STEM's Many Branches:

College Planning for Students Considering Majors in Science, Technology, Engineering, and Mathematics

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Why did I write this guide?

College can be a wonderful time to explore your interests, find out where you excel, and discover your ideal career. But for many students majoring in Science, Technology, Engineering, or Mathematics (STEM), college is a demanding path, and one that requires a lot of focus from the get-go. This can put a lot of pressure on a high school student.

Maybe you're interested in one or more of the STEM fields but aren't sure whether or not you should major in them. Maybe you're curious about what kind of career a STEM degree might lead to when you graduate. Or maybe you just want to get a better sense of what your life might be like during and after college if you pursue a STEM path. I wrote this guide to help answer those questions.

Why is STEM So Complicated?

The career fields in Science, Technology, Engineering, and Mathematics (STEM) are vast, complex, and very interrelated. There's a lot of mystery surrounding what engineers, technologists, scientists, and mathematicians actually do. STEM professionals are partly responsible for this. Once you're trained to talk like a scientist or an engineer, it's hard to remember how to translate what you do to someone who isn't "trained in the art" of science or engineering. These days, though, there's a real push for STEM professionals to share what they do with a broader audience. But it can still be really hard to sort out the differences. And when you're in high school, it can be difficult to figure out which subject you want to study in college and where your degree can take you after you graduate.

Who Am I?

For 12 years, I worked as an admissions officer and academic advisor for college students who were interested in studying the STEM fields. Before that, I majored in chemistry in college and spent 2 years working in research and development at a large consumer goods company (more on that later), but realized I liked talking about STEM work rather than doing STEM work. After graduate school, I worked at Purdue University, where I spent 2 years advising first-year engineering students, and then 3 years advising students majoring in mathematics, statistics, and actuarial science. I also did some recruiting for Purdue's College of Science. Those experiences led me to Cornell University, where I spent 7 years as an admissions officer for the College of Engineering. Purdue and Cornell are both recognized for their strong and rigorous STEM programs, and for good reason. During those 12 years, no matter where I was working, there was always one constant. At least once a week, I had a conversation that went something like this:

Me: "So tell me a bit about your interest in STEM."

Student: "Well, I'm good at math and science, so my [teacher/parent/counselor/friend/neighbor] told me I should be an engineer!"

I loved that students were hearing about engineering from teachers, parents, counselors, friends, and neighbors—that's great news! But not all of these students were a great fit for engineering. Some of these students were better equipped to become scientists, others mathematicians, and still others technologists. But how could they figure this out? I spent a lot of time learning to help students figure out which area was really the best fit for them, and I'm now sharing that knowledge with you.

There's a lot of overlapping when it comes to what STEM professionals do in the workforce and the kinds of projects they work on; for example, finding a cure for cancer isn't limited to any one area of STEM. But when students are considering what to study in college and how to best prepare, there can be some big differences. So in this guide, I'm going to share some "representative examples" that will help you get a sense of the differences and similarities within the STEM fields.

Beyond the STEM fields themselves, this guide will also cover some essential skills and traits that successful STEM students share, as well as suggestions for how to prepare for a STEM major while you're still in high school. I'll also share some resources so that you can explore the STEM fields on your own.

Defining STEM

While there's a lot of overlapping when it comes to career options for STEM majors (more on this later), the differences between college choices, applications, and curricula can be huge depending on which STEM field you pursue. Before you make a decision, it's helpful to first define and explore each of the individual fields.

It might seem most logical to define the fields in the order that they appear in the acronym—first covering Science, then Technology, then Engineering, and then Mathematics. Personally, though, I don't think that's the easiest way to explain them. Because they are so interrelated, I think it's easiest to understand what is unique to each field by starting with Mathematics, then covering Science, then explaining Engineering, and, finally, Technology. So that's the order I'll be using in this next section.

Mathematics

Mathematics is unusual in some ways—it is its own field of study, yet it is also a primary foundation for the other STEM fields at the same time. Most students know "math" as the arithmetic, algebra, and geometry they learn in school. In truth, mathematics as a discipline is very abstract and complex and quite different from what most students study in high school. As Peter, a friend of mine who is a college math professor, once explained to me, “You’re asking questions about the properties of the abstract mathematical universe and somehow you relate it all to pictures or counting.”

Higher-level mathematics can be tough to follow, but here are a few examples of math that’s used in the real world:

- If you’ve seen the movie *Moneyball*, you’ve seen how statistics can be used to analyze a baseball player’s performance to build a team that can win championships, and maybe even do it for less money. The movie is based on a true story, which makes it all the more interesting!

- How can we mathematically describe the way curly hair moves? The Pixar movie *Brave* needed an answer to this question in order to make Merida’s red mane move and bounce like real hair. Mathematicians wrote computer code that illustrated that movement and actually created an entirely new software package that could handle the math to make 1500 strands and segments of hair move individually to look more realistic. (http://www.wired.com/underwire/2012/06/pl_bravehairtech/)

- A book called *The Mathematics of Marriage* describes how different advanced mathematical principles can be applied to relationships, and it includes a mathematical model of marital relations. (Yes, really: http://www.amazon.com/The-Mathematics-Marriage-Nonlinear-Bradford/dp/0262572303)

Here's another example (I'm paraphrasing) that my friend Peter uses in one of his classes:

There are 52 cards in a standard deck of playing cards. When you start shuffling the cards, how many possible orders of cards are there? The answer is 52! (the exclamation mark stands for factorial). You can calculate the actual product by multiplying 52 x 51 x 50 x 49 x 48, continuing all the way down to number 1. You can tell pretty quickly that this number will be absolutely huge. If you wanted to actually list all of the different orderings of that deck of cards, it would take a supercomputer the size of the Earth itself a trillion times the age of the universe. Start listing them now! (Just kidding.) You have to come up with a clever way to solve this problem without doing any direct calculations. If working to answer that question sounds really awesome to you, then mathematics might be your thing!

Later on in this guide, I'll talk more about how you can figure out if you want to pursue the study of math itself, or if you want to use your interest in math to support your study and work in other areas.

