SWITCHER AND PERSISTER EXPERIENCES IN CALCULUS I

Jessica Ellis, Chris Rasmussen, and Kristin Duncan
San Diego State University

Previous reports show that not only are too few students pursuing Science, Technology, Engineering, or Mathematics (STEM) fields, but also many who originally intend to pursue these fields leave after their experiences in introductory STEM courses. Based on data gathered in a national survey, we will present an analysis of 5381 STEM intending students enrolled in introductory Calculus in Fall 2010, 12.5% of whom switched out of a STEM trajectory after their experience in Calculus I. When asked why these students no longer intended to continue taking Calculus (an indicator of continuing their pursuit of a STEM major), 31.4% cited their negative experience in Calculus I as a contributing factor. We analyze student and their instructor survey responses on various aspects of their classroom experience in Calculus I to better understand what aspects of this experience contributed to their persistence.

Key words: [Calculus, Retention, Instruction, Persistence.]

The number of students completing degrees in Science, Technology, Engineering, or Mathematics (STEM) continues to fall short of the demand for workers in these fields and hence is a national problem of great importance. Not only are too few students pursuing STEM fields, but also many who originally intend to pursue these fields leave after their experiences in introductory STEM courses (Seymour & Hewitt, 1997). Thus, one integral aspect to increasing the number of STEM graduates is to increase the *retention* of STEM students. The most recent report from the President's Council of Advisors on Science and Technology (PCAST, 2012) predicts that simply increasing the retention of STEM majors by ten percentage points would go a long way to meeting the need for the targeted 1 million more STEM graduates.

In the seminal book centered around student persistence in STEM fields, *Talking About Leaving*, Seymour and Hewitt (1997) noted that students leave STEM majors primarily because of poor instruction in their mathematics and science courses, with Calculus often cited as a primary reason. Using the same dataset that we use for this report (see details below), our previous analysis found that 12.5% of the STEM intending students were identified as *switchers,* those students who chose not to continue onto Calculus II after their experiences in Calculus I. When asked why these students no longer intended to continue taking Calculus (an indicator of continuing their pursuit of a STEM major), 31.4% cited their negative experience in Calculus I as a contributing factor (Rasmussen, Ellis, Duncan, Bressoud, and Carlson, in preparation). In this analysis, we investigate the Calculus I experience as reported by both students and instructors to better understand how Calculus I experiences relate to student persistence.

Methods

Data for this study come from a large-scale national survey of mainstream Calculus I instruction that was conducted across a stratified random sample of two- and four-year undergraduate colleges and universities during the Fall term of 2010. The survey was sent to a stratified random sample of mathematics departments following the selection criteria used by Conference Board of the Mathematical Sciences (CBMS) in their 2005 Study (Lutzer et al,

2007). In all, we selected 521 colleges and universities, 222 of which participated: 64 two-year colleges (31% of those asked to participate), 59 undergraduate colleges (44%), 26 regional universities (43%), and 73 national universities (61%). There were 660 instructors and over 14,000 students who responded to at least one of the surveys. For the purpose of this analysis, we focus only on STEM intending students who responded to both pre and post term surveys and whose instructors did as well, resulting in a data set of 5345 students from 421 instructors from 145 institutions.

We determined students to be STEM intending as the students that indicated intent to take Calculus II at the beginning of the Calculus I term. Students were again asked to report their intention to take Calculus II at the end of the term, and based off of their responses we classified them as either *Persisters* or *Switchers*. Persisters were those students who initially intended to take more Calculus and did not change from this intention at the end of the term (or one year later). Switchers, on the other hand, were those students that started Calculus I intending to take more Calculus, but then by the end of the term (or one year later) changed their plans and opted not to continue with more Calculus.

Before conducting this analysis, we wondered if switchers and persisters were in the same classes, or if they are in the same classes but experiencing them differently. In order to determine this, we looked at the subset of instructors for which we had at least ten students' end of term survey data[1]. Because of this clustering, our significance values are lower than they would be under complex sampling analysis. This left 181 instructors accounting for 4,280 of the students. The percentage of switchers per class ranged from 0% to 71.4%, suggesting that some of the classes have a mix of switchers and persisters, and some do not.

Student Behavior in Class

To understand how students reported their in class behavior, we examined four questions from the end of term survey. Students were asked to report how frequently they did each of the following activities during class, from never (1) to every class session (5): contributed to class discussions, were lost and unable to follow the lecture or discussion, asked questions, and simply copied whatever was written on the board. For each of these questions, we conducted an independent-samples t-test to compare responses for switchers and persisters. As can be seen in Table 1, there was a significant difference in the responses for the amount of time spent contributing to class discussions between switchers and persisters, time spent lost and unable to follow the lecture or discussion, and time spent simply copying whatever was written on the board, but there were not significant differences between switchers and persisters on time spent asking questions. These results indicate that switchers report spending less time in class contributing to class discussion, more time lost and copying down what is written on the board, and the same amount of time asking questions as reported by the persisters. Taking these together, switchers report being *less engaged* than persisters during class.

