How should you participate? Let me count the ways

Rachel Elizabeth Keller — Virginia Tech
Karen Zwanch — Virginia Tech
Steven DeShong — Virginia Tech

Retention of students in STEM majors is an issue of national stability because government projections indicate our nation to need one million additional STEM majors by 2022 (PCAST, 2012); thusly, the current trends in attrition are alarming. Students leave STEM for various reasons, but poor experiences in Calculus I seem to be a significant contributing factor for many switchers, especially female students. Using data situated within a larger study (Characteristics of Successful Programs in College Calculus), the present report looks specifically at student participation and its influence on Calculus I success. Results indicate that while participation is significantly correlated with success, this effect is not uniformly distributed across types of participation or gender groups. Interestingly, overall success rates were equal, but gender differences were noted in frequency of participatory behaviors and distribution of grades; specifically, males (who reported more A grades) preferred in-class participation and females preferred out-of-class participatory activities.

Key words: Calculus, Student Success, Participation, Gender

Calculus serves as an introductory course for college freshmen everywhere, but especially for those intending to enter into science, technology, engineering, and mathematics (STEM) majors; therefore, of critical importance is student success in Calculus I – without which continuation in a STEM major is impossible. The retention of students in STEM majors has been identified by the President's Council of Advisors on Science and Technology (PCAST) as a key contributor to the ability of the United States to remain a leader in the STEM fields (2012); PCAST specifically advises that over the next decade, in order to retain our dominance, the nation will require an additional one million STEM majors beyond those currently projected. With calculus acting as a gatekeeper to a student's ability to successfully complete an undergraduate STEM degree, post-secondary educators and students alike must develop a better understanding of what factors may contribute to success in calculus. This work aims to serve that goal by exploring the relationship between student participation and success in Calculus I. In this report, we investigate the following research questions: (1) Does there exist a positive correlation between student engagement in participatory behaviors and student success in Calculus I? (2) If so, can particular behaviors be identified as critically influential and is this association consistent for both genders?

Theoretical Framework and Literature

Research (e.g., Rasmussen & Ellis, 2013; Seymour & Hewitt, 1997) indicates that many students are in fact leaving STEM majors as a result of poor experiences in calculus, and that instructional factors within the calculus classroom contribute to this departure. The historically predominant reliance upon lecture as the conduit of calculus material appears to be a contributing factor in students' discontent with their experiences in STEM majors. Instructors of calculus need to carefully reconsider their pedagogical decisions if they wish to combat the disengagement that leads to attrition; however, it is important to note that each student's achievement is ultimately the result of her own actions within the course; i.e. participation, and thus students must share in the responsibility for their success. While we concur with previous research (e.g., Rasmussen & Ellis, 2013; Johnson, Ellis, & Rasmussen, in press) that indicates student retention and success is influenced by instructor actions, we choose to neglect that variable for the purposes of this study and opt instead to focus our analysis on students' investments in their learning

We believe that a student's interactions – with the material, with the instructor, with her classmates – are of critical importance in determining success and therefore we frame our research within the theory of social constructivism. Social constructivism emphasizes "the claim that higher mental functions in the individual have their origins in social life" (Wertsch, 1990). Thus, in order for students to learn and achieve academically, they must engage socially with others. This engagement can occur in many forms. Engagement with the instructor, for example, occurs when the student contributes to class discussion, corresponds with the instructor regarding course content, or completes assignments designed by the instructor.

The theory of social constructivism is well represented in the educational literature. An example of such research in support of social constructivism is Tinto's (1997) work, which indicates that "the more students invest in learning activities, that is, the higher their level of effort, the more students learn" (p. 600). The implication is that in order to be academically successful, students must first engage in the learning process. This finding is neither unique nor modern; put bluntly, participation increases student learning (e.g., Johnson, Johnson, & Smith, 1991; 1998; Lyman, 1981).

Student participation manifests itself in a variety of ways, both inside the classroom and outside of it, but there has been research (Lucas 2009, Rasmussen & Ellis, 2013) indicating that homework completion and participation in classroom discussion are of critical importance. In addition to considering different types of participation, it is important to consider that participation patterns do not indiscriminately influence student success across demographic groupings. Tinto (1997) determined that students from various minority groups necessarily seek inclusion in the learning community as their main goal prior to seeking academic success. This is consistent with cognitive evaluation theory, which indicates people must feel competent, related, and autonomous prior to engaging academically (Deci & Ryan, 2000). Tinto's contribution to this theory is that different individuals require different levels of satisfaction of competence, relatedness, and autonomy. Tinto does not further elaborate on which minority groups are more likely to seek out relatedness prior to competence, or any other combination of factors, but his findings are important in understanding that not all students will participate in, gain interest from, or learn from the same activities in an equal manner.

