Driving Up or Dialing Down Competition in Introductory STEM Courses: Individual and Classroom Level Factors

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In nearly 50 years of student data collection, we are witnessing the highest number of entering freshmen at four-year colleges interested in STEM degrees (Eagan, Lozano, Hurtado, & Case, 2013). In spite of this, the recent report from the President's Council of Advisors in Science and Technology (PCAST) indicated only 40% of students who start in STEM complete a degree, and most leave within the first two years of college (PCAST, 2012). To reverse this trend, the federal government and private foundations have focused on the primary goal of increasing the number of STEM graduates toward producing over a million more graduates in the coming decade.

These goals will not be reached without addressing student and faculty behaviors and perceptions in introductory classrooms. Students encounter large classes and increased competition in particular STEM courses, with many faculty in STEM departments slow to change their teaching practices to become more student-centered (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012). Moreover, most courses are not providing sufficient intellectual engagement, and very talented students leave STEM for other fields within their first two years of college before they have the opportunity to take more discipline-specific coursework. Competitiveness in introductory STEM courses in particular has been shown to adversely affect women and underrepresented racial and ethnic minorities in STEM (Baldwin, 2009; Palmer, Maramba, & Dancy, 2011; Shapiro & Sax, 2011), two groups whose participation in STEM has been of pressing national interest (National Academy of Science, 2007). As a result, research is needed to demonstrate how pedagogical factors in introductory STEM classrooms lead to students' perceptions of competition.

This study identifies factors that contribute to students' perception of competition in introductory STEM courses. We specifically focus on the relationship between norm-referenced grading, or grading on a curve, and perceptions of competition, as one way faculty “drive up” or “dial down” competitiveness in their courses. Although faculty may utilize norm-referenced grading for various reasons, such as demonstrating high academic standards or motivating students to increase their academic performance, these practices may push students out of STEM fields who otherwise possess the talent to be successful.

More public attention and dollars are available to fuel transformation in STEM undergraduate education today. During this current policy window, agencies such as the National Science Foundation (NSF) and National Institutes of Health (NIH) have committed funding aimed at incentivizing campuses across the country to transform and innovate undergraduate education to increase production of STEM graduates for the scientific workforce. Evidence in this study will begin to help faculty, department chairs, and deans to identify areas of emphasis that involve the use of evidence-based practices that develop talent and address the negative effects of ‘weeding’ out and promoting unfair competition among students who may otherwise be successful in STEM. Few studies in higher education are able to capture students in multiple classrooms across multiple kinds of institutions to reveal some universal faculty behaviors, elevation of competition, and student responses. This study opens new pathways for research and evaluation in STEM classrooms that link behaviors, attitudes and performance.

Competitiveness in Introductory STEM Courses

Students report that STEM courses, especially introductory STEM courses, foster a competitive environment (Seymour & Hewitt, 1997; Strenta, Elliott, Adair, Matier, & Scott, 1994). Faculty often assume that not every student who pursues a STEM major is capable of succeeding in further STEM study, especially graduate work, and thus use pedagogical strategies aimed at “weeding out” those students perceived as less capable (Baldwin, 2009; Bok, 2006).

One of these strategies is norm-referenced grading, or grading on a curve, aimed at identifying the highest performing students in these courses who are assumed to be the most likely to succeed in a STEM research career (Seymour & Hewitt, 1997).

The effect of norm-referenced grading on competitiveness in the introductory STEM classroom is exacerbated by an increased presence of premedical students on campus (Garcia, Gasiewski, & Hurtado, 2011), most likely driven by the competitive nature of the medical school admissions process. In fact, while most STEM students report classroom competitiveness to be detrimental to their learning process, premedical students report competitiveness to *increase* their engagement with coursework (Gasiewski et al., 2012). Even still, premedical students at universities where higher proportions of STEM faculty use norm-referenced grading are more likely to leave STEM and either complete a non-STEM degree by their sixth year or leave college altogether and not complete by their fourth year (Hurtado, Eagan, & Hughes, 2012), although Hurtado, Eagan, and Hughes did not examine the use of norm-referenced grading at the individual classroom level. Premedical students may find competitiveness stimulating, but it appears to have a detrimental effect on their pursuit of their medical school goals as well.

Competitiveness in STEM classrooms is also most detrimental to those groups historically underrepresented in STEM. For URM (underrepresented racial/ethnic minority) students, competition places an intense focus on individual performance and can exacerbate their feelings of racial isolation in STEM courses (Palmer et al., 2011). Women can also be discouraged by a competitive environment in STEM courses, as competition may not be a meaningful way for them to receive feedback on their learning (Shapiro & Sax, 2011). Michaels (1978) contradicted this claim, however, in finding that women solving math problems under competitive conditions performed just as well as men, but this study was conducted in a laboratory and thus likely did not simulate the classroom environment very well. Alternatively, McShannon and Derlin (2000) found specifically that URM women were better retained in engineering through the use of cooperative learning strategies as compared to their counterparts enrolled in “traditional” engineering programs. Although competitiveness appears to contribute greatly to the persistent underrepresentation of women and URM students in STEM, the use of cooperative and collaborative learning strategies could reverse these outcomes and improve equity within STEM fields.