Science

Science is really about discovering and describing the world we live in. It often focuses on answering the "how" and "why" questions of the world. Here are several examples:

- Why does acid turn mouse blood cells into mouse stem cells? How can we use this information to create human stem cells? (http://www.npr.org/blogs/health/2014/01/29/268171016/a-little-acid-turns-mouse-blood-into-brain-heart-and-stem-cells)
- What does the flu virus look like, and how can we use its shape and characteristics to make vaccines that will prevent future outbreaks?
- How do we find and identify other planets that are similar to Earth?
- How do we prove whether or not global warming exists?
- Why do birds fly in a V formation? For a long time, scientists have offered theories on the reason behind this, but technology has finally given them proof: http://www.npr.org/2014/01/15/262607399/the-science-behind-flying-in-v-formation
- What are neutrinos and how do they help keep the sun burning? http://www.npr.org/blogs/13.7/2014/01/12/261939210/the-ghosts-of-physics

Scientific discovery is rooted in the scientific method (http://www.sciencebuddies.org/science-fair-projects/project_scientific_method.shtml), which students usually study in their K-12 science classes. It involves asking a question, creating and testing a hypothesis, and then analyzing the results of the test and drawing conclusions from those results. (This is different from the method typically used in engineering and technology, but more on that later.)

Folks who work in theoretical science (the "science only" side of things) are exploring knowledge for the sake of knowledge. There might be a specific use for it later on, but that's not the reason for the exploration. The exploration is about building knowledge, and there's often no way to know if or when that knowledge will have a practical application. Sir Alexander Fleming didn't set out to discover a revolutionary drug known as penicillin. He just noticed something unusual happening in his world and approached it in a curious and methodical way. (http://inventors.about.com/od/pstartinventions/a/Penicillin.htm) That's good science.

Engineering and Technology

If science is about answering "why" and "how" questions, the engineering response to those questions is something along the lines of "Okay, so what?" Engineering is about using math and science as tools to solve problems and improve people's lives.

Once you learn about engineering, you start to see it everywhere.

- Lots of people know that designing and building cars involves engineering, but you might not realize that the roads on which cars drive, and the design of the intersections and timing of stoplights, are also the result of engineering.

- Disney World is essentially built on a swamp. It took great engineering to figure out how to build a multi-billion-dollar theme park on a swamp, and then to make sure that the swamp would not reclaim the park. And within the park itself are all sorts of engineering feats, from Fast Passes (which manage the traffic in lines) to the coasters and rides themselves. Plus, engineers have to figure out how to keep so much foot traffic and waste from damaging the swamp that's still there—and that's not easy.

- Most of us take clean water for granted—it's a well-established feat of engineering where the majority of us live. In developing areas of the world, though, it's a problem that many engineers are still working on.

- A lot of modern medical tools are based on good engineering. Scopes and monitors are the result of engineering. So are prosthetic limbs and dissolvable stitches.

- Your smartphone? Engineers made that.

You're starting to get the idea.

One common misconception about engineering is that you have to love math and science to be an engineer. That's kind of like saying that someone becomes a chef because they love to chop vegetables. If you've ever watched *Top Chef*, you'll know what I mean. The chefs talk about the creativity involved in cooking, about having a passion for food, about wanting to nourish people and wanting to create great-tasting and nutritious food. But in all of the episodes I've watched, I've never seen any of the chefs talk about their passion for chopping things as their primary reason for becoming a chef. For an engineer, math and science are like a chef's knives: primary tools that need to be used with a great deal of skill and proficiency, but tools that are really just the means to an end. If they love those tools, great! But it's not a requirement for the job.

Engineering vs. Technology

Technology is very closely related to engineering. ABET, which is the accrediting organization for engineering and technology programs, describes the difference this way on their website: "Engineering programs often focus on theory and conceptual design, while engineering technology programs usually focus on application and implementation." (You can find that definition and more here: http://www.abet.org/engineering-vs-engineering-technology/.) Sometimes technology programs are called "Engineering Technology," and sometimes simply "Technology."

Because engineering and technology are so closely related, it can be hard to separate the pure engineering from the pure technology. This chart on typical entry-level job tasks (which is modified from a lovely color slide on this Cal Poly Pomona website http://www.csupomona.edu/~et/) might help:

More mathematical/scientific

Engineering Tasks	Technology Tasks
Research	
Complex Analysis	
Complex Design	
Product/Prototype Development	Product/Prototype Development
Manufacturing	Manufacturing
Test and Evaluation	Test and Evaluation
	Routine Design
	Production
	Operation, Service, and Maintenance
	Distribution and Sales

Less mathematical/scientific

Basically, engineers focus more on theories, ideas, and initial prototypes, while technologists focus more on the hands-on component of making things happen and improving and maintaining something once it has been created. An engineer will design a new car, while a technologist will "tweak" the design to improve it for future models. Again, this isn't an absolute —some engineers focus on the hands-on side and some technologists focus on the conceptual design—but it is a general distinction.

Instead of the scientific method, engineers and technologists use something called the engineering design process (http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml). Engineers and technologists identify and research a problem, brainstorm solutions within required parameters, choose the best solution, and then create a prototype to test and refine. If the original solution fails completely, they can go back and choose a different solution to prototype and refine. Just think about all of the different solutions people came up with to try to make human flight possible before the Wright Brothers found something that ultimately worked.

Curriculums: Engineering vs. Technology

When it comes to college classes, the curriculum in a typical engineering program has a very different focus than that of a typical technology curriculum. In both kinds of programs, students will get some theoretical and some hands-on study, but the emphasis will depend on the program. In college, engineering coursework emphasizes a lot of higher-level mathematics (typically 2-3 semesters of calculus along with linear algebra and differential equations) and typically requires more pure/theoretical science courses. An engineering student can also expect to take a calculus-based physics class or two. Technology coursework tends to focus more on math at the algebra and trigonometry level, along with applied calculus and other more applied courses. A technology student will typically take algebra-based physics classes rather than calculus-based ones.

For the remainder of this handbook, I will be blending math and science under the "science" label, and combining engineering and technology under the "engineering" label. Since pure math and pure science are usually concerned with the same kinds of "why/how" questions, and engineering and technology are usually concerned with similar kinds of problem-solving and design issues, this is more or less a shortcut. I don't want to shortchange math or technology in this process, but I do want the rest of the guide to be easily understood. Where there are issues specific to math or technology, I will highlight them separately.