One particular minority group of interest in the STEM community is women. Karp and Yoels (1975) identified differences in the participation of male and female students in the college classroom, and moreover, that these differences are influenced by the instructor's gender. Specifically, female students participate more in classes led by female instructors (42.4% of interactions compared to 24.6% in male led classes). Conversely, male students are responsible for 75.4% of interactions in classes led by males as compared to 57.8% of interactions under female instructors. These differences must be seen as a function of both the student's choice to participate and the instructor's choice to prompt participation. Karp and Yoels' (1975) findings are mirrored in more recent literature. Sadker and Sadker (1995; Sadker, Sadker, & Zittleman, 2009) have similarly determined that both the quantity and quality of teacher-student interactions with male and female students are different. Teachers tend to ask more questions of male students, allow more wait time for male students, and ask more follow-up questions. Female students, on the other hand, are asked lower level questions and provided less constructive feedback and encouragement than male students in the mathematics classroom (Sadker & Sadker, 1995). The persistence of these gender differences in the participation and inclusion of female students over time in the mathematics classroom are troubling – if the circumstances are such that female students are not provided an equal opportunity to participate in classroom discussion, then their learning is being affected before they can even make the choice whether or not to participate.

Perhaps not coincidentally, gender differences are also being noted in STEM retention in addition to participation. PCAST (2012) specifically notes that the retention and success of women in STEM majors is critical, as they represent a majority of college students but a minority of STEM graduates. Despite this need for female STEM graduates, significantly more women switch out of STEM majors (20%) than do males (11%) (Rasmussen & Ellis, 2013).

Data Sources and Methods of Analysis

The present study is situated within the larger research project entitled Characteristics of Successful Programs in College Calculus (CSPCC) that was designed to gain a nationwide overview of the college calculus programs as well as to identify more successful programs based on a combination of factors including: grades, affective variables (e.g., interest, enjoyment, and confidence), and intention to continue on to Calculus II. The CSPCC project[1] used a stratified random sample of colleges and universities in the U.S. based on the highest degree granted at each university (Associate's, Bachelor's, Master's, or Ph.D.). The first phase was comprised of a total of six surveys—three for the students (one at the beginning of Calculus I, one at the end of Calculus I, and one a year later to the students that gave their email addresses), two for the instructors (one at the beginning of Calculus I and one at the end of Calculus I), and one survey given to the Calculus course coordinator. For the purposes of this study, we limited our dataset to those student respondents who had completed the end of semester survey.

In order to answer our research questions, it was necessary to operationally define both success and participation. Previous research had suggested the use of the rates of *persisters* and *switchers* as a proxy for success; however, we feel that measure is more appropriate as an indication of the success of a university's academic courses and STEM programs overall and not the best measure of individual student success. We chose instead to define success in terms of reported/expected[2] course grade (A-F). As educators, we acknowledge that success cannot and should not be measured only in terms of final grades; however, we were both limited by our use of a pre-existing data set and also constrained by our desire not to duplicate research already performed in this area. We recorded the reported/expected letter grade for each student and also coded each student as 'successful' (A, B, C) or 'not successful' (D, F).

For consideration in the initial regression analysis, we selected eight items from the Student End survey that we felt captured what we considered to be instances of participatory behavior: talking in class, preparing for class, reinforcing content, seeking help. These questions (see Figure 1) reflect activities for which the ability to participate was provided, placing the choice to participate in the hands of the student. From the perspective of social constructivism, participation is the vehicle of student learning; thus, these items were selected to demonstrate the student's perception of her engagement.

[1] For further details, see the *MAA Notes* volume *Insights and Recommendations from the MAA National Study of College Calculus* (Bressoud, Mesa, & Rasmussen, 2015) or visit the website at www.maa.org/cspcc).
[2] On the post-survey students were asked: *What grade do you expect (or did you receive) in this course?* We are unable to determine if this question was asked before or after students received their final grades.

From the eight questions, we collapsed this into seven independent variables: *ContributedtoDiscussion, AskedQuestions, ReadText, OfficeHours, UsedTutor (*composite variable computed by summing frequency of tutor and online tutoring), *CompletedHW,* and *MetToStudy*. Depending on the analysis being conducted, the dependent variable was measured either by *Grade* (recoded from 0.0 to 4.0 to reflect the usual grading scale) or by *Success* (coded 1 for A, B, C grades and 0 for D, F grades). A combination of ordinary least-squares and binary logistic regression models were run in order to address the first research question; i.e. to determine the ability of our selected participatory behaviors to predict academic success. Subsequent analyses involved comparing the behavior of specific groups (successful versus unsuccessful, males versus females) on those behaviors deemed statistically significant.