Competitiveness in the College Classroom

Even though most educators and scholars agree that competition is more likely detrimental to students’ learning (Krumboltz & Yeh, 1996; Slavin, 1977), a debate persists in the literature due to experimental evidence that competition increases academic performance (Johnson & Johnson, 1989). For example, Lam, Yim, Law, and Cheung (2004) found competitive conditions improved seventh graders’ performance in a Chinese typewriting course, but decreased students’ self-esteem and motivation to master the course material. Opponents hold that competition distracts students from deeper learning and mastery of course material by focusing their attention on their peers’ performance. Deutsch (1979) argued that even though competition is not itself necessarily detrimental to students’ learning, without attention to the host of conditions under which competition could improve both performance *and* mastery, competition for course grades specifically will more likely than not provide a disservice to students. These conditions include the requirements of the task at hand, cultural differences in terms of responsiveness to competition and cooperation, and how well-matched students are in terms of academic ability (Kulick & Wright, 2008). If these conditions are not met, final grades likely reflect other qualities than academic performance (Johnson & Johnson, 1989), or are potentially based on chance (Kulick & Wright, 2008), which calls into question the validity of students' grades.

Slavin (1977) added that cooperative learning structures could contribute to increased performance through the use of small groups, and would facilitate social connectedness. These outcomes would be of interest to STEM educators because, if connectedness leads to a greater sense of science identity and sense of belonging within the scientific community of practice (Carlone & Johnson, 2007; Hunter, Laursen, & Seymour, 2007), competitive reward structures in the STEM classroom would impede this goal.

In addition, the effects of competitive, cooperative, and individualistic conditions on student behavior are not only a result of these conditions themselves but also of the instructions given under each set of conditions; that is, the person giving these instructions is activating these conditions (Scott & Cherrington, 1974). In Scott and Cherrington's study, competitive conditions on an individualized task led to increased performance, but not increased satisfaction, while cooperative conditions led to the greatest interpersonal mutual attraction. Even though Scott and Cherrington's study was performed in a laboratory setting, these effects would also be salient in the classroom where the conditions of tasks to be performed are outlined by the professor at the outset of the course, either verbally or within the syllabus.

Norm-referenced Grading

Norm-referenced grading, commonly referred to as "grading on the curve," is a method for grading academic performance that assumes the distribution of student performance should resemble a statistical normal curve (Bresee, 1976). Faculty assess a student's performance relative to other students in the class, rather than against some standard for performance as in the case of criterion-referenced grading, and assign grades accordingly (Aviles, 2001). In practice, norm-referenced grading results in instructors limiting the total number of A grades assigned to academic performance in a given course which is cited as a source of competition in the classroom (Aviles, 2001; Bresee, 1976; Wall, 1987; Zimmerman, 1981).

While the practice of norm-referenced grading in STEM has been written about extensively, much less empirical work has been performed to determine its specific effects on other STEM outcomes. In one simulation study, Rask (2010) determined that shifting the distributions of STEM course grades at a liberal arts college to mirror those of non-STEM courses would improve student likelihood of enrolling in the next STEM course in their sequence. For premedical students, at the classroom level, Eagan, Garibay, Soh, Hurtado, and Chang (2012) found norm-referenced grading to increase premedical students' commitment to health research and practice, but only for those students who found the difficulty level of the course set by the professor to be intellectually stimulating. In other words, the grades students receive in a course influence their perception of their ability within a given field and thereby affect term-to-term retention.

Although less research has been conducted on the effect of norm-referenced grading on its own, many more scholars have examined differences between the effects of norm-referenced and criterion-referenced grading on different student outcomes. In comparing two chemistry courses where one utilized norm-referenced grading and the other criterion-referenced, Church, Elliot, and Gable (2001) found students in the criterion-referenced course were more likely to develop goals around content mastery and were more likely to report greater intrinsic motivation for chemistry. Wilkinson, Wells, and Bushnell (2007) observed in a New Zealand medical school that changed from norm-referenced evaluation practices to a system based on a set of pre-determined standards, students developed a stronger sense of identity as doctors, and the decline in intrinsic motivation over time that had been observed under norm-referenced conditions was abated. No differences were observed in scores on the school's high-stakes comprehensive exam given before students progress to their medical internships. However, the school also changed from letter grading to a pass/fail system that may also have contributed to these outcomes.

Outside of STEM, academic performance differences were not observed between two psychology courses that were graded under norm- and criterion-referenced systems (Williams, Pollack, & Ferguson, 1975). Differences were observed based on students' performance early in the term—among those who performed poorly early on, those under the criterion-referenced condition scored higher on later tests than their peers under the norm-referenced condition. This finding suggested students in the norm-referenced condition may have seen their initial scores as a measure of their ability while students in the criterion-referenced condition used their initial tests as feedback for improving their later performance. Covington and Omelich (1984) also found students in a psychology course where criterion-referenced grading was used perceived greater fairness in the classroom than peers under norm-referenced conditions. Finally, criterion- and norm-referenced conditions activate different areas of the brain associated with cognition and affect; areas associated with negative affect are activated for students with low perceived competence under norm-referenced conditions and for students with high perceived competence under criterion-referenced conditions (Kim, Lee, Chung, & Bong, 2010). Norm-referenced feedback appears to reinforce feelings of inadequacy among students who perceive their competence to be lower, but also appears to reinforce perceptions of high ability among those who perceive their competence to be higher.

