How to Use This Book

0.1 For Students

Congratulations for picking up *Navigating the Math Major: Charting Your Course*! We hope you won't be able to put it down! While you might take all the same courses as another math student, we know that there is no "one size fits all" math major. Not only the courses you take, but also the extracurricular activities you participate in, the communities you become a part of, and ultimately what you do after completing your math degree all depend on one critical factor: YOU! Your goals, your interests, and your passions are what drives your math major. The goal of this book is to give you more information about the options that are available to you so you can prepare yourself to achieve your goals.

Because of this, there might be different sections of the book that will be more useful to you at different parts of your academic career. We will divide our advice very broadly into two pieces: advice for students who are new to the math major (first/second year students or students who just declared their math major) and advice for students who are already math majors and who are thinking about what to do in their last 1–2 years of college and post-graduation.

0.1.1 For students who are new to the math major. Maybe you just declared your math major or you're thinking about becoming a math major and you're in an exploratory phase where you want to know what your options are. In that case, the following chapters might be useful:

- Chapter 1, "Introduction: Start Here," includes some prompts to help you think about your goals and passions.
- Chapter 2, "Planning Your Course of Study," gives a high-level overview of different degree options and math classes you might take.
- Chapter 3, "Extracurricular Explorations," has information about extracurricular activities. This is a good chapter to at least skim for now, but you may skip over the sections with concrete advice about applying for research programs/internships or what to do once you're accepted. It's never too early to start thinking about summer research/internship opportunities, though, even if you won't be applying for another year or two.
- The scavenger hunt in Section 3.7 is a good way to acquaint yourself with the resources that exist on your campus to help support you in your major.
- Chapter 4, "Failure and Growth," is worth reading and revisiting as needed. Math can be hard. The struggle is sometimes very real. This chapter includes resources to help you find support and community when you need it.

- The beginning of Chapter 5, "Networks and Communities of Support," has information about professional societies in the mathematical sciences, along with other groups that you might consider joining, especially if you are from a group that has been historically marginalized in STEM. This chapter also includes information on finding and developing community with your fellow mathematicians and how to attend conferences (and *which* to attend), which is an experience we recommend even if you are a first- or second-year student.

- Chapter 6, "Technical Skills," may be beyond what you need to know right now, but you may find value in reading the first section on developing good collaboration skills. We also recommend skimming the section headings for the rest of the chapter to familiarize yourself with the types of resources available to you, so you know where to look when you need them.

- Chapter 7, "Careers for Math Majors," contains interviews with former math majors who have gone on to a wide range of different careers. Even if you don't read every single interview right now, we recommend skimming through the section headers to see what kinds of jobs people with math degrees are doing and then dive deeper on any careers that seem interesting to you.

0.1.2 For students who are already math majors. Now that you have taken most of your introductory math courses, you might be thinking about how to get the most out of your last year or two of college and/or what you will do after graduation.[1] Here are some sections of the book that might help you think about what you will do next based on your interests and experience.

- Chapter 1, "Introduction: Start Here," is worth revisiting frequently. It is likely that your goals, interests, and priorities will change throughout your career. How do you need to change your plan and priorities to meet your new goals?

- Even after you have taken your introductory math courses and declared your major, Chapter 2, "Planning Your Course of Study," has information about different electives you might consider taking to help you meet your career goals. (Or if you're grad school-bound, you can identify some subjects you want to learn more about in grad school!)

- Read Chapter 3, "Extracurricular Explorations," more carefully. There are tons of opportunities to get a paid summer job that is related to your math major. It takes time to find these positions and apply for them, but first you need to know about the options that exist.

- Some (highly capable!) students begin struggling in mathematics very early on while others don't encounter their first brush with failure or discouragement until late in their undergraduate studies or even in grad school. When you hit a roadblock, we encourage you to read Chapter 4, "Failure and Growth," to gain some perspective.

[1] By the way, it's absolutely fine if you don't know what you want to do after graduation; each of us, at some point, has awkwardly changed the subject when faced with a question about our future plans from a probing family member.

- Chapter 5, "Networks and Communities of Support," has information about professional organizations and what to do if you are attending a conference for the first time. If you have a research or internship position, a talk at a conference is a great way to share your work with the community and make connections with people who are interested in your work.
- Read Chapter 6, "Technical skills," more closely at this point. What skills do employers want to see and how can you develop them in your time as an undergraduate?
- Chapter 7, "Careers for Math Majors," contains interviews with former math majors who have gone on to a wide range of careers. As the time to actually get a job gets closer, these interviews will help you get a feel for different career options open to you.
- Chapter 8, "Applying for Jobs," and Chapter 9, "Graduate School in the Mathematical Sciences," are all about two very common career paths for math majors: jobs in industry and graduate school. If you are just starting to think about the question of "what's next?", skimming through these chapters can give you some high-level ideas. If it is the fall of your last year of college and you will be applying for jobs in 3 months, read these more carefully to learn more about how to apply and how to find resources on campus to help your application stand out.