33. During class:

	Never	Some class sessions	About half the class sessions	Most class sessions	Every class session
I contributed to class discussions.	○	○	○	○	○
I asked questions.	○	○	○	○	○

34. How often did you do the following?

	Never	Once a month	A few times a month	Once a week	More than once a week
Read the textbook prior to coming to class.	○	○	○	○	○
Visit your instructor's office hours.	○	○	○	○	○
Use online tutoring.	○	○	○	○	○
Visit a tutor to assist with this course.	○	○	○	○	○

35. Check the box that describes your level of agreement with the following statements.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I completed all my assigned homework.	○	○	○	○	○	○

36. Did you meet with other students to study or complete homework outside of class?

○ Yes ○ No

Figure 1. Items Selected from the CSPCC Student-End Survey

Results and Discussion

Primary Analysis

The logistic regression model based upon the students' self-reported levels of participation, despite having a pseudo R-square value (Nagelkerke = .146) lower than what would have been preferred, had predictive accuracy of 95.59% in projecting success. Using a forward stepwise Wald procedure, the resulting model identified four of the seven initial independent variables as being significant: *ContributedtoDiscussion* (β = .482; $p < .001$), *CompletedHW* (β = .448; $p < .001$), *UsedTutor* (β = -.290; $p < .001$), and *ReadText* (β = -.168; $p = .002$). Interpreting this in terms of odds ratios, all other factors being equal, for a one-unit increase in frequency of homework completion (or contributions to discussion), a student would be 1.565 (or 1.619 respectively) times more likely to be categorized as successful by the model.

Interesting to note is that not all of these variables were positively associated with success as one might have assumed. Both *UsedTutor* and *ReadText* were negatively correlated with success; i.e. increasing the frequency of these behaviors decreases a student's odds of being labeled successful. This must be interpreted with caution because it would be tempting to think that reading the text or working with a tutor decreases one's odds of being successful; however, this is almost certainly not the case. All the model is telling us is that of those students who were unsuccessful, they were reading the text and using tutors at higher frequencies than those who were successful. Further analysis would be needed to identify the other factors at play that contributed to these variables having a negative correlation with success. Conceivably, the students who are successful do not read the text because they feel it unnecessary as they already have a firm grasp of the material. With regard to the use of a tutor, perhaps it is the timing of the help-seeking behavior that is confounding the situation. It is possible that failing students are waiting until they have already established themselves as unsuccessful before seeking tutoring help. This is perhaps less a reflection of the tutor's effectiveness and more a proxy for traits of unsuccessful students.

According to social constructivism, learning occurs through engagement in social activity; therefore, since all of the previously identified participatory behaviors are social activities, we would expect that they all positively influence success. That being said, because mathematics is constructed individually and understood uniquely, all participants in the social activity affect the quality of the mathematics being constructed. In this report, the two most significant and positively correlated variables contributing to student success are representations of high quality interactions with the course instructor. As Tinto (1997) indicated, high quality engagement is paramount to student learning. Therefore, we hypothesize that *ContributedtoDiscussion* and *CompletedHW* are both the most significant and positively correlated with success because they represent high quality, structured social engagement with the instructor who designs and assesses their learning. Class discussions are likely the result of the instructor's lesson plans, and homework directs the students toward the instructor's learning goals. As students participate in planned discussions led by the instructor and complete homework assignments designed to help the students review or learn new material, the student is actively engaging with the instructor and constructing mathematics in a manner which is consistent with that which will be assessed.

Previously in this article, we discussed two variables which were not found to positively correlate with success in Calculus I: *ReadText* and *UsedTutor*. Through the lens of social constructivism, we offer an additional theory as to why these are negatively associated with success in the current model. While each of these variables does represent a social interaction on the student's part, it is one in which the instructor is absent. Therefore, we hypothesize that the quality of these interactions is not likely to be as high as those student-teacher interactions previously described. When a student reads a textbook or engages with a tutor, they are interacting with an expert; however, the mathematics being constructed is not necessarily in alignment with that intended by the instructor.

