the women.

Finally, for the upper-class biology course we were able to further examine the impact of exposure because these students were exposed to the social dilemma four times (three exams and a final exam). Figure 6 shows the percentage of cooperative and competitive responses for the four exposures for upper-class biology students, and then separately for Men and Women in that group. In all cases there was a significant increase in cooperative responses as exposure increased, $\chi^2(3)=33.46$, $p<0.001$, $\chi^2(3)=23.43$, $p<0.02$, and $\chi^2(3)=13.60$, $p<0.01$, respectively.

Discussion

Using a large sample size which was over an order of magnitude larger than most previous studies (e.g., Peden et al., 1990; Brown and Hummels, 1993; Mosler, 1993;

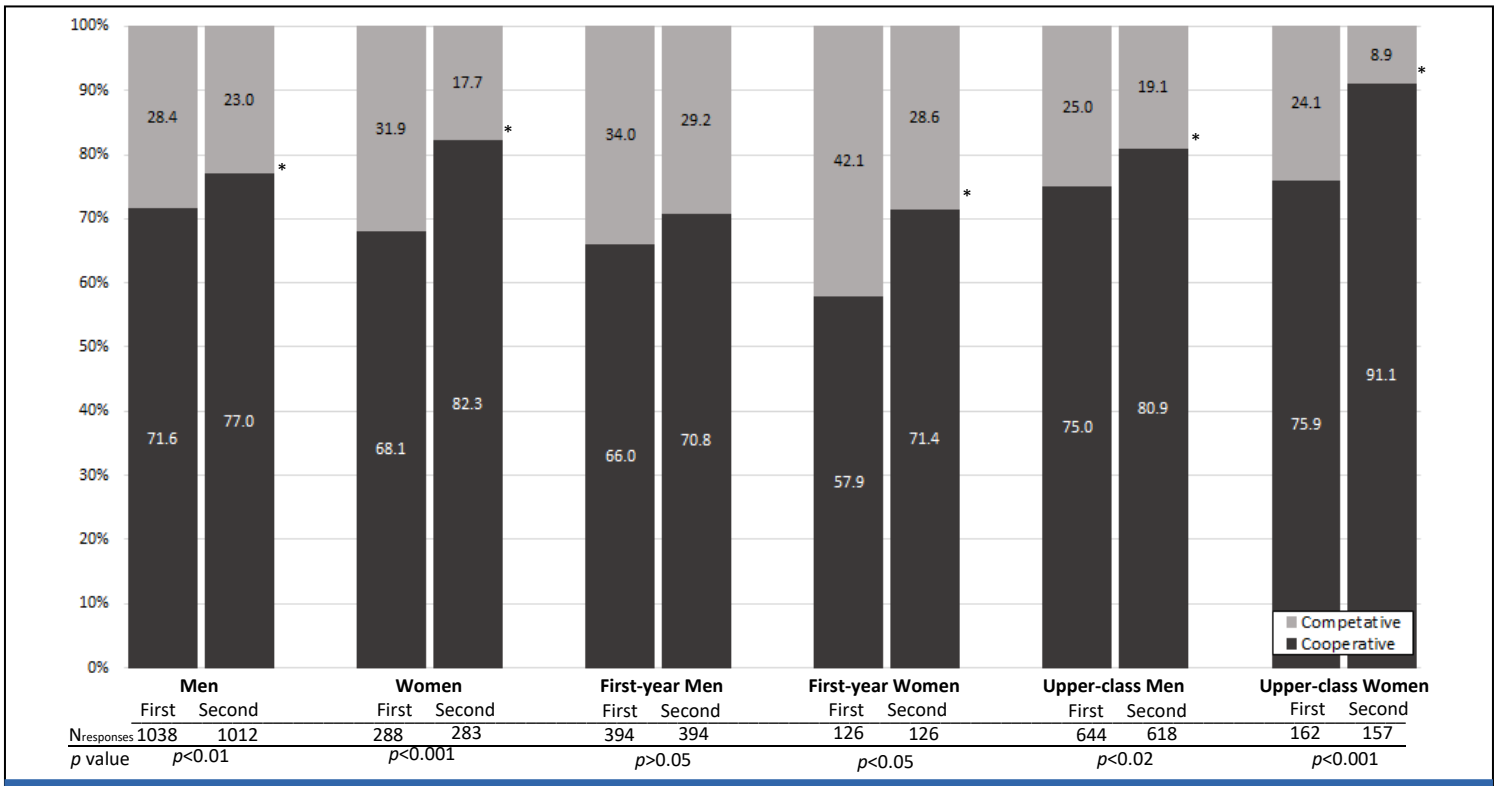

Figure 4. Cooperative versus Competitive Responses for Gender, Class year, and Exposure number.

