

Advice to Undergraduate Engineering Students

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Introduction

By my experience as a college student, both undergrad and grad, and as a professor for some 30 years, I have gained many insights into what science and engineering students can do to improve their learning, understanding, and grades, as well as maximize their career opportunities. Here, I share a few of those insights. Some of the advice centers around choosing to do an undergraduate research project. Although not a requirement for graduation, it is important in many respects, and is discussed here at some length.

1. Become involved in your studies

Very often, a topic will be introduced to students without much context, or the student will not fully appreciate the relevance and context of new material even after a short introduction. Context is critical to understanding new material because it provides a frame of reference to which new learning can be connected. Don't be afraid to ask your engineering professors, "How will we use this material in the future?" or "Why is this material important?" Some material forms the foundation for more-sophisticated concepts, and as such must be mastered first. It may seem that the material isn't relevant, and at the level it is being taught it may not be so directly, but after another course that builds on the material, it could become essential in your development. Be assured that textbooks and engineering curricula are thought out and planned by faculty, both individually and in committees, in order to deliver the most value within the short three years of your major.

Another aspect of engagement with your class material might be due to intellectual curiosity. By that, I mean going beyond caring only about your grade. Of course grades are important, and good grades ought to be a high priority in your life. However, don't be afraid to risk a little bit of spare energy being intellectually curious by exploring more deeply into a topic that interests you, or seeking a deeper understanding of material presented in the textbooks. Strive to *understand* what you are taught, in addition to being able to get the right answers on homeworks and exams. After all, the purpose of the homework exercises is to promote understanding as well as skills, but that won't happen unless you ask questions. Be like the proverbial child, always asking "why?" Try to see connections amongst your classes. If a concept shows up in two different classes, try to rise above the material and figure out what it is in common between the two that makes that concept relevant to both. When you see an equation, ask "What are the units used in the equation?" "Why are these the units?" "Why does the equation have this form?" Look for physical meanings in equations, so that you can understand them from first principles.

Here is a simple example. A traveling wave has group velocity, or speed, $v = fl$ where f is the frequency in cycles per second, and l is the length of one wave cycle in units of distance, say meters. Why does this equation make sense from first principles? Well, if a wave of length l is emitted from a source in one cycle, and one l of length is generated for each cycle, then f wavelengths are generated each second, and the wavefront will progress by f times that length for each cycle in each second. So, the speed of the

wavefront is just the frequency times that wavelength. Most equations can be broken down in this way, but sometimes it isn't so obvious, and a deeper understanding can almost always be gained by looking deeper into the material that you are studying.

2. Get to know your professors (through office hours, research, or as your advisor)

You will eventually apply for a position, for either for an internship, full time job, or admission to graduate school. A successful application will require references and perhaps an interview. References from your professors can read like this- "I had Mary in my class for one semester. She did well on the exams and finished the course near the top of the class." In general, you would be better having a personal reference that can say more about your personality, work ethic, skills, etc. You might get to know your professors better by attending office hours regularly, talking with your advisor or mentor, or doing undergraduate research or some other project. For example, if you did an undergraduate research project, the reference letter could read like this- "I got to know Mary very well as her advisor on an undergraduate research project. Mary spent two semesters as a member of my research group, and helped in the development of a motor control system that was used in my laboratory. Mary was very productive.... Her skills in the lab were..... Mary also got along very well with my graduate students and proved very helpful in....." I think you get the idea.

Also, an interview can be spent talking about your class projects and homework assignments, which will likely not be unique from the interviewer's perspective, or you can display your knowledge of, and enthusiasm for, a special topic and experience that you obtained through a project such as undergraduate research. The value of showing that you have been industrious and capable of learning independently in some depth will be much more impressive.

3. Start preparing early for what comes after graduation

Think ahead. Do you want to go into industry or continue your education in graduate school? This is a difficult choice, but considering this early will have benefits. Talk to your friends and your instructors about what opportunities are offered in each path. There is too much to say about this topic here, but many engineering departments or colleges offers a session each semester about applying to graduate school. You should try to attend one in your sophomore year, and not wait until your junior year to start considering your options.

Doing an undergraduate research project is becoming a greater part of graduate school applications. I am not saying that is an absolute requirement, but it definitely gives you topics to discuss in interviews and to write about in applications, not to mention the actual experience of learning about research. If you think you might have graduate school in your future, strongly consider doing an undergraduate research project with a professor that you either would like work with, or who does research in an area that interests you. Do NOT be afraid to approach your professors. They welcome the interaction, and understand that having undergrads in their research groups is good for everyone.