The three variables remaining – *AskedQuestions*, *OfficeHours*, and *MetToStudy* – were either insignificantly correlated (logistic model) or negatively correlated (OLS model) with success in Calculus I. This is interesting because these certainly represent social interactions, and moreover, two of the three involve both the students and the instructor, so by our previous explanation it seems as though they should correlate to student success. The distinction is that asking questions and attending office hours are unplanned, unstructured interactions and therefore are likely lack the careful consideration and depth of a high quality social interaction. We hypothesize that the quality of these interactions is not as high as the pre-planned classroom discussions and carefully constructed homework assignments. Furthermore, the survey questions as written do not capture the level of sophistication and purpose of the questions being asked. If the nature of the questions is that of high-level cognitive demand (i.e. beyond-the-scope) and helps to advance the mathematical agenda, then we argue that this should be positively correlated with successful students; however, if the questions being asked are low-level clarification questions (e.g. What does that symbol mean? Why are we using that formula? etc.) or worse yet, logistical questions (e.g. Will this be on the exam? Do we have to memorize that? Does my calculator have a button for that?), then it seems plausible that these are being asked by students more likely to be unsuccessful and therefore would rightly be negatively correlated.

In the case of students meeting to study with other students, the quality of the social engagement is even more questionable, as the group of students working together may or may not have mastered the mathematics which they intend to learn. These variables certainly represent social activities. The learning which takes place during these participatory activities, however, is not necessarily high quality, as it was not designed by the same person who will assess the students' learning.

Secondary Analysis

In addition to determining a correlation between participation and success in Calculus I, we also sought to determine whether the distributions across categories of these positively correlated participatory behaviors were similar when comparing successful versus unsuccessful students and when comparing males to females (see Figure 2). Unsurprisingly, results from independent-samples Kruskal-Wallis tests reveal that the distribution across categories of *CompletedHW* was not the same for successful and unsuccessful students ($H(1)= 79.278$, $p < .001$) and the distribution across categories of *ContributedtoDiscussion* was not the same for successful and unsuccessful students ($H(1) = 30.941$, $p < .001$) either. Successful students, on average, contribute to discussion *more* frequently (2.65 as compared to 2.16) and complete homework *more* frequently (4.70 as compared to 3.73) than unsuccessful students.

Looking at gender differences, results from independent-samples Kruskal-Wallis tests reveal that the distribution across categories of *CompletedHW* was not the same for males and females ($H(1) = 58.6$, $p < .001$) and the distribution across categories of *ContributedtoDiscussion* was not the same for males and females ($H(1) = 42.94$, $p < .001$) either. Male students, on average, contribute to discussion *more* frequently (2.74 as compared to 2.48) and complete homework *less* frequently (4.51 as compared to 4.90) than do female students.

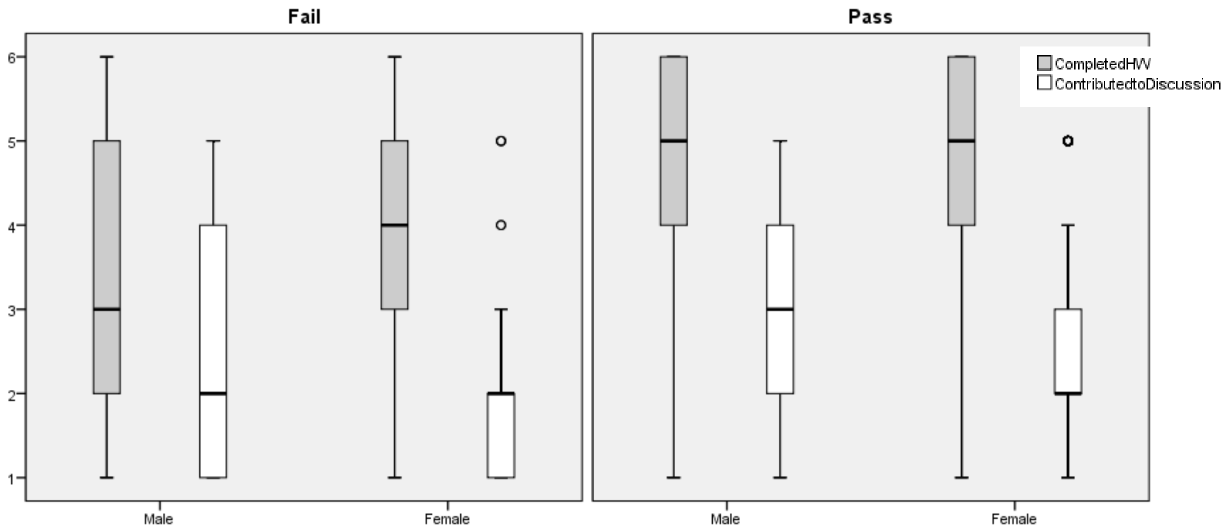

Figure 2. Patterns of Participatory Behavior by Gender and Success Category

These results are consistent with previous research. Researchers (Karp & Yoels, 1975; Sadker & Sadker, 1995) have previously determined that male students are more likely to be called on during class and to have higher quality in-class interactions with their instructors. This finding also coincides with the determination that different groups of students benefit from and engage in social activities in varying capacities as they are ready to do so (Tinto, 1997); it moreover extends Tinto's results in specifying the participation of males and females to be significantly different.