In some ways, the "science vs. engineering" question is an exaggerated distinction. Once you're out in the workforce, the tasks start to blend together in many cases, and there aren't a lot of real-world issues that involve only pure science or only pure engineering. At this point, though, it's a vital distinction because a number of colleges will require students to make a choice during the application process. So here's the question. Do you want to be a scientist or an engineer? A mathematician or a technologist?

Math, or...?

Students who are passionate about math often have a really tough time with this choice. Since mathematics is its own specific discipline but also a foundation for science and engineering and technology, it can be tough to make a decision about which STEM area to pursue at the outset.

A former mentor of mine, Alan, used to pose the following question to students who were debating the "math vs. other STEM area" question: *Are you more interested in knowing how to make the calculus work to solve other problems, or are you more interested in the proofs of why the formulas/procedures in calculus are working?* Someone who likes math for the sake of math is probably going to be more engaged by pure and theoretical mathematical coursework and should therefore seriously look into a math major. However, students who want to make the math work so they can use it to solve other problems will probably find one of the other areas more appealing. This isn't a perfect solution, but it gets students thinking along the right lines. And it's not unusual for students who major in science or engineering to end up taking a lot of math courses, perhaps even to the point of a double major or dual degree. It's less typical for students in technology, though, given the different math needs of most technology majors, as I described previously.

When I was at Purdue, I worked with a student while I was advising engineering majors. Shortly after I made the switch to advising math majors, I ended up working with this same student again when he changed his major from chemical engineering to mathematics. We talked about why he had made the change, and he told me that he finally realized he loved math for the sake of math. He realized that he was spending more time working the proofs in his advanced math classes than he was on his engineering calculations. And he worked them by *choice*, not because they were homework assignments. He just really loved what he saw as the beauty and elegance in the math.

Science vs. Engineering

If you already know that you want to use math to help solve problems in other fields, now is the time to figure out where you want to focus your attention. As I mentioned earlier, science majors are generally more concerned with understanding how and why the world is the way it is, whereas engineering majors like to find and create solutions to problems in the world. If you compare the scientific method with the engineering design process (http://www.sciencebuddies.org/engineering-design-process/engineering-design-compare-scientific-method.shtml), you'll get a sense of the different approaches.

When you think about your interests, are you mostly curious about how and why things work the way they do and why our natural and physical world is the way it is? Or are you more interested in harnessing facts to create new solutions to problems in the world?

If you have a pretty clear internal answer to those two questions, then you have a pretty good idea of whether you want to study science or engineering in college. When in doubt, look at a plan of study for a science major at a few different schools and compare it to a plan of study for an engineering major. Read the descriptions of the courses you'll take at those schools. If you have any "Oooh, that sounds so cool!" or "Ugh, that's not what I want to study!" moments, you'll probably have your answer.

During my time at both Purdue and Cornell, I had frequent conversations with students and families about the similarities and differences between chemistry and chemical engineering. This is a great example of an instance when reviewing the plans of study for each major made a huge difference. At most colleges, chemistry majors will take classes in organic, physical, analytical, and inorganic chemistry. Chemical engineers will also take organic chemistry, but then they'll study topics like heat and mass transfer, separation processes, and process dynamics and control. For most students, seeing those differences was a great first step toward determining which field was the best fit.

This technique also helps students understand the differences between engineering and technology. When I was at Purdue, one of the students I was advising realized in the middle of his first semester as an engineering major that he wanted to study technology instead. He figured this out when he saw what his hallmates were doing in their technology classes and realized that he was more interested in working with them on their hands-on homework assignments than working on his own theoretical calculus homework. He took a serious look at the coursework ahead of him as an engineering major, and then at what he could be doing in technology. It was a pretty clear-cut "Ooh!" vs. "Ugh!" moment for him, and he listened to the voice inside and made the necessary changes.

Real-World Science and Engineering

I know I've already said this a few times, but there's a lot of overlap when you look at what scientists and engineers do once they're out in the workforce. I'm going to give you a few examples here that show how things start to run together.

Curing cancer involves folks across all STEM disciplines. A mathematician will model how a carcinogen moves through the air or water. A scientist will explore how that carcinogen triggers cancer in a living body. Once we know how the cancer is triggered, an engineer or a scientist (or maybe both) will see what math and science facts they can use to "turn off" the cancer—such as chemotherapy. An engineer or a scientist (or both) will identify chemotherapy drugs that work against this particular kind of cancer. An engineer will design a delivery system for that chemotherapy drug. A mathematician or scientist (or both) will model how the chemotherapy drug moves through the body to minimize damage to non-cancerous cells. An engineer or a technologist (or both) will continuously improve the chemotherapy delivery system.

As I wrote earlier, my first job after college was in the research and development department for a large, well-known company. We were working with biodegradable plastic, and our team was made up of individuals from across the STEM fields who came together to try to figure out how this plastic could be used out in the marketplace. A mathematician used different models to describe how traditional plastic behaved at a variety of temperatures, and he worked to tweak the models so that they could also describe the behavior of the biodegradable plastic. A scientist (that was me!) worked on exploring how the plastic actually behaved under different temperature and stress conditions. Other scientists were modifying how the plastic was made to see if it would behave differently if it was made differently. An engineer worked to figure out what this plastic could be used for, and also made prototypes of things like plastic bags, travel-sized bottles, and plastic syringes. A technologist worked with the engineer to create and improve the equipment used to make the different prototypes.

I've laid both of these examples out to resemble something of a sequence, but you can probably tell that the work wasn't sequential. One person's results impacted the next and created new areas for scientific research or new problems that required engineering solutions. Everyone works together on a team to achieve breakthroughs. It's pretty exciting stuff.

Qualities of Good Scientists and Engineers (and how to develop those qualities now)

There are a number of skills you need to hone if you want to succeed in the STEM fields. Yes, you need technical skills, but I'm talking about the skills that go beyond just math and science.

Persistence

In high school science labs and math classes, students are asked to complete tasks where the outcomes are already well known by the teachers. In real life, things are quite a bit different. Folks in STEM are working to discover and build new knowledge and solve problems that have no existing solutions, so there are no road maps. There's no lab manual or answer key. Maybe you'll try something new and it won't work out the way you thought it might. So you tweak it and try it again. And again. And again. And again. And yet again. It can be very frustrating sometimes. But you have to keep trying, and eventually you'll get results. And it is SO exciting when you do!

