

Mathematical Vanishing Act: Why Students are Walking Away

Amanda Lake Heath
University of Houston - Downtown

Jordan E. Kirby
Francis Marion University

Sarah K. Bleiler-Baxter
Middle Tennessee State University

Jennifer Webster
Harpeth Hall School

This study explores the crucial issue of attrition in the undergraduate mathematics major. In this report, we thoroughly examine open-response survey data from seven former mathematics majors describing why they chose to major in mathematics as well as when and why they chose to leave. We situate these data within findings from the 2019 study Talking About Leaving Revisited. Findings from the present study indicate students may leave mathematics because they are intrinsically drawn to a new discipline, or they may feel pushed out of mathematics due to perceived poor instruction and/or lack of outreach and support.

Keywords: mathematics major, retention, recruitment, enrollment

Undergraduate major enrollment is a nationwide topic of discussion in university STEM (science, technology, engineering, and mathematics) departments, especially in the mathematical sciences, in which many mathematics major programs are being eliminated due to low major enrollment (e.g., D'Agostino, 2023). It is imperative to recruit students to major in the mathematical sciences for both the preparation of the STEM workforce and the vitality of university mathematics departments, yet the true issue of enrollment in the mathematics major may lie in retention; mathematics has the highest attrition rate of any undergraduate major at 52% (Leu, 2017). The question remains, why are students, who at one point chose mathematics as their major, walking away? In an effort to answer this question and provide recommendations for how mathematics departments can support retention in their majors, we launched the **Mathematics Journeys of Retention: Why Individuals Switch Educational Paths** (MAJORWISE) Survey Study. In this report, we detail the stories of seven former mathematics majors, including why they chose mathematics as a major, when and why they chose to leave, what majors they changed into, and what supports might have retained them in the major.

Background Literature and Framing

Recruitment and retention in undergraduate STEM majors has been a topic of concern for over three decades (Seymour et al., 2019; e.g., McDade, 1988; Seymour & Hewitt, 1997). One line of research of STEM majors (broadly) has investigated trends among students leaving STEM majors, including demographic variables, college readiness, and instructional methods experienced. These quantitative studies have indicated women, students from minority racial groups, students with low mathematics standardized test scores, students who receive lower absolute (or relative) grades in university STEM courses, and students who take courses taught through strict lecture methods may be at a higher risk for leaving a STEM major (e.g., Belser et al., 2018; Chen & Soldner, 2013; Cundiff et al., 2013; Rask, 2010; Watkins & Mazur, 2013). Although quantitative data may allow researchers to find patterns and speculate why students chose to leave their major, research drawing upon qualitative data and the student perspective may help to identify the circumstances and reasons students remain in or leave STEM. A major effort to conduct large-scale qualitative research on reasons students leave undergraduate STEM

began in 1990 with the study *Talking About Leaving: Why Undergraduates Leave the Sciences* (TAL; Seymour & Hewitt, 1997; Seymour & Hunter, 2019). In this study, researchers interviewed 460 students who had either switched from or persisted in STEM majors from ten undergraduate institutions. Seymour and Hewitt (1997) classified *switchers* as those students who entered their university as STEM majors and then switched to non-STEM majors and *persisters* as seniors who were persisting to graduation in their original STEM majors. This study resulted in a framework of explanations for student academic and career decisions; this framework was characterized by a complex push-pull decision making process. *Push* factors are defined as “problems in students’ precollege and college experiences that made it difficult for them to persist with their original choices of majors and career aspirations” (Seymour & Hunter, 2019, p. 7). *Pull* factors are defined as “perceived attractions or advantages that drew students to alternative majors and career possibilities” (Seymour & Hunter, 2019, p. 7). The TAL project team conducted a follow up study, *Talking About Leaving Revisited* (TALR; Seymour & Hunter, 2019) from 2013 to 2014 in which they interviewed 96 switchers and 250 persisters from six different undergraduate institutions.