Implications and Future Directions

The results of this report demonstrate that successful students' participatory behavior is both qualitatively and quantitatively different than unsuccessful students. Coupled with the fact that the same can be said about the differences between male and female students, does that not raise the logical follow-up question: Do males and females succeed at different rates? An independent-samples t-test establishes no significant difference ($t(3094.252) = 1.583$, $p = .114$) between the percentage of successful students by gender; however, an independent-samples Kruskal-Wallis test does provide evidence ($H(1) = 5.773$, $p = .016$) that distribution across reported/expected grades is not the same for males and females. In other words, males and females are equally likely to have passed or failed the course, but for those who passed, the males are disproportionately likely to have reported earning (or expected to earn), an A ($z = 2.46$, $p = .014$).

It is important to note that while students are likely to accurately predict success or failure in a course, it is unlikely that they are equally adept at predicting final grades. Since the data in this study was based on *reported* grades that may or may not have actually matched the final grade received, the interpretation of the distributional analysis and subsequent conclusions must be interpreted with caution. Future research warrants attempting to replicate these findings in the cases for which final grades can be verified.

When choosing survey items for consideration in this research, the decision was based on participatory behaviors that we felt the student had the ability to self-select; however, based on the research of Sadker and Sadker (1995; Sadker, Sadker, & Zittleman, 2009), it seems that female students are not given equal opportunity to ask questions or contribute to class discussions and thus these participatory behaviors cease to be ones of personal choice. We conjecture that each student requires a certain minimal level of attention for social constructivism and since females don't receive attention, approval, or reinforcement during class time at levels comparable to their male counterparts, they seek to make up for it on their own time. This would explain the fact that female students complete homework and enlist the use of a tutor more frequently than male students. While this out-of-class participation leads to/contributes to success rates for females equivalent to those of males, it does not appear to translate into comparable levels of high performance (i.e. A grades), suggesting that in-class participation is somehow superior to out-of-class participation in terms of measuring success by academic achievement. This hypothesis, along with the implications for STEM attrition, warrants further research. Although both an A-student and a C-student might be equally likely to continue from Calculus I to Calculus II, can the same be said about the ability to complete a STEM degree or even persist in the major beyond Calculus II? It is our opinion that students who earn borderline grades in Calculus I are disproportionately likely to ultimately depart from their current major and possibly the STEM field altogether. This argument might explain why females represent approximately 57.5% of all college students, but only 29.7% of STEM graduates – a dangerous imbalance that carries societal and economic implications.

References

Deci, E., & Ryan, R. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*, 54-67.

Johnson, D., Johnson, R., & Smith, K. (1991). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book.

Johnson, D., Johnson, R., & Smith, K. (1998). Maximizing instruction through cooperative learning. *ASEE Prism, 7*(6), 24-29.

Johnson, E., Ellis, J., & Rasmussen, C. (In Press) It's about time: The relationships between coverage and instructional practices in college calculus. *International Journal of Mathematical Education in Science and Technology.* (Accepted pending revisions)

Karp, D. A., & Yoels, W. C. (1975). The college classroom: Some observations on the meanings of student participation. In *Proceedings of the American Sociological Association Annual Meetings, 60*(4), 421-439.

Lucas, A. (2009). Using peer instruction and i-clickers to enhance student participation in calculus. *PRIMUS, 19*(3), 219-231.

Lyman, F. (1981). The responsive classroom discussion: The inclusion of all students. *Mainstreaming Digest*, 109-113.

President's Council of Advisors on Science and Technology (PCAST). (2012). Who is switching out of calculus and why? *Report to the President, Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*.

Rasmussen, C., & Ellis, J. (2013). Who is switching out of calculus and why. *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education, 4*, 73-80.

Sadker, M., & Sadker, D. (1995). *Failing at fairness: How America's schools cheat girls*. New York: C. Scribner's Sons.

Sadker, D., Sadker, M., & Zittleman, K. (2009). *Still failing at fairness: How gender bias cheats girls and boys in school and what we can do about it*. New York: Scribner.

Seymour and Hewitt (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview.

Tinto, V. (1997). Classrooms as communities: Exploring the educational character of student persistance. *Journal of Higher Education, 68*(6), 599-623.

Wertsch, J. (1990). The voice of rationality in a sociocultural approach to mind. *Vygotsky and Education: Instructional Implications and Applications of Sociohistorical Psychology,* 11-126.