You can practice being persistent in a lot of ways. If you are frustrated by a math problem, don't give up. Work on something else for a while, and then come back to it. If your jump shot isn't as strong as you'd like, don't give up. Practice your dribbling and your foul shots for a while, or walk away from the court for a bit and then come back to it. If there's a part of your piano recital piece you just can't get quite right, don't give up. Spend some time on a different piece or another activity entirely, and then come back to it. With persistence, you will improve.

Creativity

As I mentioned above, scientists and engineers spend a lot of time trying things, tweaking them, and trying them again. Sometimes the tweaks might be pretty obvious ideas, like turning up the heat a little, or changing an angle slightly. Sometimes, though, scientists have to look beyond the obvious and find inspiration in unexpected places. NPR recently ran an article on a new surgical adhesive that was inspired by spiders and slugs (http://www.npr.org/blogs/health/2014/01/08/260746223/sealant-inspired-by-beach-worm-could-become-surgical-superglue). That's not exactly where you'd think a surgeon would get his or her inspiration, but that's what makes it creative!

Creativity isn't the first quality people think of when they consider STEM careers. But innovation and breakthroughs require creativity—it's just as vital as math and science skills. And that's what keeps STEM fields moving forward. An interest in art or music or theater doesn't detract from strength in math and science. It really adds to a student's potential in the STEM fields. If you love singing or drawing or acting, or you write music or do improv comedy, keep doing it!

Patience

Since real-life work as a scientist or an engineer doesn't have a clear cut path, you can't predict when you'll have a breakthrough. And a lot of scientific experiments and design processes simply can't be rushed. You'll spend a lot of time waiting for an experiment to run, or waiting to have a complete data set of your results, or waiting to see whether or not the computer code you've written will do what you want it to do, or whether or not your first prototype will work. And these processes all require patience.

We are so used to text messaging, Twitter, and overnight delivery from Amazon that it's tough to remember that not everything happens instantaneously. And it's hard to practice being patient. (I'm not a particularly patient person, so I know this from experience!) Earlier, I talked about persistence and sticking to a problem—your math problem, jump shot, and piano piece will all improve over time if you are persistent in your work. But none of them will improve instantaneously, and that's where patience and persistence go together. You have to allow time for the work you do to show results.

Teamwork

The stereotypical image of a scientist or engineer is usually some individual working alone in a lab or at a computer. Most people assume that STEM work is solitary. This could not be further from the truth! Think of those real-world examples I shared earlier in the guide. STEM work is nearly always done as part of a team, where each individual's work relies on someone else's work and/or ideas. Sure, there are times when you might be alone in a lab or at a computer working on your own part of a project. But STEM work is far from a solitary endeavor.

In high school and in college, it can be very frustrating to work on a team. Maybe you care a lot about a particular project, but you've got a teammate who isn't pulling his or her own weight, so you're worried about the project's outcome. Maybe the person in charge of the team is insisting on doing it his or her way and won't listen to ideas from the group, even when they're good ideas. Maybe it just seems easier for you to do the whole thing yourself.

Being a good teammate is hard work, but there are a lot of places to practice this skill. The soccer team, the student council, the mission trip, and the part-time job all offer you plenty of opportunities to be a valuable part of a team. You can practice being in charge of a team, listening to others' ideas, and bringing them all together. You can also practice giving other team members the opportunity to take the lead, asserting your ideas to the team leader, and trusting others to do their share, even if they don't do it the way you would have done it. And you can practice pulling your weight and meeting deadlines, even when the project is a low priority in your life. At some point, you'll need all of these skills in STEM careers—and beyond.

Tolerance for Ambiguity

One of the most exciting things about science and engineering is that there aren't always clear cut answers. On the other hand, one of the most frustrating things about science and engineering is that there aren't always clear cut answers. In high school, there's a right way and a wrong way to do that math problem. There's a right way and a wrong way to run that physics experiment. In real-world STEM work, this is rarely the case. Yes, there are safety considerations, and you will need to be accurate and precise in your work in order to achieve accurate and precise results. And there are real-world limitations such as money…and gravity.

But beyond that, a single problem or question can be approached using any number of different ideas or methods. Some approaches will yield great results, some will yield acceptable results, some will yield poor results, and some ultimately won't yield any results at all. You don't know which ones will be best when you start out, though. You discover the best solutions through persistence, patience, creativity, and teamwork.

When I was an academic advisor, this was a major challenge for a lot of students—they were so used to the "right way/wrong way" model that they got frustrated when their professor would suggest one approach to a problem or question, a teaching assistant would suggest a different approach, and a classmate would suggest an entirely different approach. Every fall, I would have a handful of students tell me, "My T.A. doesn't know what she's doing. She can't figure out how to solve the problem my professor assigned in class. She ignored what my professor showed us and started the problem a completely different way!"

I found that students could accept this ambiguity in other areas of life—it's easy to understand why there are so many different plays in football, or why there are so many different recordings of *Beethoven's 5th Symphony* by different orchestras around the world—but in math and science, this was a revelation. Even if you complete your homework the "right way" (i.e., using the same method your teacher does), is there a different way to do that math problem and still get the same results? How about that physics experiment? If you start looking for these differences now, it'll be that much easier when you start to run into multiple approaches and ambiguous experimental results in your college classes.

Application considerations and picking a school

If you are pretty darn sure which STEM area you want to major in, choosing which schools to apply to can be pretty easy. For folks who aren't as sure, this part can be pretty intimidating. In the back of the guide, there's an appendix that lists some well-known schools that require you to select a STEM major when you apply, and other schools that don't.

Schools that don't require a declared major when you apply

There are some schools that don't require you to declare a major when you apply. These schools are great for students who have an interest in multiple areas within STEM, or who simply can't pick which area they want to focus on yet. If you decide to apply to any schools like this, you'll want to make sure that they offer whichever STEM majors appeal to you the most. You'll also want to take a look at the classes you'll take in the first year and make sure you're aware of the requirements for declaring a major in terms of grades and coursework.