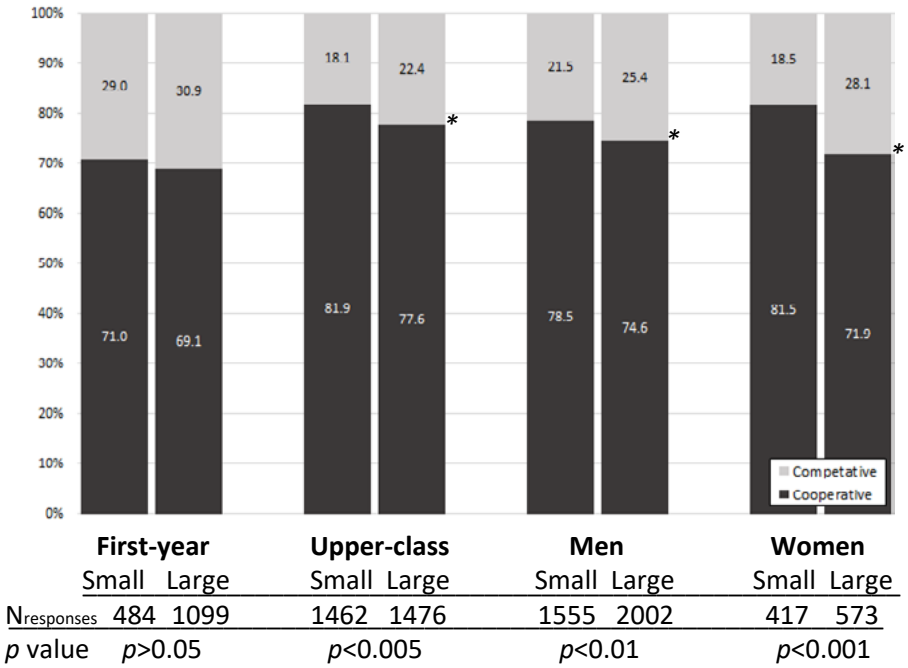

Figure 5. Cooperative versus Competitive Responses for Group size, Class year, and Gender.

Van Lange et al., 1997; Henry, 2000; De Cremer and Bakker, 2003), overall our results support our hypotheses and reveal some interactions between our variables, extending the literature and allowing more complex, realistic understanding of the factors that might support cooperative decision-making. These results also lead to suggestions regarding how instructors might consider fostering environments that develop this valuable, cooperative decision-making perspective, thereby helping to reduce the "leaky pipeline" and aid in the retention of females in STEM fields (Blickenstaff, 2005).

Maturity (using class year as a proxy) has a clear effect and interacted with gender, group size, and exposure, suggesting that this pivotal time period of development during the college years might be one to target with respect to the development of cooperative decision-making. However, the interactions suggest that a simple, "one-size-fits-all" approach will not be the most effective to develop cooperative decision-making. For example, although there was no overall effect of gender, women in our study showed some the lowest rates of cooperative behaviors (e.g. first-year women first-exposure and overall women in large groups). Conversely, women also showed a larger shift to cooperative decision-making than men as they became upper-class students, were part of small groups, and experienced a second exposure even as first-year students. Further, when more than two exposures occurred (upper-class core biology course), women started to reach asymptote after the second exposure, while men did so after the third exposure, and over 93.5% of women chose the cooperative choice after four exposures, compared to men, who were cooperative only 84.5% of the time on the fourth exposure. This pattern of gender effects suggests that, at least in our institution's particularly competitive and male-dominated culture, first-year women might feel the need to respond competitively, especially if in large groups. This unwanted pressure to be competitive might be exacerbated by the typically large first-year STEM courses at many other institutions. Unfortunately, prior research (Blickenstaff, 2005) has shown that more women than men tend to desert STEM fields as they progress through college, with a major reason often being the competitive nature of the STEM fields (Utano, 2014). On the positive side, our women respond strongly to small groups and multiple exposures – the two of our situational factors that potentially could be controlled by instructors. These two factors also increased male cooperative choices, though less strongly. Perhaps if instructors incorporated several opportunities to create small-group experiences and explicitly engage in and discuss cooperative decision-making, we might achieve a climate shift, so that more women would remain in STEM fields, and, overall, we would achieve more cooperative decision-making.