Much of this work has either been performed under laboratory settings, the findings of which scholars have questioned with regard to their validity in the real-world setting of the classroom (Slavin, 1977), or in single classrooms under quasi-experimental conditions. Of those single-classroom studies, many take place in psychology courses as the researchers themselves tend to be psychology faculty. This literature has only theoretically, but rightfully so, connected the scarcity of high grades under norm-referenced conditions to competitiveness among students in the classroom; few studies directly test the relationship of students' perceptions of competitiveness with grading on a curve. In addition, more research needs to be conducted on norm-referenced grading and competition in introductory STEM classrooms specifically, especially across multiple courses, given how crucial students' experiences in these courses are to their longer-term retention along STEM pathways.

Understanding Competition in the Classroom through Social Interdependence Theory

The conceptual framework guiding this study is social interdependence theory (Johnson & Johnson, 1989). Social interdependence exists when people's actions and outcomes are affected or influenced by the actions and decisions of others. Competition is considered to be negative interdependence in that individuals work to each other's detriment in attaining a goal, as opposed to focusing on their own benefit. Johnson and Johnson indicate for competition to exist, participants must perceive a scarcity of the reward for participating, and that social comparisons take place during participation. As indicated previously, norm-referenced grading leads to a situation where professors assign a limited, small number of A grades to students' academic performance, resulting in students competing with each other for grades, focusing their attention less on mastering the course material than on their peers' performance (Aviles, 2001; Bresee, 1976; Fines, 1997). In introductory STEM courses, this has been observed to lead to situations where students become selective about their study groups, refusing to help each other out to protect one's own chances of receiving that artificially scarce A grade (Gasiewski et al., 2012; Seymour & Hewitt, 1997).

In addition, goal theory provides insight into the individual factors that contribute to competitiveness in the classroom (Covington, 2000; Kaplan & Maehr, 2007). Specifically, achievement goals differ along the basis of people's motivation to pursue them, classified as either mastery or performance goals (Kaplan & Maehr, 2007). Performance goals are particularly motivated by competiveness, as they are defined as the demonstration of competence in relation to others' performance (Ames, 1992; Dweck, 1986; Nicholls, 1984). Performance goals can be further parsed out into performance-approach and performance-avoidance, reflecting the extent to which students are motivated by the opportunity to demonstrate high competence or avoid the appearance of low competence (Kaplan & Maehr, 2007). Factors such as a person's drive to achieve or the desire to attain a scarce reward lead to a person setting performance goals, motivated by their desire to compete. Criterion-referenced grading conditions tend to encourage students to set mastery goals, while norm-referenced conditions lead to both performance-approach and performance-avoidance behaviors (Ames, 1992), thereby boosting classroom competitiveness.

Methods

Data Source and Sample

To test the relationship between norm-referenced grading practices in introductory STEM courses and the degree to which students perceive the classroom environment to be competitive, this study analyzes data from a longitudinal dataset of 2,753 students in 79 introductory STEM courses at 15 colleges and universities across the United States. Students were surveyed twice during the spring of 2010; at the beginning of the course to gather background information and establish pre-test measures and then again end of their academic term as a post-test and to survey their classroom experiences.

In addition to student survey data, the faculty teaching these courses were also surveyed to better understand the practices employed in the classroom and their perceptions of the classroom environment. Finally, final course grades were provided by each institution's registrar's office and merged into the dataset as well. Registrars also provided final grade distributions for all students enrolled in the course regardless of whether the student had participated in the survey, and these data provided evidence as to the total proportion of A's awarded in each course. The overall longitudinal response rate was 42.1% and a weight was computed based on students' probability of responding to both surveys to adjust for nonresponse bias and allow generalizability of the post-survey results to the sample of students enrolled in the classrooms.

Measures

The dependent variable of interest to this study is a measure from the post-survey of students' perception of competition within their introductory STEM course. Students were asked how often they felt competition from other students in the class, and their responses ranged from "never" to "very often" on a five-point scale.

The main independent variable tested in this study was a classroom-level measure that reflects faculty use of norm-referenced grading. This variable was computed from the final course grades provided by the registrar to reflect the number of A's assigned at the end of the course as a proportion of the course's overall final grades. For those courses where faculty assigned final grades according to a normal curve, the proportion of final grades that are A grades is expected to be lower, reflecting the artificial scarcity of A grades in these courses.

From the pre-survey, student-level independent variables include a set of background characteristics, such as URM status, gender, mother's level of education, and whether the student is a premedical major. Final grades in high school biology and math, the extent to which students studied with their peers in high school, and whether they participated in a STEM-focused precollege program accounted for pre-college academic preparation. Measures of self-concept from the pre-survey were included, such as self-rated drive to achieve, to account for the influence of students' intrinsic motivations at the outset of the course.

From the post-survey, several classroom experiences were captured to control for their influence on perceptions of competition in the classroom, such as the reason for taking the course, the extent to which the student felt the professor encouraged collaboration, how often students worked in groups, and students' perceptions that final course grades reflected their effort. Co-curricular experiences were also tested to account for the extent to which students participated in STEM-related activities outside of class.

With the exception of final course grades, the remaining classroom-level independent variables were taken from the faculty survey. This set of variables included the extent to which the faculty member encouraged collaboration or working together, faculty perceptions of student readiness to take the course, and the extent to which the faculty member feels supported to improve teaching and learning in the course. These measures helped capture the other ways the faculty member may be intentionally or unintentionally contributing to perceptions of competitiveness in the classroom environment.