0.2 For Instructors

Many math departments around the country are introducing courses for their incoming math majors as a way to offer their students extra support in navigating their college experience. Such courses help to level the playing field, especially for first-generation college students and others who do not have robust networks of mentors. This book is designed to be a resource for such a course.

If you are teaching an Introduction to the Math Major course, you might implement some activities suggested by the book. For instance, there's a scavenger hunt in Section 3.7 your students could complete to learn more about resources available to them on your campus. There are also several lists peppered throughout the book, like our favorite YouTube channels, which could be used as the basis for a class project. Several other resources are discussed, like *Living Proof*, *Testimonios*, *Mathematically Gifted and Black*, and more. You might consider having your students read a few stories about the experiences of successful mathematicians in these books and websites and write reflections on what they read.[2]

Given how extensive "Part 3: Life After Graduation" is, this book could also be a helpful resource for a senior seminar, populated by students who are planning for what comes after they complete their degree. We explore a wide variety of careers through interviews with former math majors who are in those careers. We also give tips on applying for and interviewing for jobs, as well as applying for graduate school. This book could be a useful supplement to other career-oriented books like the *BIG Jobs Guide* [**23**] and *101 Careers in Mathematics* [**15**].

If you're working with students who are further along in their studies, you could consider activities like having each student research a particular career path that

[2] `https://tinyurl.com/2mxs989d`

interests them. Each student could begin by reading the interviews related to their selected career in this book. Then, they could find an alum from your institution or someone working for a local business who is doing a related job and conduct their own interview. They could search for additional information, like job ads and salary stats online, too. Students' investigations could culminate in presentations on what they learned to the class.

There are so many directions you could move in if you would like to teach a class using this book, but we know that not all math departments offer these seminar-style courses. You might still find it useful, as an academic advisor or mentor for students, to have a few copies of this book available for students to check out as needed.

For instance, suppose one of your students is having a crisis of confidence after failing a math exam. After sharing your own words of wisdom, you may point them to Chapter 4 to help them gain some perspective on the situation. As another example, let's say that a student is unsure of which advanced courses to plan in their schedule. You could point them to Chapter 2 to read descriptions of common course offerings that go beyond what they might read in your course catalog. Or if your mentee is trying to learn skills to help them in an undergraduate research project, you could steer them towards Chapter 6. If you have a student who is a member of a historically marginalized group in mathematics, you might point them to Chapter 5 in this book to help them identify communities of support. You could also suggest to your students that they read Chapter 3 to learn more about REUs and internship opportunities.

As you may have gleaned, this book is designed to be a resource in a number of dimensions. Familiarizing yourself with the content by looking over the table of contents and skimming the book will help you connect your students with the resources they need to be successful.

1

Introduction: Start Here

"There were four **P** thoughts that I had...

- Mathematics is my **passion**. What I want to do is be a mathematician.
- What classes and experiences would I need to be a mathematician? How will I **prepare** to be a mathematician?
- If I worked the **plan** that I had—if I found out what the classes are that I need to take and started taking them, that would put me on the road to preparing.
- And then I would need to **persist** in this journey to be a mathematician, to persist when I would run into problems. I would have to solve those problems and then continue on my journey without quitting.

That's the way I would get to be a mathematician."

-Dr. Christine Darden, MAA MathFest, August 6, 2021[a]

[a] https://bit.ly/Darden-MathFest

Welcome to your guidebook! We're so happy you're here.

Before you explore all of the resources this book provides, we encourage you to start here with some self-reflection. The first step in any journey should be to check in with yourself. Who are you, what do you value, and what are your passions?

Figure 1.1. Dr. Christine Darden in Langley's Unitary Plan Wind Tunnel in 1975. Credit: By NASA.[1]

Let's begin by channeling the four Ps in Dr. Darden's quote:

(1) Passion: Your passion helps you see yourself as a mathematician. It motivates the work that follows.

(2) Plan: To set yourself on a path for success, plan what classes and experiences you need to achieve your mathematical goals.

(3) Prepare: Invest in your plan! Find the strategies, resources, and support you need to achieve your goals.

(4) Persist: Do the work, even when the math gets tough.

1.1 Identity

Like many words, identity has a specific meaning for mathematicians. But let's consider for a moment the definition that comes from psychology. According to the American Psychological Association, identity is "an individual's sense of self defined by (a) a set of physical, psychological, and interpersonal characteristics that is not wholly shared with any other person and (b) a range of affiliations (e.g., ethnicity) and social roles."

One's identity is multidimensional and can be measured along many axes. As you think about your identity, you might think about gender, race, ethnicity, nationality, politics, sexuality, or religion. But also: are you a listener or a talker? Are you an introvert or an extrovert? The way you approach a problem may also be part of your identity. Do you pride yourself on leaps of intuition? Or on your

[1] `http://www.nasa.gov/centers/langley/news/researchernews/rn_CDarden.html`, Public Domain, `https://commons.wikimedia.org/w/index.php?curid=38582453`

methodical approach? Are you fast, priding yourself on how quickly you can solve a problem, or do you prefer to take your time to study and think?

