

Encouraging Achievement in Engineering Classes

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Introduction

How often have you scratched your head over that engineering student whose performance at the end of the term did not match the abilities and potential that you saw in class? It's easy to slough this behavior off as laziness, as having too many outside interests, or even as a mismatch of teaching and learning styles. These students often will tell you that they are trying to do the work and that they really like the class, but they rarely earn more than high C's. Perhaps there is an explanation for this seeming disparity. If the student is really trying but not performing up to either your or the student's expectations, the gap between perceived ability and actual performance may have an explanation. This paper will look at the possibility that these students may have an "under the radar" learning disability. In other words, there is a learning disability of some sort, but it's not severe enough to be found in a formal diagnosis. Over many years of teaching, this prognosis has become more apparent to this author while observing and helping students with these characteristics.

Student A

Let's look at two typical students whose grades were lower than it seemed they should be. I'll introduce you to Student A who is an average student in Engineering Technology. The professors would say this individual is not their favorite student because of a seemingly non-caring attitude in class. The individual doesn't participate unless called on but is able to answer oral questions well and often asks perceptive questions. The student performs about average on tests but some of answers are excellent and explore an area that even the professor hadn't thought of. A professor might even suspect cheating because of the wide range of quality on homework and tests.

Meanwhile the student has found a co-op job with a local company, and after several co-op terms, is considered by his boss and co-workers to be one of the best co-op students they have ever had. The strengths they see are the ability to relate to employees, perceive problems, and work on solutions without even being asked. In fact, they offered the student a full-time job with the engineering staff at a handsome salary after graduation. It wasn't until the college records went to personnel that management became aware of his GPA. The company's policy was to hire engineers who had over a 3.0 accum – student A's grades were a 2.5. Although the boss was shocked at his lackadaisical grades, he had no problem with the student's performance on the job. Clearly Student A could apply classroom learning outside the academic environment but had trouble with traditional assessments in school.

Student B

Student B provides another example of a student with a borderline learning problem. This student was not a star in the mechanical engineering technology classes, receiving C's in both Fluid Dynamics and Metrology. However in the Senior Project course this individual became the team leader and was responsible for keeping everyone on schedule, communicating with the team, dealing with the customer, and producing the final product. This student handled all the tasks far better than expected and was a surprising natural leader. The student positively impressed the two professors who taught the course, the company they designed the product for, and the team members who had not seen these abilities at all in the classroom.

Clearly, both students had the skills and abilities that just didn't show up in class work but which became apparent when they needed to be productive on a job. The challenge becomes finding ways to help individuals like these two students increase their self-confidence in class to earn better grades and to ensure confident performance on the job.

Challenges presented by college classes

It's a rare college professor who isn't aware of learning disabilities; however, this paper is not about students identified with learning disabilities, but it's about those with milder symptoms. Just because a learning disability is not found in formal evaluations does not mean that it is non-existent. Learning problems can be minor but still interfere with a student's learning especially in the more rigorous engineering classes. Many intelligent students manage a learning problem quite well through high school, but the challenges offered by college curriculum may begin to tax the student causing frustration and disappointment. The student may wrongly conclude that his intelligence is just not as keen as he thought.

Trying to determine why the student is not performing to expectations can be very troubling for the professor. And it is even more frustrating for these students who are probably being told by professors that their performance could be much better with a little more application to the subject. Put yourself in the shoes of one of these student hearing the same mantra that he has heard from teachers and parents possibly since grade school. By the time this student reaches your class in college, a less-than-positive attitude and various defenses may be well in place. And often the student can give no reason for this attitude or lack of better performance.

Engineering programs typically get the students who are very capable academically. These individuals have been successful in math and science classes in high school. Often their intelligence alone allowed them to overcome or mask learning problems in high school. These disabilities will still allow them to perform adequately in academic work because these students have learned a few techniques that help. But with the expectation in college to learn new material and complete most of the work outside the classroom, these students are having to learn lots of new ways to deal with a learning problem.

Prevalence of learning disabilities

Students with disabilities are attending college in increasing numbers. According to the National Center for *Education Statistics* (1999), of those students who graduated from high school in 1992, ...56% of students with learning disabilities enrolled in college, compared with 70% of students who did not have a disability. This postsecondary enrollment trend has resulted in the percentage of full-time college freshmen with disabilities increasing from 2.3% in 1978 to 9.8% in 1998.¹ With this increase in students with identified learning problems, we must conclude that the number of students with some form of learning problem not identified is also on the increase. Research in this area of learning problems that are not as severe is almost non-existent but it makes sense that there are many students who fall into this category.