You'll probably find that many of the smaller schools won't necessarily offer every single specialty in engineering and science. As long as you choose the right school for you, though, don't worry about this too much. Since the STEM fields work together, a solid STEM foundation in a major that excites you at a school you love will get you started. While you're in school, you can look for electives, internships, or activities that can give you experience in your specialized area of interest. Some students opt to work for a while before transitioning into their specialized field, and some decide to go on to graduate school.

When I worked in the industry, one of my labmates had also attended a small college. But while I had majored in chemistry, he had majored in Earth science. We were working side by side and utilizing the same skills, but we had developed those skills in different majors at different small colleges. And there was another graduate, also from a small college, who worked down the hall from us in an analytical chemistry lab. She had studied biology in college. For all three of us, developing our STEM skills and taking advantage of opportunities in college mattered more than the actual majors we selected.

Schools that require a declared major

A lot of larger schools require you to choose a major when you apply. At a minimum, they often require you to decide on "engineering" or "science" or "technology," even if you don't have to choose "mechanical engineering" or "biology" or "electrical engineering technology" right off the bat.

When you're considering schools like this, find out what steps you'll need to take if you decide to switch from science to engineering, or engineering to technology. Is switching majors allowed? How often does it happen? Is there someone who helps and advises students who want to make the change? Who decides whether or not you can make the change? How and when do they decide? Do you have to take certain classes or earn certain grades? And is there a website you can access to learn more before you even apply to the school? At a lot of schools, you are officially allowed to switch between science and engineering, or engineering and technology, but it can be somewhat complicated. That's why it's really important to spend some time thinking about which part of STEM you like the best before you apply.

There are a few ways to get a better sense of your interests. Read the descriptions of the classes you'll take in the different STEM majors you're considering and see which one sounds more interesting to you. (I've got some suggestions for this in the appendix at the end.) Check out a school's career services office to see what their graduates from the different STEM areas go on to do. Use the resource list at the end of this guide to explore the STEM areas more fully. And ask yourself the following questions that I covered earlier in the guide:

- Do you like understanding how math works for the sake of the math itself, or do you prefer applying the math to other kinds of problems? If it's the first part—you loved the proof of the Fundamental Theorem of Calculus—then take a look at majoring in math.

- Are you mostly curious about how and why our natural and physical world is the way it is, or are you more interested in harnessing facts about the world to solve problems? The first part is more of a science approach, and the second is more of an engineering approach.

- When you look at the scientific method and the engineering design process (http://www.sciencebuddies.org/engineering-design-process/engineering-design-compare-scientific-method.shtml), does one of them appeal to you more than the other?

- Are you more interested in focusing on ideas, theories, and initial prototypes, or are you more interested in taking a prototype or existing item and tweaking it to improve it? Engineers usually fall more into the first category, and technologists more into the second.

When I worked at Purdue, I read a profile of an alumnus who had graduated with his degree in materials engineering 10 years earlier. At the time the profile was written, he was working as an aeronautical engineer; his transferrable skills allowed him to cross-train and learn information that was new to him and critical to his new field. I also advised a young math major at Purdue who, since graduating, has consistently landed jobs that focus more on engineering than math. These are both examples of students who chose schools that they loved and majors that excited them and have found success in the workforce.

You might still not be 100% clear on whether you would rather be an engineer or a scientist, and that's okay. Finding a school you love, pursuing a major you enjoy, and taking advantage of all the opportunities you'll find in college are the most important pieces of this puzzle. If you make those things your priority, everything else will likely fall right into place.

Frequently Made Mistakes

I know I just spent a lot of time telling you that everything will work out even if you're not 100% clear on what field of STEM you want to major in. But the more work you can do to clarify this for yourself, the better off you'll be. You can make sure to choose a college or university that offers the majors you are most interested in, and a school that is also a great fit for you in other ways as well. And there's no excuse for not making an effort—you've got the resources and the time!

Here are a few examples of folks who have learned this lesson the hard way:

- When I was at Cornell, we specifically asked an essay question about the applicant's interest in engineering. We wanted to make sure that the student knew something about engineering and that she could see herself as an engineer. Even if the student had just discovered engineering within the past year, she could still help us to see that she understood engineering. The most disappointing and frustrating essays were from students who didn't seem to have any awareness of engineering. Those essays typically highlighted engineering clichés. The two I saw most often were "I'm good at math and science and that's why I want to study engineering," and "I want to go to med school (or law school) and I hear a degree in engineering is a great foundation for that." (There was also a healthy dose of "My parents say it's a great career choice," which didn't bode well when the student himself didn't show any engineering interest!) Students who fell back on these simplistic explanations while writing about their interest in engineering didn't help their applications. It was really hard to say yes to an applicant who didn't seem to have any idea of what engineering was really about— and students who wrote those kinds of essays were rarely admitted.

- While at Boston University, I worked with students who were withdrawing from the university for any reason. I met with one student who was withdrawing after his first year because BU didn't offer his major of interest, which was civil engineering. I assumed it was a new interest of his since he had chosen BU, but he said he'd always known that he wanted to be a civil engineer. He had no clear answer as to why he had chosen to attend a university that did not offer the major he was most interested in. As a result, he had to transfer schools to finish his bachelor's degree. A bit of simple research would have saved him a lot of time, hassle, and heartache.

- When I was at Purdue, the university offered majors in computer science, computer engineering, and computer engineering technology. At that time, each of those majors was housed in a different college on campus, and they each had their own entry point in admissions. Each of the majors covered different—although overlapping and clearly related—content. Most students had a predominant interest in developing computer software, designing computer hardware, or maintaining and improving existing computer networks, software, and databases. But every summer during new student registration, a number of incoming students would realize they were in the "wrong" program for their interests—they wanted to work with hardware design but had applied to the more software-focused program, or they really wanted to be an IT and database administrator, but they were in a track that would focus more on hardware design. As an academic advisor, it was horrible to see the look on these students' faces when they realized they were starting out their college career in the "wrong" major. It was even more horrible when they saw the number of steps and amount of time it would take to switch over (it was rarely an option to switch programs on the spot). Sometimes it would take them an extra semester or even an extra year to get the classes they needed in order to transfer into the "right" major. Reading over the plans of study of those majors BEFORE applying would have saved those students a semester or a year, and also would have prevented them from feeling like they were already behind and scrambling to keep up.