Some identities become important to you only in certain settings. For instance, did you discover in college that you're part of a group of "first-generation college students" or "nontraditional" students? Sometimes identities are fluid: constantly shaped and redefined by your life experiences. Perhaps you have always thought of yourself as a "math person" because math classes have seemed easier than classes in other subjects. Or perhaps you did not think you were a "math person," but you're now really interested in the subject because you have been in classes that reveal more creative depths or include hands-on or computational ways to engage! All of these interests, experiences, and identities combine to make us who we are. Embrace your uniqueness as a strength!

You might be thinking, "Why is a math book starting by talking about identity?" While writing this book, we spoke with many folks who have found success in their mathematical journeys (and beyond). Each person's journey and definition of success differed according to their unique constraints, passions, and (ultimately) identity. In a book that promises to have lots of advice for math majors, we acknowledge there's variation in the advice and path that works for each person. It's important for you to assess all advice through the lens of your identity and needs. So before you dive into this book, take a moment to think about who you are and what's important to you.

What are some important aspects of your identity outside of mathematics?

(1) _____

(2) _____

(3) _____

What are some important aspects of how you identify that relate to your study of mathematics?

(1) _____

(2) _____

(3) _____

PS: If you identify as a "hardcore" math person, taking every math class you can—that's great! And if you take the classes you need to get a math degree while you take classes for a second major or various interests, that's great too!

1.2 Values: What's Important to You?

If you are studying mathematics, we expect that you value some aspect(s) of the abstraction of patterns that is mathematics. Perhaps the intellectual challenge appeals to you. Maybe you're drawn in by applications to other fields or beautiful logical arguments. You might be interested in studying math because you enjoy being a member of the community of math majors. No matter which of these reasons resonate with you, understanding what aspects of mathematics you value is important. Your values will shape the career options you consider, whether (and where) you go to graduate school, and more.

You have values outside of mathematics that should also influence your mathematical journey, adding constraints such as geographic location. Is it important for you to remain geographically close to your family? Do you practice a religion that informs your lifestyle? Do you value time and opportunity for a personal interest or hobby? Is a regular routine important to you? Is variety or novelty? Do you value setting your own goals and your own approach? Do you value well-defined structure and goals? Do you value collaborations and social connections with colleagues?

There is no Platonic form of a "successful mathematician." Success won't look the same for everyone. To be a "successful mathematician" is something that you define for yourself. **You** define your own success. Some mathematicians are passionate about proving new theorems while others want to explore math problems related to biology or chemistry. Others are passionate about teaching or community outreach and social justice. Math is flexible. You can study math for math's sake, or you can use math to understand something you are passionate about. All you need to do to be a "math person" is (1) be a person and (2) be curious about math or its uses.

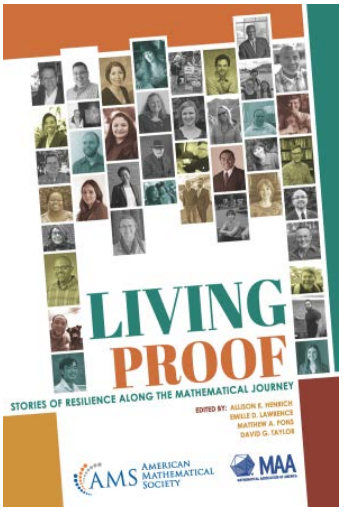

Figure 1.2. *Living Proof: Stories of Resilience Along the Mathematical Journey.* Image courtesy of the AMS.

To learn about the paths that other math people have taken, we recommend that you read the book *Living Proof: Stories of Resilience Along the Mathematical Journey* [**20**], which can be downloaded for free from the Mathematical Association of America's website[2] or the American Mathematical Society's website.[3] *Living Proof* contains stories written by 41 mathematicians about times when they struggled with math and how they persevered to find their place in the mathematical community. In these stories, we learn from mathematicians who became "successful mathematicians" in different ways on their own terms. We will refer to various stories from *Living Proof* throughout this book.

Later, we'll discuss the importance of mentors and role models as examples of how those who have gone before you have navigated their educational waters. But your path will be unique to you and your interests. What do *your* passions and

[2] `https://www.maa.org/livingproof`
[3] `https://bookstore.ams.org/lvngproof/`

past experiences make you excited to study? Sometimes it is hard to see how your interests could be related to a math problem, but often your professors and mentors can!

For example, one of my (CDE) students had a family member struggling with Lyme Disease. She was a wildlife major and really enjoyed field work as well as teaching mathematics. We started a research project on tick ecology, which led to an internship, and then to an offer of funding to join a PhD program! Now she's Dr. Alexis White and works as a New York County epidemiologist.

As another example, I (SRK) had a student who played on our university's basketball team and was interested in taking a more analytic approach to understanding the team's performance. He was able to use his expertise as a basketball player to develop insightful models that he could share with his coach. The coach ended up making decisions based on his results, and the student was accepted to a prestigious Master's in Data Science program after graduation.