Analysis

First, as missing data may be a source of statistical variation, the expectation-maximization (EM) algorithm was run to analyze missing data and impute missing values where appropriate. EM combines maximum likelihood estimation with multiple regression imputation techniques in an iterative process to estimate model parameters. After missing data were accounted for, descriptive and bivariate statistics were run to understand the distributions of the data and examine the simple relationships between variables. Descriptive statistics for the sample are provided in Table 1.

The primary method of analysis employed for this study is hierarchical linear modeling (HLM), as the outcome variable was treated as continuous and the data are “nested” in nature; that is, student-level data is nested within classrooms (Raudenbush & Bryk, 2002). HLM provides an advantage over ordinary least-squares regression in that the technique partitions variance into that which occurs within groups, or classrooms in this study, and that which occurs between classrooms. Partitioning the variance reduces the probability of committing a type-I statistical error, or erroneously concluding the significance of a model parameter that may not be significant in the population. Additionally, HLM provides flexibility in examining cross-level interaction effects. The models in this study analyze the direct relationship between norm-referenced grading (as measured by the proportion of A’s assigned in each course) with perceived competition, and the models also examine how norm-reference grading moderates the relationship between the outcome and certain student-level variables (e.g., URM status, self-rated drive to achieve, and students’ sense that hard work was reflected in their grades).

Limitations

This study is also limited in several important ways that need to be taken into account when interpreting findings. First, while the study improves on prior literature by testing norm-referenced grading across a large number of STEM classrooms, 91 classes within 15 universities may not be representative of the population of introductory STEM courses across the nation. Our weighting procedure assures our confidence that the findings are generalizable to the population of students in these 91 classes, but caution should be exercised before generalizing these findings to the universe of introductory STEM courses in the United States.

Secondly, use of a single-item dependent variable means we have a greater risk for measurement error. Unfortunately, the student survey was not designed specifically to assess competition in courses, so no other items on the instrument tapped into students' sense of competitiveness in the classroom.

Finally, as this analysis relies heavily on survey data, our analysis could be limited by factors related to ability to recall experiences and social desirability among the study participants. For instance, students may have chosen responses that reflect them, or their classrooms, more positively. Although any analysis using survey data is susceptible to these biases, research has demonstrated very strong correlations between, for instance, students' self-reported grades and their actual grades (Baird, 1976), and in many cases these measures could not be practicably collected in any other manner (Astin, 1993). The inclusion of course grades from university registrars also helped us address this limitation.

Results

Descriptive statistics for all variables in the model are provided in Table 1. More than three in five (61%) respondents were female, and about 20% of students in the sample identified as an underrepresented racial minority student (Black, Latina/o, or Native American). Just more than 40% of the sample indicated they were pursuing a premed track. The average classroom in the sample had 27% of students earn an A.

Results from the full multilevel model are presented in Table 2. The intra-class correlation coefficient (ICC), which measures the proportion of variance in the outcome attributed to differences across classrooms, was greater than 10%, which justified the use of a multilevel model for this data. Only two background characteristics were significant in the final model. Women perceive greater competition among their peers in introductory STEM courses than men, and premed students perceive greater competition than students aspiring to other degrees. Both of these findings support prior literature (e.g., Gasiewski et al., 2012; Shapiro & Sax, 2011). However, underrepresented racial/ethnic minority students did not perceive competition in the classroom differently from their White/Asian peers, and this effect also did not vary based on the distribution of final grades in the course.

Students who had higher grades in high school biology perceive less competition in their introductory STEM courses than their peers who scored lower. An alternative interpretation is that students who did not perform as well in high school biology perceive more competition among their peers, possibly due to social comparisons made in the classroom. High school chemistry grades, the extent to which students studied with peers in high school math and science courses, and whether students participated in a pre-college research program did not relate to perceptions of competition.

As students' self-rated drive to achieve increases, they also perceive more competition in the classroom, congruent with goal theory (Kaplan & Maehr, 2007), and this relationship between drive to achieve and perceptions of competition did not vary based on the extent to which the professor used norm-referenced grading. Initiative-taking and ability to work collaboratively with peers did not relate to perceptions of competition in introductory STEM courses.

Several experiences in the course were significantly related to perceptions of competition in different ways. Interestingly, the extent to which students worked together in the class increased their perception of competitiveness among their peers—students who report more time spent studying with peers, more time in class spent on group work, and feeling collaboration among peers more frequently also perceive higher levels of competition. What is likely happening here is that students who perceive higher levels of competition are more likely to engage in these collaborative activities, which are likely strategies employed by students to manage the competitive atmosphere. Students who are in an introductory STEM course to fulfill a professional school admissions requirement also feel higher levels of competition; many of these students may be premed students taking the course for medical school admissions requirements, but given the inclusion of premed aspirations in the model, this finding suggests this effect applies more broadly.