I'm not trying to scare you by sharing these examples—it is very un-Collegewise to try to scare families about the college process. And none of the situations I listed were so permanent that they couldn't be shifted. It is my hope, though, that you'll be more thoughtful than some of those folks were now that you are armed with a little knowledge and wisdom.

STEM and employment

As you're probably aware, there's a lot of talk right now about STEM training and employment, from the presidential level right on down. The details differ from source to source, but the general consensus is that STEM graduates are highly employable as a whole, and that we need people with a wide variety of backgrounds to be involved in STEM careers.

- The Brookings Institute released a study in 2013 called "The Hidden STEM Economy" that talks about high employability in STEM fields, even for graduates with 2-year degrees and certificates. (http://www.brookings.edu/research/reports/2013/06/10-stem-economy-rothwell)

- An organization called Change The Equation released a brief that talks about how folks in STEM professions were more likely to have job opportunities, even during the Great Recession. (http://changetheequation.org/stemdemand)

- The National Association of Colleges and Employers (the professional association for college career counselors) regularly shows that students heading into STEM jobs will be at or near the top of the salary ranges for students right out of college. (http://www.naceweb.org/salary-resources/starting-salaries.aspx)

Money isn't everything, and in my experience STEM education is truly at its best when it's balanced with the study of the liberal arts and humanities. But in an age of rising college costs and questions about the return on an investment of college tuition, it helps to know that STEM education typically sets the stage for careers that are financially sustaining and provides opportunities for personal and professional growth. As always, students who are full participants in their education and take advantage of the opportunities their college offers will be in better shape come graduation than students who simply "exist" in a STEM curriculum. A student pursuing STEM education simply because of the potential for a large paycheck is no different from a student who pursues a high-prestige college simply for the name. But there is a lot of room within STEM for people with a wide variety of skills and interests. You can steer your STEM education in many different directions. And we need people with a variety of backgrounds and interests to get involved (and stay involved) in STEM careers!

Explore STEM

So far, I've described each of the STEM fields and talked about how they are similar to and different from each other. I've also talked about the kinds of work that STEM professionals do, and some of the qualities that will help you to be successful as a STEM student and, later on, as a STEM professional. But what can you do *now*?

Explore STEM

At the end of this guide, there is an appendix with a variety of web resources you can explore to learn more about STEM. Here are a few of my favorites:

- **"S.T.E.M. is Cool Video Contest" from Change The Equation** (http://changetheequation.org/stem-cool-video-contest): Most of this site is for STEM professionals, but the winning videos are pretty fun tools that can help you learn a bit more about STEM. In particular, check out the videos from Activision, Dow, IBM, Intel, Raytheon, and SAS—personally, I found them to be the most engaging and informative of the videos.

- “**The Secret Life of Scientists and Engineers” from PBS** (http://www.pbs.org/wgbh/nova/secretlife/): Each profile on the left side of the site is for a different scientist or engineer. If you hover your mouse over each image, you'll see the person's “science”—from neurobiologist to architectural engineer—and the person's “secret”—from NFL cheerleader to professional wrestler. Each profile is broken down into short video clips, and they are wonderful profiles on the people, their science, and their lives. Seriously fun and seriously fascinating.

- “**Pathways to Science**” (http://www.pathwaystoscience.org/K12.aspx): My favorite part of this site is the extensive list of summer programs—many of them paid programs—available to high school students who want some hands-on STEM experience before applying to college. It also includes a lot of information on career paths for students interested in STEM.

- **Sloane Career Cornerstone Center** (http://www.careercornerstone.org/index.htm): I'll admit, this is a VERY information-dense website that doesn't have a lot of personality to it. But the information is incredibly extensive and very high quality. And it's free. If you are specifically interested in the differences between chemical engineering and chemistry, or if you want specific information on career paths for mathematicians, this is a great starting place.

Consider your high school classwork

It won't come as a surprise that you should take challenging math and science classes at your high school if you think you want to pursue STEM in college. It might surprise you, though, to know that you can't ignore your social studies, English, and foreign language coursework.

Always pay attention to your high school's particular graduation requirements. Within those, try to aim for the following recommendations for pursuing STEM study in college:

- Math: 4 years (including calculus if possible)
- Science: 3 or more years (including biology, chemistry, and physics if possible)
- Social Studies: 3 or more years
- English: 4 years
- Foreign Languages: 2 or 3 years
- Other Electives: 1 or more years

By the way, if you have to choose between statistics and calculus in your senior year at your high school, I strongly encourage you to choose calculus if you can handle the class. Most STEM majors require students to take a minimum of 2 semesters of calculus in college, and you often take FAR more than that. Skimping on your math foundation in high school can make things harder later on. Statistics is important in STEM, but even students who want to major in statistics in college should start with calculus in high school if it's available.

Develop the five qualities

At Collegewise, we believe that students should get to know themselves and pursue their own interests—there's no "magic formula" for college applications. Find out what you want to pursue and get involved. There are a number of STEM-specific activities available at many high schools, such as FIRST Robotics and Science Olympiad, but don't worry if your school doesn't offer those. Playing soccer, working a part-time job, volunteering at a food pantry, and singing in the choir all provide great opportunities for developing persistence, creativity, patience, teamwork, and tolerance for ambiguity.

Find the right college for you

Now that I'm a college counselor who makes my living helping both STEM and non-STEM majors find the right schools for them, here's one piece of advice I share with all of them: Unless you apply to a binding early decision school, remember that for now, you're just applying. You don't decide where you're actually going to go until May of your senior year.

The fact that there is a difference between applying to a college and actually deciding to attend that college is a powerful realization for many students. For example:

- You can apply as a math major at some schools and an undeclared major at others.
- You can apply to a few schools whose appeal has absolutely nothing to do with STEM programs.
- You can apply to a rigorous engineering program at one school and a psychology program at another.
- You can apply to some schools that are big and others that are small, some that are close and others that are far away, some that have football teams and some that don't.

I'm not suggesting that you should be so unfocused that you apply to 40 colleges—that's always a bad idea! But don't force a focus that isn't there yet. For now, you're just researching and applying. You'll get much more focused once you actually decide where you'll go. And a lot can change in just a few months of your senior year.