What is important to you? What are your passions or interests that compel you to action?

(1) _____

(2) _____

(3) _____

Let's put this together! Make a visual representation of your identities, strengths, and passions. Get creative! If you gravitate towards the tactile, grab some poster board, glitter, and pictures from magazines. If you prefer digital design, create a slide show or a vision board. If you're a performer, choreograph a sweet dance number and shoot a video expressing your passions.[4]

1.3 Constraints and Obligations

"Constraints" and "obligations" may be negative words to use to express aspects of your life that are important to you—and lists of these aspects may fit better in the section above on identity. Nonetheless, constraints and obligations are important things to consider when making decisions, so don't neglect to consider them even if they don't feel like they define who you are.

[4]Nancy Scherich won the Dance Your PhD competition by creating a performance illustrating representations of the braid group! `https://www.youtube.com/watch?v=MASNukczu5A`

Here are some examples of constraints that might affect decisions you make about your education and extracurricular opportunities.

- You want or need to live close to your family.
- You don't have money set aside for your education, so you need to find educational opportunities that come with funding.
- You or a member of your household has a health condition that requires you to have good insurance, access to specialized medical care, and/or flexible scheduling to accommodate health care.
- You are an international student whose opportunities (e.g., NSF funded research and programs) are limited by citizenship and visa requirements.
- You have a full-time job, so you need academic programs and opportunities that fit into your work schedule.

Think about constraints that will affect decisions you make.

What are your constraints and obligations?

(1) _____

(2) _____

(3) _____

1.4 Goals and Interests

At this point, you've thought a bit about who you are, what drives you, and what other factors you need to consider when making practical decisions. Next, let's think about where you want to go. What qualities do you want in a career? What about in life?

To start off, we've written a few examples of priorities you might have. Rank each one with the following codes:

- P1 means this priority is essential, critically-important.
- P2 means you're unlikely to be happy unless this priority is met.
- P3 means that if these don't happen you'll be sad, but it'll be ok.
- Cross out any priorities that you feel are irrelevant for you.

There are a few empty lines to add some additional priorities at the end of the list. We also encourage you (especially for any P1 and P2 items) to write out specifically what you are looking for in this area.

How critical is...

(1) _____ being able to decide the geographical area in which I live?

(2) _____ making a positive impact on broader society?

(3) _____ having a positive impact on my local community?

(4) _____ making a positive contribution to my family?

(5) _____ making contributions to knowledge in my field through research?

(6) _____ having a career that allows me to continually grow over the course of my lifetime?

(7) _____ having time to spend with family and/or friends?

(8) _____ having time to dedicate to a personal interest outside of work?

(9) _____ having a clear separation between work and home life?

(10) _____ having external deadlines and/or pressure to stay motivated?

(11) _____ having regular interaction with my colleagues?

(12) _____ being able to decide which types of mathematics I research/teach/apply?

(13) _____ _____

(14) _____ _____

(15) _____ _____

Some of the answers to these questions and others we've asked in this chapter will change over time. We encourage you to take some time to reflect and write about your current goals and dreams. If you have trouble getting started, try free-writing: write whatever comes to your mind—even if it's

i am so sleepy.
i am so sleepy.
i am so sleepy.
i am so sleepy.

until you can get your thoughts flowing.

1.5 Roadmap for the Rest of the Book

This book is divided into three main parts. Part 1 focuses on the academic side of your undergraduate experience. In Chapter 2, we discuss some common paths through different types of math majors. What is the difference between a major in theoretical math, applied math, statistics, or data science? What classes are you likely to take, and what other classes should you take during your first two years of college to help prepare you for the rest of your undergraduate career (and beyond)?

What you learn in the classroom will only be a fraction of what you learn in college. Chapter 3 focuses on extracurricular opportunities where you can apply what you are learning to your passions. For example, we discuss undergraduate research experiences, summer internships, math contests, and ways to get involved in your department, university, or local community.

Math can be hard. So can life in general. Let's just be honest about that. The second part of the book is all about setting yourself up with support systems to help you when math gets hard. Chapter 4 offers advice about what to do when you stumble, fall down, or fail at some point in your mathematical journey. A common theme in Chapters 4 and 5 is one of finding community and networks of support to help you along the way. Chapter 5 focuses more on professional societies and specialized groups that may be related to different aspects of your identity.

Finally, Chapter 6 is all about your transition from college to the work force and the skills you will develop in your time as a mathematician, such as collaboration skills, writing skills, communication skills, and programming skills.

The final part of the book is aptly titled "What comes next?" The answer to this question will be informed by your 4 P's, your strengths, and your goals. Maybe you don't know what you want to do next. That's ok. A lot of people don't know what they want to do, and many will change their paths at some point along the way. In my (SRK) life, I have thought I wanted to be a professional baseball player, a high school math teacher, a civil engineer, an electrical engineer, a mathematician, and a data scientist. I changed my major from engineering to math when I was an undergraduate. I changed my career from academia to industry 20 years after that. I was never very good at playing baseball, but I learned the fundamentals of machine learning and data science by investigating baseball sabermetrics.