To make it even more difficult to identify these students informally, research is emerging that deals with gifted students (generally those with an IQ of 140 or higher) who can also have learning problems. So a very strong mind can have “disconnects” that interfere with learning in the classroom. As these students move from high schools to college or from high school to job to college, discrepancies widen between expected and actual performance. These students may impress teachers with very outstanding abilities, but contradict that the image with poor performance in other areas. Often they do excellent lab work but do not do as well in the classroom portion of an engineering course. And it’s in the academic, not in job performance that these students find problems. Granted there are students who should not be in engineering classes, but faculty members can recognize the difference between those who do not have engineering abilities and those who can complete the courses successfully.

The gifted student with learning difficulties

To better understand these unique students, it is helpful to see what research has found about these students with learning disabilities identified as gifted using traditional methods. The learning problems do not all start at the same age. Some display problems in school from a young age, while others encounter frustration only when the material and content become increasingly more challenging.² Some students with reading problems, for example, develop excellent auditory memories that enable them to memorize books and passages, and this ability helps them to mask their inability to read until later in their education.³

Accumulated research evidence supports the contention that gifted students with learning disabilities represent a very heterogeneous group of students, which makes it difficult to make broad generalizations about this unique population. Ries reports on research that shows “First, these students need focused attention on their gifts and talents -- rather than the usual singular focus on their disabilities. Second, talented students with learning disabilities thrive in a supportive environment in which their individual abilities are valued and appreciated. Third, students need to obtain a unique set of strategies to compensate for their learning problems in addition to the content instruction they so often receive. Finally, gifted students with learning disabilities must understand their unique pattern of academic and learning strengths as well as weaknesses in order to learn to compensate for these discrepancies.”

Can these students perform in engineering careers?

It is not uncommon for faculty to look at students with learning problems and wonder if they really should be in the field because of learning difficulties. Surely, they will continue to need special help and concessions to find success in the workplace. It is easy to say that good students already exist in our classes, so poor performers should find new fields to study – not engineering. However, these individuals can find success without special accommodations as described in the introductory stories of Students A and B.

Many successful scientists have enriched our lives while dealing with their own learning problems.. The lists of notable people with either proven or conjectured learning problems include Henry Ford, Thomas Jefferson, John Chambers (Cisco), Albert Einstein, Alexander Graham Bell, Michael Faraday, William “Bill” Hewlett, Galileo, and Leonardo Da Vinci.⁵ Our lives might be quite different without their contributions. Possibly having to find new pathways in the brain to solve problems may actually allow these individuals to view them in a new way and thus provide a novel solution. In other words, innovation is a product of a brain that needs to find a different route to learning and understanding an environment.

Symptoms of a learning problem

The students with minor learning problems may be identified informally by looking at several behaviors that are even more pronounced in those formally identified as learning disabled students:

- They are more unorganized. They may keep all their materials for all classes in one notebook or take too much time to find an assignment.
- They might forget homework, class starting time, or class meetings that occur outside the normal routine.
- Often they can answer questions very well in class and show insight when talking about the subject, but then display disappointing results on a test.
- They come to class without all their materials. For example, this student may take a test without a calculator because he left it was back at the residence, or not have a pencil to begin a timed test, or not turn in a completed assignment because a page got “lost.” These are definite handicaps getting better grades on tests and assignments.
- And finally performance on hands-on assignments and labs are far superior to their work in class.

These learning characteristics do not disappear with time. A poor speller will always need to check for errors in spelling before submitting a final draft. Students who have difficulty memorizing mathematical formulas may need to use a calculator to assure accuracy. Thus, simply providing remediation for dealing with weaknesses may not be appropriate or sufficient for the student with learning difficulties. Remediation will make the learner somewhat more proficient, but probably not excellent, in areas of weakness. Baum states that students who have difficulty with handwriting will ultimately fare much better if allowed to use a computer to record their ideas on paper than they will after years of remediation in handwriting.

If the above description brings individual faces to mind, you've encountered students with a learning problems that are not severe enough to be formally diagnosed. However, a learning problem is interfering with their performance in your class. These students should not be confused with those who don't try or who haven't learned to budget time to include studying. The students this paper concerns are those who try but just can't seem to perform as either you or they expected. They will not display all these characteristics but will have more difficulty in one or two areas that interfere with his ability to get the top scores that match his intellect.

Personality traits

Often students with these borderline learning problems are perceived by their professors as being uncaring and unenthusiastic about the class. They may also be the first to complain of having too much work outside of class. True learning disabled students have support staff on campus ready to help them. Many take fewer classes to give them the extra time needed to study and prepare for classes. They learn time-management skills from staff trained to work with them. They also have extra time to complete tests and homework. However, students with a borderline learning problem remains frustrated because they don't know why they're having problems. Long-term class assignments are overwhelming to someone who has trouble figuring out how to start an assignment. Both starting assignments and knowing when they are finished - especially on assignments that involve scenarios rather than actual experiences - are difficult for the these students.