Students' self-evaluations of their performance in the course also affect their perceptions of competitiveness. Those students more likely to consider dropping the course perceive higher levels of competition, as do those who feel well-prepared for the next level of study in the subject area of the introductory STEM course. The former finding builds on prior literature arguing that competitiveness in STEM contributes to attrition from STEM (Palmer et al., 2011; Seymour & Hewitt, 1997; Shapiro & Sax, 2011), whereas the latter finding indicates students who achieved in the course may recognize they had to compete as part of their academic performance. Most interesting given this study's focus on norm-referenced grading is the finding regarding students who feel their grades reflect their hard work. Those less likely to agree that their grades reflect their effort perceive more competitiveness in the classroom. A significant cross-level effect shows this relationship is moderated by the proportion of A's within the distribution of final grades for the course. Figure 1 illustrates this cross-level effect by graphing the relationship between agreement that grades reflected effort and competitiveness for courses at the first quartile (14%), median (28%), and third quartile (40%) of the sample in terms of A's as a proportion of final grades. As the proportion of A's increases, the relationship between students' sense of competition and their overall agreement that their hard work is reflected in their grades goes from being negative to being positive. Differences in perceptions of competitiveness among peers are greatest for students who disagree that their hard work is reflected in their grades. Those students who perceive their grades do not reflect their effort *and* are enrolled in courses where A's are scarce sense the greatest competition. As students across the board begin to think their hard work is reflected in their grades, differences in perceptions of competition across courses in norm-referenced grading become less pronounced. The negative relationship between perceptions of grading fairness and perceptions of competition in the classroom are most characteristic of courses where fewer A's were assigned as a proportion of all final grades, our measure of norm-referenced grading. Grading practices matter most with regard to perceived competition when students do not feel that their hard work is being reflected in their course grades.

At the classroom level, the main variable of interest was our measure of the extent to which professors used norm-referenced grading criteria, or "curved" final grades. Students in classrooms where A's comprise a smaller proportion of final grades perceive higher levels of competition among their peers. This finding supports previous assertions that establishing an artificial scarcity of A level grades leads to classroom competitiveness which could be detrimental to the students in the course (Aviles, 2001; Bresee, 1976). However, the extent to which the professor structures the course to encourage collaboration reduces students' perceptions of competitiveness. Also, the professor's preconceptions about the student talent also affects classroom competitiveness—professors who feel unqualified students are enrolled in the class may ascribe to a “weeding out” philosophy that drives up classroom competitiveness while professors who feel all students can achieve in the course with sufficient effort encourages a healthier sense of competition by encouraging individual achievement. This latter teaching and learning philosophy is best described as a “talent development” perspective (Astin, 1993).

Outside the classroom, students who participate in pre-professional or departmental clubs also perceive higher competition in the classroom, likely driven by an increase in social comparison inherent to greater levels of peer interaction. On the other hand, participation in academic support programs or STEM research programs are not related to perceptions of competition in the introductory STEM classroom.

Discussion

The purpose of this study was to test the relationship between norm-referenced grading in introductory STEM courses and students’ perception of competition in the classroom, controlling for other student- and classroom-level factors. Previous literature has indicated that “grading on a curve,” as it is colloquially called, leads to competition among students in the classroom due to the artificial scarcity of A-level grades (Aviles, 2001; Bresee, 1976; Wall, 1987; Zimmerman, 1981). The competition that results from norm-referenced grading can be detrimental for many students as the social comparisons they make in the process can distract them from mastering the course material and affect student relationships negatively (Johnson & Johnson, 1989).

Our findings show that this relationship persists in introductory STEM courses, which suggests grading on a curve is one source of the competitive atmosphere found in other studies of the introductory STEM course environment. If competitiveness within the introductory STEM classroom diverts students’ attention from mastering course material, students may lose some of the basic conceptual “building blocks” needed to succeed in advanced study. In other words, norm-referenced grading in the introductory STEM classroom is one likely contributor to attrition along STEM pathways.

Fortunately, it appears one method available to faculty to “dial down” some of the competitiveness in the classroom is to structure the course to encourage collaboration. However, our student-level findings contradicted this to some extent. Students who felt the professor encouraged more collaboration, who spent more time studying with their peers, and who reported spending more class time on group work also reported higher levels of competitiveness. First, it’s likely that students employ collaborative strategies to deal with a competitive environment, although faculty will want to pay attention to how these collaborations form to ensure all students benefit from these strategies. Second, prior research has shown that competition and collaboration can function together in ways that benefit students’ learning processes. Third, previous research has identified a “premed phenomenon” in introductory STEM courses where premed students may contribute to a negative dynamic in the classroom (Gasiewski et al., 2012). More than 40% of students in our sample identified as premed, and the dynamics of having premeds involved in group work and other collaborative activities may contribute to a collective sense of competition in the classroom. Although competing for grades may work to students’ detriment, structuring the course with activities that allow small groups to compete in terms of academic performance may enhance learning (Pate, Watson, & Johnson, 1998; Slavin, 1977).

The professor’s attitude toward the nature of student ability also appears to be related to the perceived level of competitiveness in introductory STEM classrooms. One of the strongest classroom-level predictors of perceived competitiveness is the extent to which faculty agree that unqualified students are enrolled in the course. A common philosophy in STEM education driving the widespread use of teacher-centered pedagogy aimed at “weeding out” students is that not all students who seek a STEM degree possess the innate ability to excel in STEM (Baldwin, 2009; Bok, 2006). Norm-referenced grading is one method faculty utilize to identify who they consider are the most talented STEM students and assist them in advancing, while pushing other students out of STEM into other fields. In spite of this, competitiveness also seems to be present in the classrooms of faculty who believe all students can excel in STEM, with enough effort, representing an alternative “talent development” philosophy. Again, given the different ways competitiveness can affect learning (Johnson & Johnson, 1989), these faculty may be encouraging competitiveness in productive ways. Future research on introductory STEM education should investigate these experiences further to understand how competition is being used pedagogically in both productive and detrimental ways.