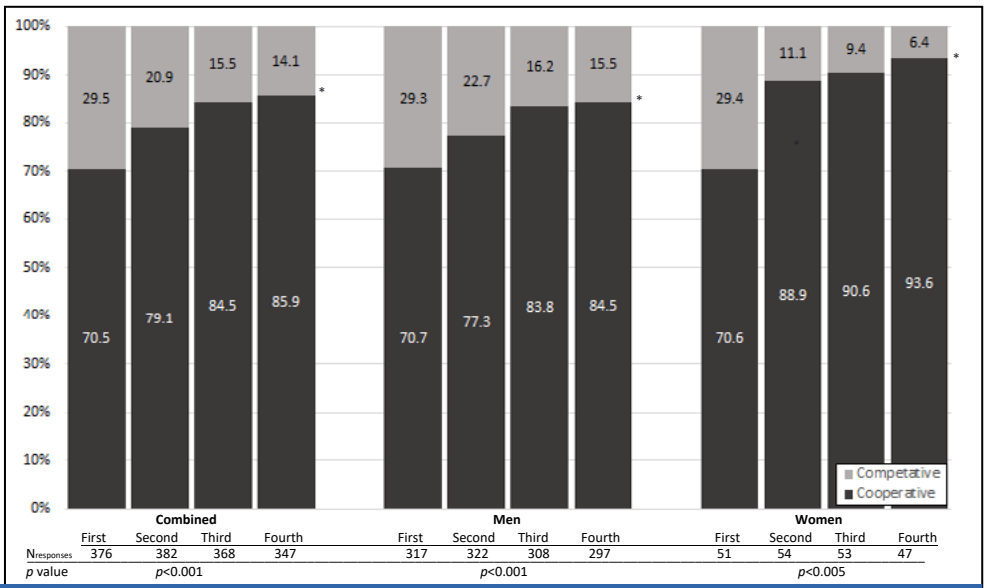

Figure 6. Cooperative and competitive responses for Upper-class biology students for the four Exposures overall and by Gender.

The interaction of class year with group size merits some further discussion. While there was no difference between small and large groups for first-year students, small groups led to more cooperative decisions for upper-class students. This interaction is interesting because all of the courses investigated were required core courses with relatively random assignment to course section; thus, the students likely did not know each other any better in the upper-class courses than the first-year courses. A possible reason for this interaction is that, as students mature, they develop better communication skills, which in turn lead to a stronger sense of community within their group and increased discussion-induced cooperation (Dawes et al., 1980; Orbell et al., 1988). Unfortunately, because none of our classes have more than twenty-eight students, our large groups were artificially created as a collection of small groups that had no formal interaction with each other. Future research should examine the effect of group size with both small and large groups comprised of single course sections so that the effect is more clearly due to group size rather than ability to make face-to-face interactions.

We cannot determine whether our intentional officer development training programs are the key factor driving the class year differences, or if natural developmental maturation (Piaget, 1932, Kholberg, 1958; Perry 1970) is most influential. The gender differences suggest that at least some of the effect is due to general maturation because all students, regardless of gender receive the same officer development training. Future research at other in-

stitutions could help determine how generalizable these maturation effects are across different contexts.

In general, our results suggest that social dilemmas can be a useful tool to develop cooperative decision making within an academic setting, supporting institutional outcomes such as teamwork and cooperation. This tool is helpful because cooperative behaviors are often hard to directly observe, and thus, may not be rewarded (Kerr, 1999), decreasing their likelihood especially in competitive environments. Although gender and inherent maturation are individual differences that are not under our control as instructors, we can do something about the situational factors of group size and the number of exposures. We also influence the design of developmental programs, such as our officer training program that might increase the rate of maturation in targeted, desired areas. Overall, challenging students through social dilemmas can be useful for students to learn about themselves, the choices they make, and how their decisions affect others.

The value of developing cooperative decision-making extends beyond academic settings. Many major resources are rapidly becoming more limited, and when large masses of people engage in excessive consumption, there can be wide-spread, detrimental effects (Mosler, 1993; Selterman, 2019). A current example of the need for cooperative efforts was highlighted regarding the growing problem of waste plastics in our oceans. "While changing the economic and business role of plastic is key, it's not sufficient. The spirit of communities and nations must change. And once again, collaboration, not argumentation, makes it possible." (Poulos, 2019). Such positive change will not happen without intentional effort to provide education and developmental opportunities.

Acknowledgements

Many individuals who taught Introduction to Engineering, Introductory Biology with Laboratory, and Introduction to Aeronautics at the United States Air Force Academy have contributed to this effort. The authors would like to extend a sincere thank you to the instructors and the students who helped with this work.

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