It becomes clear that these students are confused by too much input at one time. And if these students are less than cordial, it's because they have learned that they are not perceived in a positive manner when called on in class to talk about new learning when they may need to internalize it before they can comment clearly. Research is lacking on identifying and providing the right type of learning environment for these students. However a new trend called Universal Design may hold some answers.

Strategies

Scott, et al, suggest that educators adopt Universal Design, a concept conceived by the architectural community. For instance, how often have you chosen to use a ramp to enter or exit a building rather than use the steps? If you have, you have enjoyed the benefit of Universal Design. Using this paradigm, instead of reluctantly making an adjustment for the handicapped in a building design, architects decided to try to make it a viable part of the architectural design so that anyone could use the design feature. Scott continues by asking if there is an analogy for instruction in higher education. She suggests that methods that work for a minority of people might benefit a much larger population of students in the classroom and build-in approaches to learning and assessment that are more inclusive of a broader range of learning needs.⁵

So what does a classroom look like that is helpful in promoting learning for those who struggle with some physical impediment to learning? Must professors take weeks of training in order to work with learning problems that are unidentified? Thankfully not. Helping these students achieve at a level commensurate with their abilities is not a task that will require a lot of extra

work for the professor. The methods described below will benefit all students especially those who are ESL students, those having trouble adjusting to a more complex learning environment than they had in high school, or those trying to cope with life and learning in a new geographic or economic arena. Just as we often find ramps more convenient as we enter a building, what works for one, might just serve others as well.

This paper proposes a formula for building success for students with some learning problems. It includes three areas in the teaching/learning environment - physical, evaluation, and environment. Without much time involved, the instructor can control these elements in the classroom.

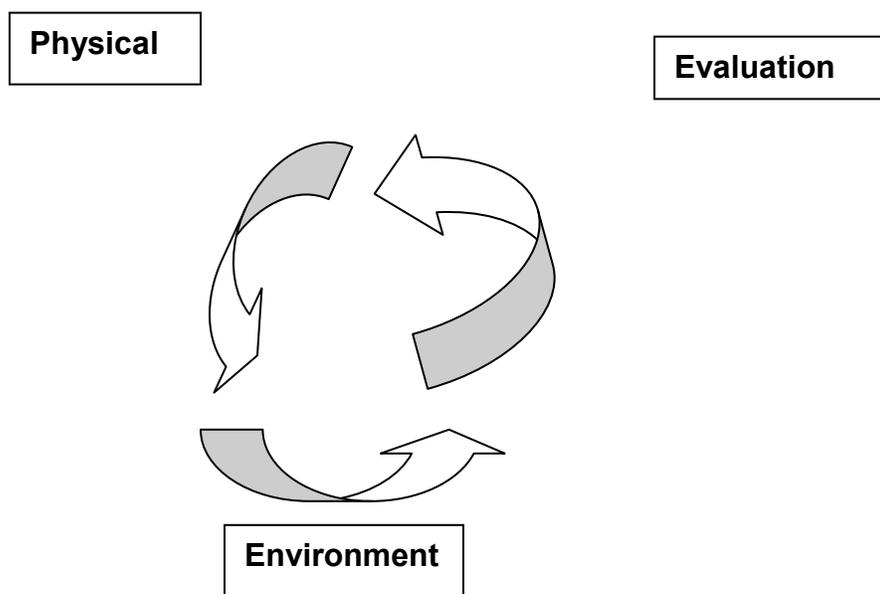


Fig. 1. Three areas that benefit learning for the C+ student

Physical

The physical changes will take only a small amount of time for the professor but will help students who have organization problems. These changes mostly involve visual solutions since many of these students are better visual learners than they are auditory learners. The lists include traditional best practices for the learning disabled as applied to the engineering classroom.

1. Use different colored paper for different types of information.. For example, to help students organize due-dates for projects, tests, and homework, handout a calendar with all assignment deadlines on red paper. In addition, use one color for assignments, a second for readings, a third for syllabus, etc.
2. Hole-punch all assignments and insist that students keep a three-hole notebook for your class with all the handouts and assignments in it. Grade these several times during the term to stress its importance.

3. Create checklists for students as they do assignments. This will help all students get started and know when the assignment is completed. (See Fig. 2.)

Sample of a class assignment using a checklist for a programming class using Excel VBA

1. Download the class grade sheet and do the following:
 - ___ Use Excel tools to add the grades and total possible up to this week.
 - ___ Use Absolute Cell Reference to find the percent for each student.
 - ___ Turn the percents into whole numbers using an Excel formula or macro code.
 - ___ Write a macro that uses a loop to put letter grades in the last column: A = 90-100; B = 80-89; C = 70-79; D = 60-69; F= below 60.
 - ___ Add code to the macro to total the number of each letter grade and report the letter grade and number on the spreadsheet.
 - ___ Add code to color your row something other than white.
 - ___ Copy this grade sheet to an empty sheet and determine your grade if you have perfect scores through the end of the semester. Determine your new final percent.
 - ___ Insert the spreadsheet into a memo to your faculty advisor that tells how you are doing in the course.
 - ___ Size the spreadsheet to fit on the memo.