Hand-in-hand with findings regarding faculty attitudes are results connecting students’ perceptions of their own ability and performance in introductory STEM courses. Students who feel like dropping the course during the academic term perceive higher levels of competitiveness, which is possibly contributing to their desire to drop the course. Students who feel prepared for the next level of study also perceive higher levels of competitiveness, but this may be similar to the finding about students’ drive to achieve and indicate students who feel prepared worked hard, thus succeeding in the “competition” among students in the course. One interesting finding related to students’ perception of their ability is how the relationship between students’ perception that their grades reflect their work, or that their grades were assigned fairly, and perceptions of competition was moderated by our measure of grading on a curve. Students who perceive their grades to be less fair—that their grades did not reflect their effort—perceive greater competition in the classroom, and this relationship is most characteristic of class environments where fewer A's were assigned at the end of the term. As prior literature has suggested norm-referenced grading likely reflects other qualities than solely academic performance (Johnson & Johnson, 1989; Kulick & Wright, 2008), students may be more likely to perceive curved grading as unfair and negatively respond to the competitive situation created through the artificial scarcity of A grades.

Implications and Conclusion

One primary implication of this study is that faculty play an important role with respect to students' perceptions of competitiveness in an introductory STEM classroom. The attitudes of faculty toward teaching and learning, as well as the way these courses are structured, can all influence how students perceive the environment. Competitiveness in and of itself is not necessarily harmful, but faculty who wish to use competition as a pedagogical tool should pay attention to the conditions under which classroom competition is structured, such as how well-matched students may be academically or the ways students culturally respond to competition (Johnson & Johnson, 1989; Pate et al., 1998). The racial, gender, and social class inequities in pre-college academic preparation point to an important reason as to why classroom competitiveness, and especially norm-referenced grading, contribute to the attrition of women and underrepresented racial and ethnic minorities from STEM fields.

Instead of using curved grading to assess academic performance, Pate et al. (1998) recommend faculty consider activities such as small-group competitions to structure both collaboration and competition into the classroom, with the caveat that groups be allowed sufficient time for processing information. Cooperative learning structures facilitate social connectedness (Slavin, 1977), which in turn leads to a greater sense of science identity (Carlone & Johnson, 2007). Small groups composed of groups of students of differing academic ability can also encourage peer-facilitated learning within each group and improve how academically matched each group is in terms of the competitive activity (Michaels, 1978; Pate et al., 1998).

Even though high proportions of college freshmen are entering college with STEM degree aspirations (Eagan et al., 2013), only about 40% of those students are expected to complete a STEM degree (President's Council of Advisors on Science and Technology, 2012). Introductory STEM courses have been indicted in particular due to extensive use of lecturing and an environment of competitiveness stoked by norm-referenced grading (Gasiewski et al., 2012). This study found that norm-referenced grading does contribute to perceptions of competitiveness in the introductory STEM classroom, but faculty can play an important role in “dialing down” this competitive environment. In addition, faculty could structure competition into the classroom in other ways that promote both academic performance and the engagement of students who already possess a deeply ingrained interest in STEM. A focus on the development of STEM talent, rather than “weeding” out underperformers, will cultivate the STEM workforce needed to maintain our nation’s economic competitiveness.

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Table 1.

Descriptive Statistics for All Variables Included in Model

	Mean	St. Dev.	Min	Max
Student-level variables				
Dependent variable				
Frequency: Felt competition among students in this course	3.05	1.24	1	5
Background Characteristics				
Gender: female	1.61	0.49	1	2
Mother's level of education	4.37	1.94	1	9
URM student	0.2	0.4	0	1
Premed student	0.41	0.49	0	1
Pre-college academic preparation				
HS Biology Grade	3.73	0.5	1	4
HS Chemistry Grade	3.66	0.56	1	4
Studied with other students for HS math or science courses	2.02	0.66	1	3
Precollege research-focused program	1.05	0.22	1	2
Self-concept				
Self-rated ability to work collaboratively with others	3.84	0.83	1	5
Self-rated drive to achieve	3.98	0.82	1	5
Self-rated initiative-taking	3.68	0.84	1	5
Course experiences				
Course fulfills requirement for professional school admissions	1.78	0.42	1	2
Agreement: professor encouraged collaboration among students	3.04	0.81	1	4
HPW: Studying with other students for this course	2.34	1.04	1	4
Group work used in classroom	1.5	0.5	1	2
Frequency: Felt collaboration among students in my course	2.95	1.12	1	5
Agreement: I felt my hard work was reflected in my grades	2.69	0.84	1	4
Agreement: I considered dropping this course during the academic term	1.96	1.02	1	4
Agreement: I feel well-prepared for the next level of study in the subject area	2.84	0.74	1	4
Co-curricular experiences				
Participated in a pre-professional or departmental club	1.35	0.48	1	2
Participated in an academic support program	1.37	0.48	1	2
Participated in a STEM research program	1.2	0.4	1	2
Classroom-level variables				
General educational goal: Encourage collaboration among students	3.42	0.67	2	4
Course structure: Work effectively with others	2.01	0.67	1	3
Agreement: In my classroom, there is no such thing as a question that is too elementary	3.59	0.73	1	4
Agreement: Unqualified students are enrolled in my course	2.89	0.92	1	4