TAL and TALR shared many results with respect to the reasons students chose to leave STEM. These shared top reasons included *loss of incoming interest and motivation* (push factor), *rejection of STEM careers and associated lifestyles* (push factor), *shift to a more appealing career option* (pull factor), and *poor quality of STEM teaching* (push factor). The more recent TALR study identified a few new reasons (or a dramatic increase in the prevalence of reasons identified in TAL) for switching out of STEM, such as *discovery of an aptitude for a non-STEM subject* (pull factor), *discouraged/lost confidence due to low grades in early years* (push factor), and *competitive, unsupportive STEM culture makes it hard to belong* (push factor).

The TAL and TALR studies provided a unique student-centered and qualitative perspective on attrition and issues in undergraduate STEM majors. Yet, this research neglected to investigate (a) issues specific to the mathematics major and (b) reasons students might switch from one STEM major to another. The TALR study sample was predominately life science, engineering, or physical sciences majors, with only 7.4% of participants from mathematics, even though the authorship team identified the mathematics major as having a higher-than-expected switching rate compared to other STEM majors (Seymour & Hunter, p. 76). Seymour and Hunter’s assessment of mathematics students as especially high risk for leaving STEM mirrors the NCES Beginning Postsecondary Students Longitudinal Study data, which indicate that of students who declare a mathematics major only 43% (NSF/NCSES, 2012) to 48% (Leu, 2017) will complete their degree in mathematics, which is the lowest retention rate among all degree programs.

There is a need to investigate reasons students leave the mathematics major not only because it leads undergraduate majors in attrition, but also because mathematics students may encounter challenges which would not be identified as reasons for attrition in STEM more broadly. For example, students may struggle with their mathematical identities and self-efficacy as they transition from computational mathematics courses to more abstract and theoretical proof-based mathematics courses (Civian & Schley, 1996). The mathematics students learn become increasingly advanced, and the transition to abstract mathematical thinking and theoretical concepts in university mathematics can challenge students’ view of the nature of mathematics and competency in the subject (DiMartino & Gregorio, 2019; Liebendörfer & Hochmuth, 2013).

A few international qualitative studies from the United Kingdom (Rodd & Bartholomew, 2006; Ward-Penny et al., 2011) and Australia (Hall et al., 2022) have investigated retention in the mathematics major specifically. These studies indicated students may become disaffected

with mathematics at the undergraduate level because they dislike lecture-based instruction and feel as though their courses place a strong emphasis on memorization. Many chose to major in mathematics because it was easy for them in secondary school, but it became a challenge at university. We seek to contribute to this extant research by focusing specifically on (a) math majors, and (b) the context of higher education in the United States. In particular, we aim to understand the journeys of students who chose to leave their mathematics majors at four-year undergraduate institutions in the U.S..

Methods

Data Collection and Recruitment. During Fall 2023, our team carried out a nationwide survey, using Qualtrics, with free-response items of students who have been enrolled in a mathematics major at four-year institutions during the years 2013-2023. In addition to general demographic information (race, gender, age, etc.), this survey solicited information such as: reasons for enrolling in a mathematics major, mathematics courses taken at the university level, type of institution attended, instructional methods experienced in university mathematics courses, and timing of and reasons for considering leaving, actually leaving, or staying in the mathematics major. We recruited survey participants through dissemination of our survey through professional networks, social media, and snowball recruitment (requesting participants share the survey with others). Participants were offered an opportunity to provide their contact information to enter a chance to win one of four \$50 Amazon gift cards.

Survey Participants. The MAJORWISE online survey received 147 applicable responses from a total 176 responses, which were filtered for responses from participants meeting our sampling criteria. We removed responses when, for example, individuals did not indicate they were enrolled in a mathematics major during the years 2013-2023, the quality control question was not answered correctly, or individuals did not complete survey questions beyond providing consent to participate.

Among the 147 survey respondents, 92 (62.5%) were still pursuing a mathematics major, 48 (32.7%) had graduated with a degree in mathematics, and 7 had previously been enrolled as a mathematics major but had switched into a different degree program. We have reported on findings from the participants who are still completing a mathematics major or who graduated with a mathematics major in other publications (e.g., Heath et al., 2024), and for the purpose of this report we restricted our sample to the seven participants who left their mathematics major.