Each person's journey through mathematics is unique, and our (the authors') experiences are still limited in the grand scheme of things. In Chapter 7, we share interviews with dozens of former math majors who have gone on to a wide range of careers. Some of these careers are things you might expect: actuaries, software engineers, and data analysts. Others might be more surprising and represent the

true diversity of careers former math majors end up in: veterinarians, policy advocates, artists, and writers. Our hope is that these stories can give you a sense for the options that may be available after you graduate with a math degree.

Finally, Chapters 8 and 9 focus on getting a job after college. Chapter 8 is all about applying for non-academic jobs, while Chapter 9 focuses on applying for graduate school in math or math-adjacent fields.

Our goal in writing this book is to share things your professors know about navigating your undergraduate journey as a mathematician but that you may not know to ask about, and perhaps a bit of context from outside academia that your professors may not be familiar with. There is no one-size-fits-all math major, and there is no single piece of advice that will work for everyone. You certainly don't need to do everything in this book in order to be a successful mathematician. Rather, we want to tell you about some options so you can get the most out of your time in college and be prepared for whatever comes next. Good luck. Have fun. We're rooting for you!

4

Failure and Growth

> "You may encounter many defeats, but you must not be defeated. In fact, it may be necessary to encounter the defeats, so you can know who you are, what you can rise from, how you can still come out of it."
>
> — Maya Angelou

It may seem strange to talk about failure and growth in the same chapter, but in reality they go hand-in-hand. Growing as a mathematician and learning new, more complicated mathematics are inherently processes of overcoming failure. Take a moment to reflect on this. What is a concept (mathematical or otherwise) that you struggled to understand at first, but that you have mastered now? Can you think of an example from early in your educational journey? How about something from last year? Something from the past month? If you haven't mastered something completely in the past month, what is something you understand better today than you did a month ago?

Adopting a growth mindset is an important tool to wield as you pursue your goals. For example, changing your self-talk from "I can't do this" to "I can't do this... yet" shifts the focus from a static view of education to an ongoing process of learning. At the same time, there are any number of factors in our lives that we cannot directly control (for example, illness or systemic barriers that prevent equal access to education or opportunities). For such issues, we share information about communities of support in Section 4.3 and information on finding community in Chapter 5.

4.1 Overcoming Failure

Studying mathematics requires a certain amount of comfort with failure. Everyone reaches a point where they fail. Everyone. Whether it is failure to solve a homework problem, failure to prove a theorem, or failing an exam, at some point or another

it happens to everyone. *Everyone.* A whole section of stories in *Living Proof*[1] focuses on highly successful mathematicians (including Fields Medalist Terence Tao![2]) who overcame failure at one or more points in their lives. Failure, in fact, can ultimately lead to success, because learning from your mistakes leads you to gain more knowledge. Was it Confucius or Chumbawumba who said, "Our greatest glory is not in never falling, but in rising every time we fall"?

Some people encounter failure early in their mathematical careers, perhaps in middle school or high school. Others experience it when they take their first college math course. Others experience it later in college or graduate school. Others, even later.

So what do you do when it happens to you? Here, we will focus on the question of "I just failed a math test for the first time in my life! Now what do I do?" What does it mean to "fail" a test? It can mean a lot of things to different people. Here, we will examine it in the strictest sense of the word—you earned a grade that puts you at risk of not passing the course and needing to repeat it. However, the advice here can apply more broadly to cases where you feel disappointed at not doing as well on the exam as you typically did in previous classes.

First and foremost, **know you aren't alone because it happens to everyone!** This does not define you as a person. You aren't "bad" at math. You are still a human being who is worthy of being loved and respected. One of the best ways to realize that you are not alone is to connect with a community of support. These communities can also help provide you with strategies, resources, and support relevant to your particular context and positionality.

On the other hand, failing an exam should be viewed as a sign that something needs to change in your approach to the class. There are many productive ways to react to failure.

People react to failure in different ways. Some people get mad. Some people cry. Some people go take a nap. Some people exercise, pour energy into a creative outlet, or talk with a friend or family member. You know what you need better than anyone, and you should give yourself space to attend to these needs. Don't try to force yourself to focus on school work if you know you need to go for a run or spend an afternoon binge watching shows on Netflix and eating a pint of ice cream. As a first step to recovery, take a break to deal with the grief.

Once you have a clearer headspace, there are a few important things to do, which do not necessarily need to be done in order: (1) figure out what happened, (2) learn from your mistakes, (3) get mathematical and non-mathematical support, and (4) make a plan for how to better prepare for future tests.

Have an honest conversation with yourself about why you failed the test. College math is harder than high school math. Upper-level college math is harder than lower-level college math. Graduate classes are harder than undergraduate classes. There are spikes in difficulty at every step of the process, and these spikes require changes in study strategies and habits. Maybe in high school, you could do your homework while simultaneously watching TV, listening to music, walking your dog, and perfecting your choux pastry recipe. In college, that probably won't work. College is harder, and your study habits need to adapt to that increase in difficulty. Here are a few questions you can ask yourself:

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[1] `https://maa.org/livingproof`

[2] The Fields Medal is one of the highest honors a mathematician can receive, and it has been described as the Nobel Prize of Mathematics.