Fig. 2. Example of an assignment with checkboxes.

4. Allow students to work in groups for some assignments so that more verbal students can talk about the work as well as complete the assignment. Talking about the assignment will help establish vocabulary, pattern a method to do the work, and focus on more than one modality. For instructors reluctant to have grades based on group work, start with group time in class and then require that the final product be individual only.
5. Provide a calendar of due-dates and encourage students to keep personal calendars with them as a reminder for all their classes.
6. Encourage students to use a different colored binder for each class to help keep class materials separate and organized.
7. Suggest or demonstrate using flashcards to help memorize terms, formulas, or procedures.
8. Publish the grade criteria for each assignment.

Environment (Classroom Management)

In the Classroom

Environmental aids will require setting some standard practices that occur in each class. The following strategies will give instructors a focus for establishing a positive learning environment in the classroom.

1. Begin each class with a reminder of due dates, assignments, and other grade-generating materials.

2. Repeat major concepts verbally as well as in writing and rephrase them in several ways to help understanding of new material. It is also helpful to have students try to explain major concepts either orally or in writing as they understand them.
3. Stick to a routine for class structure, i.e., start class with assignments and due dates, present material, summarize material in the last few minutes of class.
4. If you have some good mnemonic tricks to learn material, teach them to the students.
5. Provide plenty of examples when teaching new concepts.
6. If possible, allow students to start homework in class to allow for questions and clarification.

In the Lab

1. Provide an orientation to the laboratory on the first meeting day to familiarize the students with the name, purpose, and safety issues of each piece of equipment.
2. Provide checklists for using machines with multi-step operations and include any results they will see if they use it correctly.
3. Compliment areas of strength in student's lab work as much as possible.

Evaluation

Testing and grading are always stressful for the student with learning problems. To alleviate some of the stress and fear of testing, the following strategies can help:

1. Use a variety of methods to test knowledge such as matching, multiple choice, and essay. In a programming class, I use problems where they create code to solve a problem, fill in blanks in already finished code, write code from a flowchart, and create a flowchart from code. By using different logical paths you allow the student a chance to use a strength to prove they know the material. You won't use all methods for each test, but vary the test style during the term to assess learning.
2. Give lots of quizzes or tests throughout the term to allow students who have built up a fear of failure to get used to having evaluations. As students gain confidence, they are more prepared to take major tests during the term. Provide both take-home and in-class quizzes.
3. Using projects rather than just tests to allow a more hands-on approach to demonstrate learning.
4. Give students choices of test questions such as:
 - a. Answer two of the following three
 - b. Choose either the multiple choice or essay question for #4
5. Allow for the creative response: How would a mechanical engineer solve this problem if he didn't have a calculator? OR What are three solutions to make this circuit more efficient.
6. Break larger assignments into sections with different due dates at least for rough drafts.
7. Try as much as possible to inform students of the exam format and what portions receive the most points. Most teachers find that *all* students worry about this aspect of exams, and appreciate the information.

Student reactions

In an informal survey of engineering technology freshmen in computer programming classes over several semesters, students of all abilities ranked having the grade sheet included with the

assignment and having a list with checkboxes as part of the assignment as the most beneficial. Close behind were having a partner to help with new learning before tackling the independent assignments, and having their progress in class posted weekly. Many also mentioned that having the assignments, deadlines, and any other class material available on the web was also very useful.

The above lists are common for learning disability students, but were adapted more to engineering classes. However, each class has unique needs and the course content will dictate which of these suggestions will work.

Since there are no formal assessments to find the student with minor learning disabilities, applying some of these that work with students with identified disabilities techniques in the classroom and labs will help students with less severe problems. As students use some of these methods and find them helpful, they will begin to incorporate them into their preparation for other classes. For instance, after using a checklist, students might start creating them for assigned problems or case studies in other classes. Using color as an organizing technique is easy to implement after students see the benefits of good organization.

Conclusion

The burden of learning rests with the student, but removing detours on his road to achievement is the responsibility of the classroom teacher. Often just indicating interest in a student's performance or doing some individual counseling to suggest ways to improve learning will be enough to encourage a student to excel, but others may need more help in the classroom to improve. Implementing some of the ideas from this paper can help the student with learning difficulties achieve with less frustration and provide this student with tools that will enhance performance in other classes also.

These students will be successful on a job and a credit to their university, and with a little help in the classroom they can have success in their academic life as well. Everyone has strengths and weaknesses, and helping these students use their strengths to overcome the more pronounced weaknesses can lead to a grade that matches their potential.

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