[1] Because overall 12.5% of STEM intending students were switchers, if an instructor was linked to 10 students this would provide on average 1 switcher per instructor.

Table 1. Student reports of in-class behavior.

During Class:	Persister	Switcher
I contributed to class discussions.**+	2.69	2.47
	(1.25)	(1.17)
I was lost and unable to follow the lecture or discussion.**	1.89	2.18
	(0.99)	(1.02)
I simply copied whatever was written on the board.**	2.86	3.26
	(1.36)	(1.32)
I asked questions.+	2.38	2.34
	(1.12)	(1.07)

Note. * = p ≤ .05, ** = p ≤ .001, + = Persister mean greater. Standard Deviations appear in parentheses below means.

Instructor Behavior

In the above section we investigated whether differences existed in students' behavior based on persistence. In this section we focus our attention on instructor behavior as reported by their students, and by instructors (when available).

The first set of 15 questions asked students to report their level of agreement, on a six-point scale from strongly disagree to strongly agree, to various statements of instructor actions, such as "made class interesting" and "discussed applications of Calculus." Table 2 shows that persisters agreed that their instructors did all but four of these actions significantly more than switchers agreed. The actions that persisters reported their instructors doing in class more include "asking questions to determine if I understood what was being discussed", "allowed time for me to understand difficult ideas", and "made class interesting." The actions that switchers reported their instructors doing in class more included "made students feel nervous during class" and "discouraged me from wanting to continue taking Calculus."

Table 2. Student reports of instructor actions.

My Calculus instructor:	Persister	Switcher
asked questions to determine if I understood what was being discussed.**+	4.44	4.20
	(1.21)	(1.32)
listened carefully to my questions and comments.**+	4.79	4.53
	(1.14)	(1.31)
allowed time for me to understand difficult ideas.**+	4.39	4.03
	(1.27)	(1.44)
helped me become a better problem solver.**+	4.43	4.02
	(1.25)	(1.37)
provided explanations that were understandable.**+	4.63	4.27
	(1.25)	(1.41)
encouraged students to enroll in Calculus II.**+	4.30	3.78
	(1.25)	(1.35)
acted as if I was capable of understanding the key ideas of calculus.**+	4.83	4.57
	(1.02)	(1.19)
made me feel comfortable in asking questions during class.**+	4.70	4.39
	(1.21)	(1.36)
encouraged students to seek help during office hours.**+	4.98	4.82

	(1.08)	(1.21)
presented more than one method for solving problems.**+	4.65 (1.19)	4.34 (1.36)
made class interesting.**+	4.33 (1.42)	3.96 (1.54)
was available to make appointments outside of office hours, if needed.*	5.10 (0.99)	4.96 (1.00)
discouraged me from wanting to continue taking Calculus.*	2.24 (1.44)	2.66 (1.51)
made students feel nervous during class.**	2.07 (1.24)	2.22 (1.37)
discussed applications of calculus.+	4.73 (1.12)	4.63 (1.21)

Note. * = p ≤ .05, ** = p ≤ .001, + = Persister mean greater. Standard Deviations appear in parentheses below means.

The second set of questions asked both students and instructors to report how frequently their instructor (or they) did various activities, using a six-point scale from never to very often. These activities included frequency of lecture, having students give presentations, students working together in class, and having whole class discussions. Two analyses of this data are presented below. Table 3 provides both student and instructor reports of these frequencies, and the significance of the difference between the switcher and persistence reports from the students only. Table 4 takes a closer look at the difference between what the instructors report and what the students report.

Table 3 shows that persisters reported these all but two of these activities occurring significantly more frequently than switchers; lecturing and being assigned to read sections of the text before class were the two actions excluded. Taken together, the description of the class provided by the persisters appears to be more student-centered and engaging than the description of class presented by the switchers. The last two columns show instructor responses for these activities, which for the most part tell a similar story to what the students report. However, there are some discrepancies. Table 4 shows these in more detail.

Table 3. Student and Instructor reports of in-class activities.

How frequently did your instructor (you)	**Student Report**		**Instructor Report**	
do the following:	**Persister**	**Switcher**	**Persister**	**Switcher**
hold a whole-class discussion? **+	3.48 (1.81)	3.13 (1.80)	3.36 (1.61)	3.36 (1.77)
ask students to explain their thinking?**+	3.83 (1.63)	3.53 (1.70)	3.96 (1.39)	4.03 (1.56)
prepare extra material to help students understand calculus concepts or procedures?**+	3.94 (1.53)	3.67 (1.60)	4.08 (1.66)	3.83 (1.674)
require you to explain your thinking on exams? **+	4.11 (1.67)	3.82 (1.77)	4.32 (1.64)	4.05 (1.64)
show how to work specific problems? *+	5.01 (1.09)	4.80 (1.20)	5.01 (1.09)	5.08 (1.09)