Data Analysis. Survey responses from the seven participants who left the mathematics major were analyzed by first compiling all responses from a single participant and using their responses to each question to compose an analytic memo (Saldana, 2016) summarizing the chronology of a given participant's journey through their decision to major in mathematics and eventually change that major. These analytic memos were then categorized as describing *push* journeys or *pull* journeys in leaving the mathematics major, according to the scheme presented by Seymour and Hunter (2019) in *Talking About Leaving Revisited*. In the present study, we defined a ***push journey*** as a story in which a student left mathematics primarily due to negative experiences in their undergraduate mathematics major. We defined a ***pull journey*** to be when a student left mathematics primarily because of a draw or allure to a different topic or degree program.

Findings

In what follows, we describe the journeys of the seven survey respondents who decided to leave their mathematics majors. These stories reflect a variety of reasons students may choose to change out of the mathematics major into another degree program. We report these journeys by

first presenting the participants who indicated they felt *pushed* out of their mathematics majors (Allen, Brody, Cora, Danielle, and Erika) and then presenting the participants who reported they were *pulled* into or drawn to another discipline and major (Yosef and Zanab).

Push Journeys

Participants' experiences deciding to leave their mathematics majors classified as *push* journeys were characterized by a disaffection with mathematics, their instruction, or their degree program and course requirements. The first three participants, Allen, Brody, and Cora, all expressed they left their mathematics major because they felt as though they could not succeed. The following two participants, Danielle and Erika, both expressed they left the major because they did not enjoy it.

Allen. Allen was a white, male student pursuing a B.S. in Mathematics from a large, public R1 institution in the Southeastern United States. He was enrolled as a mathematics major for three years until he decided to change his major to Business after his junior fall semester. Allen decided to major in mathematics before he began college, and he described that he chose mathematics as his major because he had wanted to be a mathematician since his childhood and an intrinsic love of the discipline. Allen wrote,

I wanted to be a mathematician since I was a kid. I see math as a study that is trying to make sense of the universe instead of trying to make sense of man-made things. I love analyzing data and trying to find a pattern.

While enrolled as a math major, Allen took many different mathematics courses, including upper-division courses like Abstract Algebra I and Numerical Analysis. Allen attributed his experience in Numerical Analysis to his decision to change his major. He claimed the university and the mathematics department faculty had not prepared him to succeed because he was expected to know a coding language in numerical analysis, yet he did not. After his experience in Numerical Analysis, Allen changed his major to Business. Allen said if there had been different instructors teaching his course, or different requirements set up to take certain courses, he may have been supported enough to stay in the major.

Allen's story depicts a *push* journey because despite his intrinsic passion and love for mathematics as a topic, he felt there were barriers to his success embedded in his mathematics degree program, specifically with respect to how the major prepared (or did not prepare) students to take subsequent required major courses.

Brody. Brody was a white, male student pursuing a B.S. in Mathematics Education at a large, public R1 institution in the midwestern United States. Brody decided to major in mathematics before starting college, and he was enrolled as a math major for one year before changing his major to Social Studies Education. Brody said he chose to major in mathematics because he was successful in mathematics in high school, enjoyed teaching, and wanted to be like the great mathematics teachers he had in high school. Brody took College Algebra and Precalculus at the undergraduate level, but when he enrolled in Calculus I, he struggled and decided to drop the course and change his major. Brody said, "I struggled a lot in calc 1. [I] did not want to put myself through the rigor of the program and have my mental state be worsened by math classes." Brody indicated he could not think of any supports that might have helped him stay in the major.

Brody's story illustrates how a student might initially feel drawn to mathematics because of success in the subject in high school. However, Brody perceived that the challenge of Calculus and an extended study of mathematics would worsen his mental state, and thus *pushed* him out of the major.

Cora. Cora was a Black/African American, female student, pursuing a B.S. in Mathematics at a small, private HBCU in the Southeastern United States. Cora chose to major in mathematics as a first-year student, having originally declared a Computer Science major. Her decision to pursue a mathematics major was motivated by her dislike for coding in computer science and her enjoyment of learning mathematics and solving problems. Cora took Discrete Mathematics and Calculus I as an undergraduate, but she changed her major to Education during the middle of her second year at the university while taking Calculus II. Cora attributed her decision to leave mathematics to poor instruction in her mathematics courses. She wrote,

I decided to switch when I realized that my professor and many others in the mathematics department were not efficient in teaching math courses. I did not think it was fair for me to stay in a major that did not have great professors.