Agreement: With sufficient time and hard work, all students can learn this material	3.33	0.8	1	4
Agreement: All students have the potential to excel in my class	3.14	0.86	1	4
Agreement: I try to dispel perceptions of competition	3.15	0.83	1	4
Agreement: This institution provides little incentive for me to improve student learning in my classes	2.23	0.83	1	4
A's as proportion of final class grades	0.27	0.17	0	0.67

Note. Among the classroom-level variables, the number of A's as a proportion of final grades was computed from data provided by campus registrars on all students in each course. The remaining classroom-level variables are measures of faculty perceptions and views.

Table 2

Final Hierarchical Linear Model Predicting Perception of Competition in the Classroom

	r	*p*	B	S.E.	*p*
Classroom-level variables					
Intercept			1.619	0.197	***
General educational goal: Encourage collaboration among students	0.035		-0.217	0.069	**
Course structure: Work effectively with others	0.168	***	0.144	0.074	
Agreement: In my classroom, there is no such thing as a question that is too elementary	0.000		-0.036	0.055	
Agreement: Unqualified students are enrolled in my course	0.176	***	0.21	0.054	***
Agreement: With sufficient time and hard work, all students can learn this material	0.037	*	0.155	0.06	*
Agreement: All students have the potential to excel in my class	0.042	*	-0.05	0.05	
Agreement: I try to dispel perceptions of competition	0.046	*	0.007	0.066	
Agreement: This institution provides little incentive for me to improve student learning in my classes	0.114	***	0.002	0.045	
A's as proportion of final class grades	-0.136	***	-0.777	0.314	*
Student-level variables					
Background characteristics					
Gender: female	0.090	***	0.13	0.053	*
Mother's level of education	-0.039	*	-0.025	0.013	
URM student	0.016		-0.073	0.081	
Cross-level: A's as proportion of final class grades			-0.475	0.552	
Premed student	0.112	***	0.08	0.038	*
Pre-college academic preparation					
HS Biology Grade	0.042	*	-0.111	0.053	*
HS Chemistry Grade	0.062	***	0.027	0.042	
Studied with other students for HS math or science courses	0.050	**	-0.024	0.034	
Precollege research-focused program	0.041	*	0.074	0.094	
Self-concept					
Self-rated ability to work collaboratively with others	0.066	***	0.012	0.027	

Self-rated drive to achieve	0.068	***	0.105	0.035	**
Cross-level: A's as proportion of final class grades			0.156	0.227	
Self-rated initiative-taking	0.046	**	-0.014	0.031	
Course experiences					
Course fulfills requirement for professional school admissions	0.166	***	0.234	0.063	***
Agreement: professor encouraged collaboration among students	0.084	***	0.045	0.032	
HPW: Studying with other students for this course	0.223	***	0.095	0.035	**
Group work used in classroom	0.117	***	0.134	0.049	**
Frequency: Felt collaboration among students in my course	0.286	***	0.191	0.026	***
Agreement: I felt my hard work was reflected in my grades	-0.059	***	-0.075	0.037	*
Cross-level: A's as proportion of final class grades			0.633	0.269	*
Agreement: I considered dropping this course during the academic term	0.138	***	0.148	0.02	***
Agreement: I feel well-prepared for the next level of study in the subject area	0.055	**	0.095	0.035	**
Co-curricular experiences					
Participated in a pre-professional or departmental club	0.101	***	0.164	0.058	**
Participated in an academic support program	0.149	***	0.081	0.045	
Participated in a STEM research program	0.051	**	-0.097	0.055	

Note: * $p<0.05$; ** $p<0.01$; *** $p<0.001$. Among the classroom-level variables, the number of A's as a proportion of final grades was computed from data provided by campus registrars on all students in each course. The remaining classroom-level variables are measures of faculty perceptions and views.