Did I really understand the material? An exam is an opportunity to demonstrate that you understand the material at a deep level. Many students will lament to their professors that, "I understand it when you do it, but then I have trouble doing it on my own." Your professors make these things look easy because they have been doing it for a long time. That doesn't mean it's easy! Having trouble doing problems is typically a sign that you could use a bit more practice, perhaps with a coach.

Was I physically and mentally prepared for the exam? Our brains need sleep, water, and healthy food to function properly. Taking a power nap and pounding an energy drink before you take an exam does not carry the same weight as a good night's sleep, proper hydration, and a healthy breakfast. This practice may work once or twice, but it isn't sustainable.

Our Top 6 Online Resources for Course Content

(1) Khan Academy
`https://www.khanacademy.org/`
Video resources from elementary school math through differential equations and linear algebra.

(2) Wolfram Alpha
`https://www.wolframalpha.com/`
Computes integrals and derivatives, graphs complex functions, and more.

(3) Paul's Online Notes
`https://tutorial.math.lamar.edu/`
Worked examples in algebra, calculus, linear algebra, and differential equations.

(4) Dr. Trefor Bazett
`https://www.youtube.com/@DrTrefor`
Help with discrete math, linear algebra, calculus and differential equations.

(5) The Napkin by Evan Chen
`https://web.evanchen.cc/napkin.html`
Approachable explanations of ideas from linear algebra through graduate level math.

(6) Desmos
`https://www.desmos.com/`
Easy-to-use online graphing calculator.

At the same time, sometimes our brains freeze up or go blank during an exam. This happened to me (SRK) during a qualifying exam in graduate school. The pressure was high—if I failed this exam, I would be kicked out of the program. Instead of trying to force my brain to think, I went for a walk. I walked down the hallway and got a drink of water. Then, I went into the bathroom and washed my face. I walked up and down the hallway again, then went back to the test, mentally recentered and ready to think. The math came back, and I was able to finish the exam. Sometimes, a little break like this is all you need. On the other hand, if you frequently find your brain goes blank in the middle of a test, it might be a sign of

test anxiety. We also recommend Ken Millett's story "Anxiety Attacked Me, but I Survived" in *Living Proof.*

How can I keep from repeating the same mistakes? Learning mathematics can be likened to building a house. The new material you learn is often supported by prerequisite material from other courses. It is fairly common, especially in lower-level courses, that students struggle more to fill gaps in their prerequisite knowledge than they do in learning the new material. The hardest thing about calculus is precalculus; the hardest thing about precalculus is algebra. In many cases, we don't know that there are gaps in our foundations until we reach the point where they fail us.

It can be helpful to make an appointment with your professor (or a TA or tutor) to go over the exam. They will be able to help you identify the places where you made mistakes and identify whether those mistakes came from conceptual misunderstandings or gaps in knowledge from previous classes. Once you have identified the source of your mistakes, take time to work on fixing them. In some cases, your professor may be able to suggest some practice problems related to these mistakes. Absent that, there is no shortage of online resources, such as Khan Academy, that offer free videos and quizzes to help you review prerequisite material.

Will this take extra work? Yes. Will it require you to do more while also staying on top of the new material you are learning in your classes? Yes. Is it going to be hard? Yes. Is it worth the investment? Yes.

How can I be better prepared for future exams? Time is one of the most common stressors in our lives. How do we accomplish everything on our to-do list (including work, sleep, and having fun) in the finite amount of time we are given each day? For many people, it can be difficult to make progress on *anything* when there are so many things that need to be done. As a result, many tasks (such as homework or studying) get put off until the last minute at the expense of other important tasks (like eating meals that don't feature the words "just add water!" or sleeping).

A well-structured weekly planner can be a key to being better prepared for all aspects of your life. There is a common expectation that you should spend two hours outside of class for each hour you spend in class. Make appointments with yourself (or a study buddy if group accountability serves as a good motivator for your work style) to devote two hours to your math homework for each hour of class time. Spreading this work out over the course of the week will prevent all of your homework from needing to be done at 3 a.m. the day before it is due. It also gives our brains more time to process the new information, leading to better long-term retention.

Is there something else that is preventing me from thriving in my classes?[3] This is a difficult question. There is no way to account for all the demands and sources of stress in any person's life. But perhaps you can identify something fixable that will enable you to be more successful in your classes.

In some cases, the thing that is preventing us from thriving comes from within. When I (SRK) was in eighth grade, I was struggling terribly in my algebra class. Nothing made sense. I couldn't follow what my teacher was saying in class, and as a result I couldn't do any of my homework problems. It wasn't until ninth grade, when I got glasses, that I realized the reason I had been struggling in algebra was,

[3]Credit to Drs. Pamela Harris and Aris Winger [**14**].

at least in part, that I couldn't see the board. Everything became easier once I was able to see more clearly.