When asked what supports might have helped her stay in mathematics, Cora responded that more support from her mathematics department chair and dean as well as making tutoring available for higher-level mathematics courses may have changed her journey.

Cora's story highlights how perceived poor instruction in mathematics courses and a lack of infrastructure (e.g., tutoring for upper-division courses) can *push* a student out of mathematics. Cora provided a unique perspective as a student who did not begin college as a mathematics major, and during her time as a computer science major she had potentially experienced different quality or type of instruction in another department before joining the mathematics department.

Danielle. Danielle was a white, female student pursuing a B.S. in Mathematics with a concentration in Applied Mathematics at a large, public R1 institution in the Southeastern United States. She chose to major in mathematics before starting college and she chose mathematics because she loved the subject in high school and wanted to pursue a career in applied mathematics. Danielle was enrolled as a mathematics major for three semesters; she took a variety of mathematics courses at her university: Calculus II and III, Linear Algebra, Introduction-to-Proof, Probability and Statistics, and Partial Differential Equations. Danielle's decision to leave her mathematics major was primarily motivated by frustration with her degree program and course requirements. She wrote,

The applied mathematics concentration focused too heavily on theory, in my opinion. It seems like everyone is taking the exact same classes overall, with about 3 or 4 electives to differentiate between concentrations. The degree felt poorly designed and very rigid in what students could or could not take.

Danielle's discontentment with her degree program depicts a *push* journey because, although she still enjoyed what she considered to be "applied" mathematics, she perceived her major as requiring too many theory-based courses and the concentration as not distinct enough from the standard mathematics major at her university.

Erika. Erika was a white, female student seeking a B.S. in Mathematics Education at a large, public R1 institution in the midwestern United States. She decided to major in mathematics before beginning college because she wanted to be a mathematics teacher but changed her major from mathematics to Business at the end of her second year of her undergraduate studies. Erika decided to leave mathematics because, "Awful professors made [her] very disinterested." She noted that if the mathematics courses were structured better or if she had gone to a different institution with "better professors" she would have stayed in the mathematics major.

Erika's story highlights another example of a student leaving mathematics because they considered their course instruction inadequate, *pushing* them to a different major and department. Erika did not provide a detailed account of what made the instruction she experienced poor.

Pull Journeys

Participants' experiences deciding to leave their mathematics majors classified as *pull* journeys are marked by an allure or draw to another discipline or department. Two students, Yosef and Zanab, described their decision to leave mathematics as pull journeys.

Yosef. Yosef was a multiracial, male student seeking a B.S. in Mathematics and Statistics at a large, public R1 institution in the northwestern United States. Yosef decided to major in mathematics after transferring to his new R1 Institution. Yosef majored in mathematics for three academic years before switching to computer science. Yosef expressed lack of direction with his career, and ultimately decided to major in mathematics because he enjoyed solving problems and proving statements. Yosef took several mathematics classes before struggling in Calculus II. Yosef remarked, "After I realized that math was difficult, I fell in love with arguably something even more difficult and equally as reliant on math: computer science."

Yosef expressed he preferred the instruction in his computer science courses, which involved large projects with writing and problem solving, and his mathematics courses, in comparison, felt like "busy work." Yosef said he may have wanted to stay in math if it were taught differently. He wrote,

I think the entire way we teach math would need to change. I think a project focused and problem-solution focused way of teaching math would've helped me. It was hard for me to think that integration techniques would help me in the real world, but knowing how to create a hash table felt more applicable.

Yosef's story depicts a *pull* journey because he was attracted to the instruction he experienced in another discipline and felt drawn to a more interesting and applicable major in computer science. Yosef indicated the instructional methods used in mathematics classes may be a deterrent to the retention of some mathematics majors.

Zanab. Zanab was a Black/African American, female student pursuing a B.S. in Mathematics at a large, public R1 institution in the northeastern United States. Zanab chose to major in mathematics because she liked the concepts and ideas of mathematics. She took many mathematics classes, including complex analysis and topology, before she switched to a computer/information sciences major during her second year of her studies. Zanab decided to leave the mathematics major due to a preference for her new major, writing, "I just preferred the new major. I wanted an intersection between compsci and psychology. I like the challenge of programming."