have students work with one another? *+	3.28	3.09	3.67	3.50
	(1.91)	(1.83)	(1.91)	(1.84)
have students give presentations? *+	1.83	1.67	1.74	1.76
	(1.40)	(1.26)	(1.10)	(1.20)
have students work individually on problems	3.78	3.60	2.91	3.12
or tasks? *+	(1.64)	(1.73)	(1.54)	(1.70)
ask questions? *+	4.63	4.50	5.23	5.12
	(1.20)	(1.25)	(.949)	(1.20)
require you to explain your thinking on your	3.38	3.15	3.87	3.79
homework? *+	(1.76)	(1.77)	(1.82)	(1.75)
assign sections in your textbook for you to	3.67	3.59	3.74	3.65
read before coming to class? +	(1.96)	(1.99)	(2.11)	(2.02)
lecture?	5.02	5.09	5.12	5.18
	(1.26)	(1.25)	(1.13)	(1.08)

Note. Student Report: * = $p \leq .05$, ** = $p \leq .001$, + = Persister mean greater. Standard Deviations appear in parentheses below means.

Table 4 shows that instructors and students report some activities occurring with different frequencies, and that this difference is not always consistent between switchers and persisters. For clarification, the numbers close to zero (either positive or negative) indicate agreement between the student and the instructor. Thus larger numbers in absolute value represent more disagreement between student and instructor. Positive numbers indicate that the instructor reported higher frequencies and negative numbers indicate that the student reported high frequencies.

Table 4. Difference between student report and instructor report on in class activities.

How frequently did your instructor (you) do the following:	**Persister**	**Switcher**
show how to work specific problems? **	-.019	.233
	(1.45)	(1.43)
hold a whole-class discussion? **	-.163	.243
	(2.14)	(2.28)
ask students to explain their thinking?**	.051	.457
	(1.85)	(1.94)
have students work individually on problems or tasks? **+	-.893	-.528
	(1.99)	(1.99)
have students work with one another? +	.326	.292
	(1.68)	(1.70)
have students give presentations? *+	-.114	.058
	(1.54)	(1.29)
lecture? +	.103	.086
	(1.38)	(1.44)
prepare extra material to help students understand calculus concepts	.170	.106
or procedures?+	(2.15)	(2.11)
require you to explain your thinking on exams? +	.192	.160
	(2.19)	(2.33)
require you to explain your thinking on your homework?	.487	.640

	(2.21)	(2.18)
ask questions?	.568	.588
	(1.47)	(1.61)
assign sections in your textbook for you to read before coming to class?	.045	.073
	(2.11)	(2.11)

Note. * = $p \leq .05$, ** = $p \leq .001$, + = Persister mean difference greater (in absolute value). Standard Deviations appear in parentheses below means.

Activities for which there was consistent agreement between students and instructors, for both switchers and persisters, include lecture, requiring students to explain thinking on exams, and assigning reading form the textbook before class. The activities that the instructor reported occurring much more frequently than students, for both switchers and persisters, include asking questions, having students work with one another, and requiring students to explain thinking on homework. Thus instructors appear to uniformly overestimate the amount of time they spent on these activities, as compared to their students.

Activities for which switchers disagreed with their instructor more than persisters did include the instructor showing how to work specific problems, holding an in-class discussion, and having students explain their thinking. Taken together, these three activities reflect student engagement in class. Thus, though their instructors believed they were engaging students, and persisters were engaged, switchers did not report being similarly engaged. The only activities for which persisters disagreed more with their instructor than switchers was having students work individually on problems or tasks, although both switchers and persisters reported this happening more frequently than their instructors.

Conclusion

Taken together, the analyses reveal a more complete understanding of the Calculus I experience as told by switchers, persisters, and their instructors. Across the board, switchers report being less engaged during class than persisters; the switchers report contributing to class discussions less, felt less comfortable asking questions during class, found class less interesting, were asked to explain their thinking less, and reported working with other students in class less than persisters. Based on the percentage of switchers per instructors, in some cases this may be because they were simply in classes with instructor who taught differently. However, in some cases they were in the same class as persisters and experienced class differently. Table 4 highlights these students; although persisters agreed with their instructor on the frequency of being engaged, switchers report various engaging activities occurring less. In either class situation, the level of engagement of the students is a large component of their classroom experience, and is related to their eventual persistence.

These findings have implications both for research and for teaching. First, because there are differences between what the instructor reports occurring in class and what their students report occurring, when discussing classroom activities in research the researcher must be aware that differences exist between what the students report and what the instructors report, and that these differences vary among students. Second, instructors should be aware that students in their classes are experiencing their class differently from one another. By being aware of this, instructors can be more intentionally treat students similarly and actively engage *all* students. With the goal of increasing retention in the STEM fields by increasing retention in introductory classes such as Calculus I, it is necessary to improve students' experiences in these courses. By

understanding that these experiences vary across students, we can begin to understand what aspects of their Calculus I experience negatively affect retention in Calculus.

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