There are a lot of students who struggle in a similar way to overcome physical or mental hurdles that are preventing them from excelling in the classroom. The transition from high school to college (or from a 2-year college to a 4-year college) is challenging for all students. A 2022 study[4] showed that among all first-year college students who had accommodations in high school to address a learning difficulty (such as ADHD, dyslexia, dyscalculia, or anxiety) or physical handicap, only *one in three* continued to receive similar accommodations in college. One in three. Are you part of the remaining two thirds? Would accommodations help you perform better on exams and quizzes? Most colleges have an office on campus to work with students who are *legally entitled* to such accommodations.

In other cases, perhaps there is something about the timing of the class that is preventing you from thriving. Maybe you work from 6–10 p.m. and are expected to take online quizzes at 8 p.m. or turn in a homework assignment by midnight. Or perhaps you can't attend your professor's office hours because you're a student-athlete and office hours are scheduled at the same time as your practices. In all of these cases, consider asking your professor for some alternate accommodations.

"I have been having a hard time focusing on the quizzes because I work on Tuesday nights and have to take the quiz while I'm on break. Would it be possible for me to take the quiz earlier instead?" or "I can't come to your office hours on Thursdays because I have practice. Would it be possible for us to meet on Friday instead?" It's possible that the answer will be no. But it's also possible that the answer will be yes! Most people don't know about every single thing that's going on in your life, but they may be willing to help you if you explain why a small change on their part would make a big difference for you.

4.2 Mythical Genius (and Why You Shouldn't Care About It)

There is a common lore that suggests mathematical brilliance is a privilege bestowed upon a few (mostly white, mostly male, mostly European, mostly dead) "isolated geniuses"—Newton, Leibniz, Cauchy, Hardy, Ramanujan, Euler, Erdős. The list goes on. The fact of the matter is that most people who are successful mathematicians, *even the aforementioned mostly dead white European dudes*, are/were successful not simply because of some innate talent, but also because they spent a lot of time developing their mathematical skills.

Mathematical aptitude is a skill that can be developed like any other skill, such as rock climbing, yoga, running, baking, painting, ballroom dancing, or making the Kessel run in less than 12 parsecs. You get better at it with practice, and failure and practice go hand in hand. Failure is inherently part of learning. Persistence matters more than innate talent. Talent only gets you so far. After that, it's all hard work. Coming to terms with the fact that failure is part of the process and viewing failure as an opportunity to grow can make it easier to overcome these momentary setbacks. There is plenty of literature to support this. See for example, studies by Carol Dweck [**13**] and Jo Boaler [**6**].

Warning! There is a danger—particularly for women, for Black, Latinx, and Indigenous people, and for other minorities in STEM—of misattributing failure to

[4] `https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2022071`

some innate lack of intelligence rather than acknowledging that failure is part of the learning process for *everyone*. This mistaken belief can be held by teachers, mentors, counselors, family members, friends, and others. Even more damagingly, people can hold this mistaken belief about themselves.

Believing (whether consciously or unconsciously) that you are predisposed to be worse at math can, sadly, actually make you perform worse. This phenomenon is called **stereotype threat**, and it's defined as "a socially premised psychological threat that arises when one is in a situation or doing something for which a negative stereotype about one's group applies" [**38**]. There have been scores of studies demonstrating that, if a person is reminded before a test that they are a member of a group that tends to be less successful on those kinds of tests, the reminder itself will cause the person to do worse on the test.

There is good news, though, with regards to stereotype threat. Just knowing about the phenomenon can help inoculate you to its effects. Also, seeking out role models who look like you can be powerfully protective. (See Chapter 5 to learn more about places you might find them.) You know what else can help you not fall prey to stereotype threat? Having support systems and feeling a sense of belonging in the math community.

4.3 Finding Community

The myth of the "isolated genius" can be detrimental to our mathematical journeys. It can lead us to believe that we are meant to study alone, learn alone, do homework alone, and consequently either succeed alone or fail alone.

> "I have learned to ask for help, to admit when I am struggling, and to lean on my professors and peers. Because—you want to know a secret? Everyone struggles. Even when you see them doing well in class, or publishing papers, or succeeding in any way, that success was most probably built on tears and sweat."
>
> — Alicia Prieto-Langarica, in *Living Proof*

Time out. Go read all of Dr. Prieto-Langarica's *Living Proof* story. It's a treasure trove of good advice that is particularly relevant to our discussions here. After you read her story, read the stories by Matthew Pons, Jacqueline Jensen-Vallin, Laura Taalman, and David Taylor, all of which center on the theme of overcoming failure and finding a mathematical community.

While there are still times when it makes sense for people to work independently, the world of STEM is more collaborative now than it has ever been. Employers *want* to hire people who can collaborate and listen, people who can work as part of a team. And teamwork isn't just a skill that you will need if you choose to pursue an industrial career. More research mathematicians (and scientists) are collaborating on research projects now than they were 50 years ago [**5**]. Professors and teachers need to work together to develop their curricula or plan the future of their departments and schools. Analysts, data scientists, and software engineers need to collaborate with economists and business executives. In short, you need to be able to talk to people about the things you're working on, share responsibility for projects, and settle disagreements in a productive manner.