Zanab's story depicts a *pull* journey because she felt pulled to her true passion. Zanab said there was nothing that could have changed to make her stay.

Discussion

Across the journeys of the seven participants who left their mathematics major, there were many factors influencing their decision to leave, including: (1) challenge and struggle, (2) instruction, (3) curriculum, and (4) passion and interest. These align with and supplement the findings from *Talking About Leaving Revisited* (Seymour & Hunter, 2019) to help understand why students may leave mathematics majors.

Several of the participants mentioned challenge and struggle as a factor influencing their decision to leave mathematics. Allen, Brody, and Cora, all mentioned struggling in a mathematics course as push factors influencing their decision to leave. Researchers in TALR similarly found that students across STEM disciplines may leave STEM because they were "discouraged/lost confidence due to low grades in early years" (Seymour & Hunter, 2019, p. 92). Interestingly, although Brody and Cora did change their majors during Calculus, Allen's journey

illustrates a case in which it was not courses in early years that discouraged him. Challenge was not only associated with push journeys; both Yosef and Zanab also mentioned challenge and difficulty level in their responses. Thus, for some students, difficulty, challenge, and struggle pushed them away from mathematics, while others perceived difficulty and challenge as something pulling them to a subject, whether mathematics or their new discipline.

In addition to facing challenge in mathematics courses, students discussed instruction of their courses with respect to choosing to leave mathematics. Allen, Cora, and Erika cited poor instruction of their mathematics courses as pushing them out of mathematics. TALR also found this to be a common reason for leaving STEM majors, with 96% of switchers referencing “poor quality of STEM teaching” as a concern contributing to their switching (Seymour & Hunter, 2019, p. 92). Limited by the survey format of these data, our team could not inquire further about what “poor quality instruction” meant to Allen, Cora, or Erika. Yosef, however, described being pulled to computer science because he experienced teaching he found more engaging. He noted he enjoyed instruction based in projects, problem-solving, writing, and stated if mathematics were taught more from this perspective he may have wanted to stay. Aligning with the TALR study, Seymour and Hunter also found students may switch from STEM because they “prefer teaching approaches in non-STEM courses;” (p. 92) however, Yosef’s experience of teaching he preferred was in another STEM subject.

Three students, Danielle, Allen, and Erika mentioned issues related to curriculum and program of study as pushing them from their mathematics majors. Danielle’s complaint regarding her major program was that even the applied mathematics concentration required too many theoretical mathematics courses, and Allen was frustrated he was expected to know a coding language without having been required to take a programming course. The TALR study mirrors these complaints in the concern they found, “STEM curricular design problems: pace, overload, labs, alignment” (Seymour & Hunter, p. 92). It could be debated whether or not Allen and Danielle’s programs of study were actually poorly designed, but it is also possible the intentions of the program design and expectations of students in those programs were not clearly communicated to the students.

Finally, passion and interest were primary reasons Yosef and Zanab found themselves pulled to other subjects. This aligns with TALR’s finding that students left STEM if they discovered an “aptitude for a non-STEM subject” and “non-STEM major offers better education, holds more interest” (Seymour & Hunter, 2019, p. 92). The latter of these concerns identified in TALR also resonates with Erika’s comment she “had awful professors that made [her] very disinterested,” as she indicated another major would offer a better education and hold her interest.

Conclusion

The seven stories highlighted in this report provide examples of the many different factors affecting retention and attrition issues in mathematics departments across the United States. The results from this study support that some of the findings from TALR are also applicable to the discipline of mathematics, yet it is notable that three participants in this study (including both of the pull stories) switched to a different STEM discipline, rather than out of STEM. Common across both push and pull journeys is discontentment with teaching in university mathematics. As our sample of students who left their mathematics major was small and the survey format of data collection inhibited us from inquiring into further detail regarding participant comments, we intend to continue this research and gain a larger sample of students who have switched out of the mathematics major and include more in-depth qualitative data such as interviews or written narratives to gain a deeper perspective on students’ perceptions of their mathematics programs.

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