College is a time to try new things, to learn, and to explore. You might go to college and decide not to major in STEM after all, or you might decide to switch from math to engineering, or science to technology. That's all totally normal. If you just make sure you're being true to yourself and making the most of the opportunities you have at your high school and your college, you can't go wrong.

Appendix A:

A Sampling of Schools that Do (and Do Not) Require Students to Declare Engineering During the Application Process

My amazing Collegewise colleague, Arun, put this list together for some of his students and families a couple of years ago. Many thanks to him for letting me include it in this guide!

This first table is a list of some highly-ranked universities (listed alphabetically) that ask students to declare that they are applying to an engineering program during the application process. Typically, the application will be reviewed from the perspective of whether or not this student has the preparation, background, and interest to be successful as an engineering student and later as an engineer. Remember, this is NOT a comprehensive list of all schools that require you to declare your engineering interest upon application, and you should always confirm this information with the university itself!

“Yes, I’m An Engineer!”

Carnegie Mellon University	Penn (University of Pennsylvania)
Cornell University	Purdue University
Columbia University	Rice University
Duke University	USC (University of Southern California)
Johns Hopkins University	Vanderbilt University
Lehigh University	Washington University in St. Louis
Northwestern University	Yale University

This second table is a list of some highly-ranked universities (again, listed alphabetically) that do NOT require students to declare that they are applying to an engineering program during the application process. Essentially, they are admitting students to the university in general. They typically review applications with a focus on broad preparedness for the university rather than a specific program in particular. Many of these universities still ask you to provide some information on what major you think you’re most interested in, and they might even ask you to write a bit more about your interest, but an expression of interest at these schools is NOT binding. However, you should always confirm this information with the university itself.

“Maybe I’m An Engineer, Maybe I’m Not!”

Brown University	MIT
Caltech	University of Notre Dame
Case Western Reserve University	Princeton University
Dartmouth College	RPI (Rensselaer Polytechnic University)
Harvard University	Stanford University

Appendix B:

Resources, Resources, and More Resources!

This is a list of some of my favorite "exploring STEM" resources. I've also included the links that appear earlier in the guide so you can have them all in one place. They are sorted into two categories—the top half is my all-time favorite list of links for STEM exploration:

http://www.pbs.org/wgbh/nova/secretlife/ (I seriously love this web series. Hearing about the STEM content from each expert is fascinating, and I love that you can see how to be a STEM professional and still have a really awesome life outside of the lab.)

http://www.pathwaystoscience.org/K12.aspx (Pathways to Science has all kinds of information on summer programs for high school students. If you're looking to explore some STEM goodness during the summer, this is a great resource!)

http://www.careercornerstone.org/index.htm (Sloane Career Cornerstone Center has the most extensive information across all STEM disciplines of any of the links included here. Yes, it's a little on the dry side, but the content is so valuable that it's totally worth it.)

http://students.egfi-k12.org/category/k-12-outreach-programs/
http://www.engineeryourlife.org/
http://www.tryengineering.org/become.php
(These three sites are all engineering-specific with a little technology thrown in, but they do a great job of helping students and families understand the power of engineering as well as the engineering "cool factor." I promise that's not an oxymoron!)

http://changetheequation.org/stem-cool-video-contest (This is the link to the "S.T.E.M. is Cool Video Contest" from earlier in the guide. Definitely check out the videos from Activision, Dow, IBM, Intel, Raytheon, and SAS—I thought they were the most engaging and informative of the videos.)

These are a few other noteworthy links that I think are worth checking out:
http://apps2.societyforscience.org/sciencetrainingprograms/ (Another program database for opportunities targeting both teachers and students, and searchable by state.)

http://stemconnector.org/ (Billed as "The One Stop Shop for STEM Information." Daily newsletters and a national STEM events calendar are both prominently displayed.)

http://www.asee.org/fellowship-programs/high-school (The American Society for Engineering Education lists two different national summer programs that are open to students across the country. They are Gains in the Education of Mathematics and Science—GEMS—and the Science and Engineering Apprenticeship Program—SEAP.)

http://www.usna.edu/Admissions/STEM/index.php (The U.S. Naval Academy has a summer STEM program that is very high quality and provides a great experience. Interest in admission to the Naval Academy not required!)

Appendix C:

Plans of Study—A Priceless Resource!

I've included a couple of excerpts from several plans of study for you to compare and contrast. (The links to the actual plans of study shown here are included with each if you want to read more.) These plans of study are specific to their institutions, and I chose them because I think they are pretty easy to follow and understand. That means you'll be able to see some of the similarities and differences pretty clearly among the STEM disciplines. The fine details will vary with each college, but the major-specific themes I'm illustrating here will tend to be similar across colleges.

Side-By-Side Required Courses in the Major

CSU Pomona: Electronics and Computer Engineering Technology vs. Electrical Engineering

The list starts with the lower-level courses at the top and the more advanced courses at the bottom of each list. I also want to point out that there are a lot more courses required on each of the plans of study—these are just the courses that make up the core of each of those majors.

http://www.csupomona.edu/~engineering/current/currsheets/et-elect-13-14.pdf

http://www.csupomona.edu/~engineering/current/currsheets/ee-13-14.pdf

Technology	*Engineering*
DC Circuit Analysis	Introduction to Electrical Engineering
AC Circuit Analysis	C for Engineers
Semiconductor Devices & Circuits	Introduction to Combinational Logic
Electrical Circuit Analysis	Introduction to Sequential Logic
Applied C Programming	Network Analysis I and II
Introduction to Digital Logic	**Electronic Devices & Circuits**
Electronic Manufacturing and PCB Fabrication	Object-Oriented Programming
Industrial Electronics	Electromagnetic Fields
Electronic Devices & Circuits	Discrete Time Signals & Systems
Applied Network Analysis	Network Analysis III
Advanced Programming with C++	Control Systems Engineering
Digital Logic Systems	Introduction to Power Engineering
Communication Systems	Probability, Statistics, and Random Processes for Electrical and Computer Engineering
Microcontroller Systems & Applications	Linear Active Circular Design
Feedback Systems Technology	Introduction to Semiconductor Devices
Technical Communications and Project Management for ET	Introduction to Microcontrollers
Electronic Test Instrumentation with LabView	Communications Systems
Data Communication and Networking	Professional Topics for Engineers
Senior Project	Team Project