If we are willing to believe that your time in college will prepare you not only with a technical education, but also with life skills, then we should also view the undergraduate experience as practice for the collaborative work you will need to do when you enter the workforce. By working collaboratively with your classmates, you can find new perspectives on solving problems and share your own perspectives to help other people grow. A rising tide lifts all boats. None of the authors of this book would be where they are today without the study groups and other communities of support they formed in school.

Of course, it can be hard to find good study buddies, and we recognize that it can be doubly difficult for people coming from minority or marginalized communities.[5] At first, it can be a bit awkward to ask someone if they want to study together. It can feel like trying to make new friends on your first day of school. And, like meeting people on the first day of school, you may go through a few awkward iterations until you find a group that is a good fit for your study habits and personality. Regardless, it is worth overcoming a bit of awkwardness for the potential benefit of making some friends and learning together. Your people are out there! And they probably feel just as awkward about it as you do.

In fact, one thing to know is that most people are at least a little fearful about working with others on math because they're worried their weaknesses will be "found out." It's easy to think that your classmates are understanding concepts more easily than you are—that they have more of a natural aptitude towards math. (This is related to the concept of stereotype threat we discussed before.) Having these—often flawed—assumptions about those around you can make you feel like an impostor who is merely pretending to be a highly capable math student. Practically everyone feels like an impostor at one time or another. Every one of the authors of this book felt like impostors at some point in our math journeys. Please know that the feeling is normal, but isolating yourself when you have these feelings is counterproductive. Instead, lean in. Intentionally engage with the material and your peers so that you can all learn together.

How can you go about this? You'll want to find people to study with who'll value your contributions to the group and make contributions of their own. If you are utterly lost in some math course you're taking, your valuable contribution to a study group might be showing up on time and asking lots of questions! If you are mostly getting a grip on course material, your contribution might be explaining what you understand to a study buddy. If you're in this situation, you'll find that explaining things will not only benefit your classmate, but will also help you deepen your own understanding. And please know that if you're on the receiving end of a classmate's explanation, you are not only benefiting yourself by asking for an explanation—you're benefiting your classmate, too. As math educators, we can attest that one of the best ways to help someone learn math ideas is to ask them to explain what they know.

Now, let's say you find yourself in a study group where you're doing all the work for a bunch of people who haven't started the homework yet. *Not cool!* Something needs to change. Setting norms and expectations for how you will work as a group is just as important as the mathematics you will learn together. If you're a Type A Early Riser$^{\text{TM}}$ who likes to have homework assignments completed 48 hours before they are due, then you may not want to join a study group that meets at 2 a.m. the

[5]In Chapter 5, we will give more information about different mathematical communities where you might seek friends and find mentors.

day the homework is due. If you process information by talking out loud, accepting that 90% of what you say will be wrong, be aware that there are other people who will only be willing to share ideas after they have had time to work on their own for a while. Knowing when to talk and when to listen is a difficult skill to master. But if you find that you're the only one who is talking, then it's probably time to ask someone else to share their ideas.

During my (SRK) first year of college, I took an honors physics course. I failed the first homework assignment and got a D on the first quiz. Not a good start from someone who was used to getting As on everything. I was lamenting this fact to some of my friends, saying I didn't think I should *need* to go to office hours. I was supposed to be smart. Fortunately, they all responded in unison: "Why not? That's what they're there for." So I did. I went to the professor's weekly homework help session. As a result, I learned a lot more and started to make friends in the class. We formed a study group of our own and met every week to discuss homework problems together. At the end of the semester, we all got A's in the class. By working together and getting outside help, we all learned more and succeeded.

4.4 Getting Back to Work

> "I know that things might not always end... perfectly. Or it may take much longer than expected to overcome an obstacle... small-scale failures like failing a quiz or exam are equally disappointing because they chip away at our self-confidence. I've learned to keep in mind that it isn't about the scale of the failure or the length of the struggle. It is about the lessons we learn along the way and the resilience we build up in ourselves. In the end, the struggle is most definitely real, but without struggle, there is no reward."
>
> — Matthew Pons, in *Living Proof*

He's right. Failure, on any scale, damages our self-confidence and our sense of self in significant ways. Do I belong here? Am I cut out for math? Why am I doing this? Is it worth it? It can be hard to get back up when you get knocked down.

Keep in mind that the struggle is part of the process. If math were easy, you wouldn't be taking classes and devoting years (*years!*) of your life to learning it. And learning is an ongoing process. The body of knowledge you amass during your time in college is only a fraction of what you will learn in your professional career. It is the middle of an educational journey that started before you could hold a pencil and will continue long after you have attended your last college class. There will be failures and successes at each step of this journey. Failure is a momentary setback, a sign that you are still learning, not a sign that you are incapable of learning. You've made it this far. Keep going.