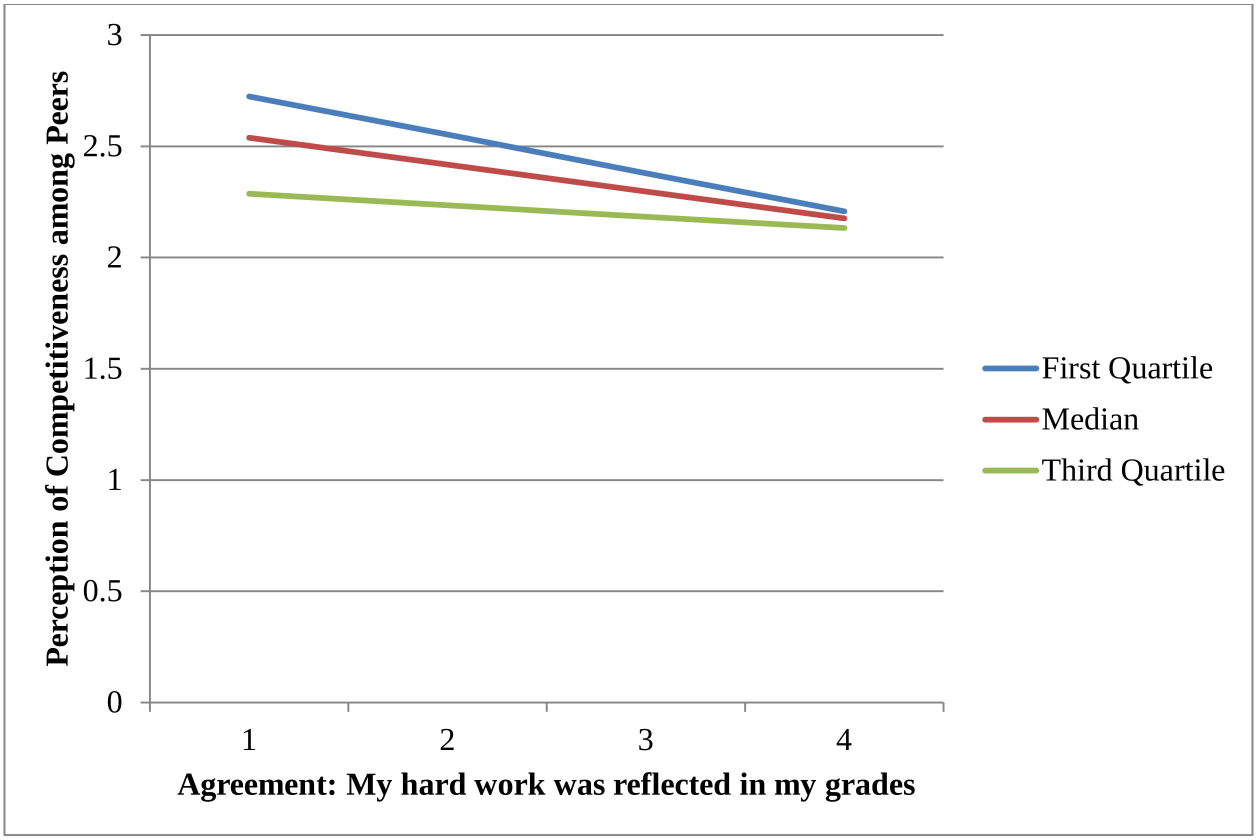

Figure 1. Illustration of cross-level effect between grading on a curve and agreement that grades reflected effort on perceptions of competition. Each line represents a class whose proportion of A's among final grades falls at the first (14%), second (28%), and third (40%) quartiles of the overall sample. The first quartile is most reflective of a norm-referenced class if final grades were normally distributed.

Appendix

Variables and Coding

Variable	Scale
Student-level variables	
Dependent variable	
Frequency: Felt competition among students in my course	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
Background Characteristics	
Gender	1 Male; 2 Female
Mother's level of education	1 Junior high/Middle school or less; 2 Some high school; 3 High school graduate; 4 Postsecondary school other than college; 5 Some college; 6 College degree; 7 Some graduate school; 8 Graduate degree
URM student	1 No; 2 Yes
Premed student	1 No; 2 Yes
Pre-college academic preparation	
HS Biology Grade	1 F…5 A
HS Chemistry Grade	1 F…5 A
Frequency: Studied with other students for HS math or science courses	1 Never; 2 Occasionally; 3 Frequently
Precollege research-focused program	1 No; 2 Yes
Self-concept	
Self-rated ability to work collaboratively with others	1 Lowest 10%; 2 Below average; 3 Average; 4 Above average; 5 Highest 10%
Self-rated drive to achieve	1 Lowest 10%; 2 Below average; 3 Average; 4 Above average; 5 Highest 10%
Self-rated initiative-taking	1 Lowest 10%; 2 Below average; 3 Average; 4 Above average; 5 Highest 10%
Course experiences	
Course fulfills requirement for professional school admissions	1 No; 2 Yes
Agreement: professor encouraged collaboration among students	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
HPW: Studying with other students for this course	1 0; 2 1 or less; 3 2-3; 4 4 or more
Group work used in classroom	1 No; 2 Yes
Frequency: Felt collaboration among students in my course	1 Never; 2 Seldom; 3 Sometimes; 4 Often; 5 Very often
Agreement: I felt my hard work was reflected in my grades	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Agreement: I considered dropping this course during the academic term	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree

Agreement: I feel well-prepared for the next level of study in the subject area	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
<u>Co-curricular experiences</u>	
Participated in a pre-professional or departmental club	1 No; 2 Yes
Participated in an academic support program	1 No; 2 Yes
Participated in a STEM research program	1 No; 2 Yes
Classroom-level variables	
General educational goal: Encourage collaboration among students	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Course structure: Work effectively with others	1 Not at all; 2 To some extent; 3 To a great extent
Agreement: In my classroom, there is no such thing as a question that is too elementary	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Agreement: Unqualified students are enrolled in my course	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Agreement: With sufficient time and hard work, all students can learn this material	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Agreement: All students have the potential to excel in my class	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Agreement: I try to dispel perceptions of competition	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
Agreement: This institution provides little incentive for me to improve student learning in my classes	1 Strongly disagree; 2 Disagree; 3 Agree; 4 Strongly agree
A's as proportion of final class grades	Computed from distribution of grades for each course; number of A grades divided by total number of final grades