In the two lists above, check out the course title in bold: Electronic Devices & Circuits. Those are actually two different classes—one for the Engineering majors (ECE 220) and one for the Technology majors (ETE 305/305L.) Here are the two different descriptions, straight from the CSU Pomona catalog: (http://catalog.csupomona.edu/preview_course_nopop.php?catoid=5&coid=20247 and http://catalog.csupomona.edu/preview_course_nopop.php?catoid=5&coid=20426)

ECE 220—Electronic Devices and Circuits (4 credits)
Structure, characteristics, operation and biasing fundamentals of 2 and 3-terminal semiconductor devices, i.e., diodes, FETs and BJTs. Biasing, bias stability, load line methods and use of transfer curves to bias and design simple amplifier and inverter configurations. Introduction to small-signal parameters. Introduction to CMOS.
Prerequisite coursework: Network Analysis I. Prerequisite or corequisite coursework: Network Analysis II.

ETE 305/305L—Electronic Devices and Circuits (Class 3 credits, Lab 1 credit)
Frequency dependent models for BJT and FET amplifiers, frequency effects upon gain and input-output impedance of single and multistage BJT and FET amplifiers, Bode plots, differential amplifiers.

Prerequisite coursework: Semiconductor Devices & Circuits, Electrical Circuit Analysis, Technical Calculus I.

Now, I know that these two descriptions are pretty opaque for someone who doesn't already know a lot about electronic devices and circuits—I sure couldn't tell you what an FET is! But even so, it's still pretty obvious that although they have the same name and cover some similar topics, they are definitely two very different courses. When you start to dig into the content of each course, bit by bit you'll get a better sense of what the similarities and differences are between the majors you're exploring. That's how you'll start to pinpoint your own interests.

Side-By-Side Coursework for Freshmen and Sophomores

Carnegie Mellon: Chemical Engineering vs. Chemistry

As I mentioned earlier, students with an interest in chemistry and chemical engineering usually find looking at the plans of study to be particularly helpful.

http://coursecatalog.web.cmu.edu/melloncollegeofscience/departmentofchemistry/#curriculum-b.s.inchemistryandrequirementsforanadditionalmajorinchemistry

http://coursecatalog.web.cmu.edu/carnegieinstituteoftechnology/departmentofchemicalengineering/

Chemical Engineering—Fall Courses 1st year	*Chemistry—Fall Courses 1st year*
Differential and Integral Calculus	Introduction to Modern Chemistry
Designated Writing/Expression Course	Differential and Integral Calculus
Computing @ Carnegie Mellon	Physics I for Science Students
Introduction to Chemical Engineering	Interpretation and Argument
Introduction to Modern Chemistry I	Computing @ Carnegie Mellon

Chemical Engineering—Spring Courses 1st year	*Chemistry—Spring Courses 1st year*
Integration, Differential Equations and Approximation	Integration, Differential Equations and Approximation
Introductory Engineering Elective (other than Chemical Engineering)	Modern Chemistry II
Physics for Engineering Students I	Calculus II for Science Students
General Education Course	H&SS Distribution Course I
	Principles of Computing

There are a lot of similarities here in the first year. Students in both programs are taking math, physics, and chemistry—although with slightly different perspectives and emphases. (Reading the course descriptions for each class will give you more details on the differences. The links above take you to the course catalog, where you can find the different course descriptions.)

In the sophomore year, things start to split off a bit more between science and engineering:

Chemical Engineering—Fall Courses 2^{nd} year	*Chemistry—Fall Courses 2^{nd} year*
Calculus in Three Dimensions	Undergraduate Seminar I
Thermodynamics	Modern Organic Chemistry
Sophomore Chemical Engineering Seminar	Lab I: Introduction to Chemical Analysis
Modern Chemistry II	Modern Biology
Computer Science/Physics II	H&SS Distribution Course 2
General Education Course	Free Elective

Chemical Engineering—Spring Courses 2^{nd} year	***Chemistry—Spring Courses 2^{nd} year***
Fluid Mechanics	Undergraduate Seminar II: Safety and Environmental Issues for Chemists
Mathematical Methods of Chemical Engineering	Professional Skills in Chemistry
Lab I: Introduction to Chemical Analysis	Modern Organic Chemistry II
Physics II/Computer Science	Lab II: Organic Synthesis and Analysis
General Education Course	Inorganic Chemistry
	H&SS Distribution Course 3

At this point, you can see that the curricular paths are starting to diverge. You'll see this kind of split pretty clearly in most science vs. engineering curricula.

Side-By-Side First Year Math vs. Engineering

Purdue University Core Mathematics vs. First-Year Engineering

http://www.science.purdue.edu/docs/study-plans-2013/core-mathematics.pdf
https://engineering.purdue.edu/ENE/InfoFor/CurrentStudents/FYE%20Plan%20of%20Study%202014

When you look at these two curricula side by side, it looks like the math major is a walk in the park compared to the engineering major. I promise you—it isn't. But at least on this campus, there is much more flexibility when it comes to the math major's schedule and requirements in the first year when compared to the first year of an engineering major. And that's not terribly unusual. (Remember when I said that it wasn't unusual for a student to major in math and a science, or math and engineering, at the same time? This'll help you see why!)

Core Mathematics	*First-Year Engineering*
Calculus I Selective	Calculus I
Calculus II Selective	Calculus II
English Composition (10600 or 10800)	General Chemistry I
Computing Selective	Transforming Ideas to Innovation I
Language I Selective	Transforming Ideas to Innovation II
Language II Selective	English Composition (10600 or 10800)
Free Elective (MA 10800)	General Education Elective
Teamwork Experience	Physics I
Free Elective	Science Selective
Free Elective	
Free Elective	

You can repeat this process with any college or major you're considering, and I definitely encourage you to dig into them.

About the Author

Meredith Graham earned a degree in chemistry from The College of Wooster and was an associate director of admissions in Cornell University's College of Engineering. She is currently the director of Collegewise – Lexington, Massachusetts.

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