4. Write in your textbooks, and keep them

By this, I don't mean doodle during class. I mean that you should record your thoughts during your study times. This presupposes that you are carefully reading your textbooks, and striving for understanding. If you are doing this, then you cannot help but have questions (which you should record for later interactions with your fellow students and instructors) or, even better, insights and realizations that come only after you have worked through difficult material. You might jot down a page that has a figure on it that you frequently refer to in order to save time searching for it. Or, you might rewrite

equations that appear in a previous chapter but are needed in later material for deriving something new.

To me, a good textbook is one that is marked up with notes, thoughts, shortcuts, equations etc. and one that you will not want to sell because it is a diary of your struggle to master the material. In that capacity, it could be of life-long value, and you will not want to part with it.

5. Maximize studying effectiveness

My personal experience as an undergrad was that I could not “shoot for a grade” and get it. If I had thought that a “B” was good enough, I did not want to risk missing the target and getting a “C.” Therefore, I felt that I had no choice but to put as much effort into studying as possible in order to not fall short. So, my goal was always an “A,” and sometimes I fell short anyway. I like to say that the hardest I ever worked was for the “B”s that I got. Had I not worked so hard, I could have gotten “C” or even worse. Sometimes the material is just plain difficult, and there is no substitute for slogging through it as much as you can.

In order to achieve the best outcome, I always read the material three times. First: to get the lay of the land, familiarize myself with the overall concepts and connections. Second: to learn the material in depth; really do the thinking. Third: to review for the exam; solidify the materials. Anything less than three times through, and I just couldn’t get it well enough to get the grade.

6. Strive for excellent communication skills

There are basically two modes of communication that are somewhat independent: written and oral. Know this: you will be judged on your ability to communicate in both modes throughout your professional careers. The better you are at communicating, the more likely it will be that you will advance in your career. Improving your communications skills will be a lifelong task. You can never reach perfection, and therefore should always be in the process of self-evaluation and improvement.

There are two underlying components to good communication: mechanics and logic. By mechanics, I mean using good speaking and writing skills such as grammar, vocabulary, presentation, etc. By logic, I mean using good sense about the intent and flow of your communication. My guiding principle is that *good communication cannot be obtained without clarity of thought*. Forcing yourself to communicate well is the same as forcing yourself to understand the material well enough that you can get others to understand it. This is not easy, and takes time. If you cannot teach something, then you likely don’t understand it yourself. Take every opportunity to teach material to your classmates. Good communication skills will serve you well throughout your career.

Regarding mechanics: There are about a thousand details of grammar and sentence structure that you might acquire with good writing skills. That is way too much to go into here, but I can tell you that good writing comes only with constant attention to detail, plus many edits and rewrites. If you want a truly good document, give yourself the time to look it over several times. Each time you read it, focus on a different aspect to improve. Finally, a word about “typos.” Many submitted documents are sloppy, containing misspellings, sentence fragments, and other errors. Often the authors get by with that kind of product. However, if you really want to impress your reader and show that you really care, you will go through it carefully to eliminate errors. My personal feeling is that attention to detail will make the best impression and increase the chances that your document will be successful, be that for a grade, a request for funding, or for publication.

Here is some advice about presentations, including the use of Powerpoint (the *de facto* world leader in presentation formats).

1. No matter what you communicate, “Know thine audience.” Decide going into a presentation whom you are speaking to. Are they experts, undergrads, coworkers, lay people, supervisors, etc.? You need to reckon how much background material to include, and at what technical level the presentation should be, before you get to your topical material. Never give a talk without providing context and background, even if it is short.
2. All communication, written and oral, should tell a story. You should clearly understand what your story is. Why is what you have to say unique and important? State that up front, and then defend it for the rest of the talk (or paper). Each slide supports the story.
3. Make the text large enough that the audience is comfortable.
4. If you use figures, and just about every slide should have one, make it as large as space will allow. The same as font size. Don’t waste space. White space on a slide is wasted space. That isn’t the same as making it busy – just make what you have as large as you can.
5. Don’t use complete sentences on slides – as a general rule, use bullets and sentence fragments.
6. Do use those bullets to help you recall your own points as much as to inform the audience. They won’t know the difference.
7. Read over your slides carefully to eliminate typos and other errors. It just doesn’t look good to have mistakes on your slides.
8. Do not memorize your talk. Rather, memorize what you want to say and the order of your slides. Know your own story and why each slide supports it. When you give the talk, you will then have a familiarity with the material that will absolve you from having to memorize it, and you will present yourself as relaxed and natural.

7. Conclusion

In this paper I have tried to give you the benefit of lessons learned throughout my education and career. Many of the lessons have taken me years to learn. I encourage you to strive for excellence, which comes only with hard work. It is worth it.