Personal Experiences Providing Engineering Education to a Quadriplegic Engineering Student

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Abstract

The author relates his experiences teaching and advising a quadriplegic baccalaureate engineering student. The author concludes that available time and the instructor's full appreciation of the processes by which the quadriplegic student must accomplish tasks are essential to successfully providing that student an engineering education. Furthermore, the author believes that the entire process could be improved, with changes in how academic institutions, the federal government, and other third party organizations operate and provide support to such students. Instructors teaching engineering courses with a quadriplegic student must be aware of the unique circumstances faced by such a student. While the quadriplegic student must be held to the same academic standards as other students, the process by which the student performs his or her work and is evaluated must allow for the student's unique circumstances. The author has observed it requires a quadriplegic student two to three times longer to accomplish most technically-oriented tasks than a student who is not quadriplegic. This means that a quadriplegic student can not be expected to successfully take the same number of credits in technically-oriented courses as other students. Consequently, the author believes financial aid decisions should consider this fact. Additional considerations include textbook choices, where selection of an electronically available text can have a tremendous impact on the quadriplegic student and the teaching institution's support structure, especially in regard to the time needed to convert paper texts into an electronic format. Finally, there is a tremendous need to develop engineering education oriented software which a quadriplegic student could easily use. This software would significantly decrease the time required for such students to accomplish technically-oriented tasks.

I. Background Information

While an accurate description of the number of quadriplegic baccalaureate engineering students could not be found, the number of such students in colleges and universities in the United States is small. This assertion is based upon the following. First, as far as was known in 2000, the student discussed in this paper was the first quadriplegic baccalaureate engineering student in the College of Engineering at The Pennsylvania State University. This is significant because The Pennsylvania State University perennially ranks in the top three engineering schools based on the number of undergraduate engineering degrees conferred. Furthermore, by using statistical data from several different sources, provided in Table 1, the number of quadriplegic baccalaureate engineering students that are first-time freshman can be roughly estimated.

Data Description	Numerical Value	Source
First-Time Freshman Reporting an Orthopedic Impairment in 2000	4,699	Henderson[1]
Percentage of Freshman with Orthopedic Impairment Enrolled in Engineering	6%	Henderson[1]
Percentage of Individuals with Orthopedic Impairments Who are Paralyzed	13%	LaPlante[2]
Percentage of Individuals With Spinal Cord Injuries Who are Quadriplegic	49%	Anon.[3]

Table 1 – Data Related to Estimating First-Time Freshman Quadriplegic Baccalaureate Engineering Students in the United States in 2002

Using this data, the number of quadriplegic baccalaureate engineering students who were first time freshman in the United States in 2000 is estimated at 18 as follows:

$$4{,}699 \times 0.06 \times 0.13 \times 0.49 = 18.0$$

While neither indicator is particularly scientific, what is important to realize is that the number of such students is quite small. As a result, information is likely to be gathered one student at a time.

II. Introduction

The purpose of the paper is to discuss the author's experience in providing engineering instruction and academic advising to a quadriplegic baccalaureate engineering student and to draw conclusions about this process and make recommendations that can improve the prospects of such students successfully completing their education. The majority of the academic experience comes from four courses that I taught to the quadriplegic student, which can be broken into two general categories. The first category is freshman-level introductory engineering courses, while the second is sophomore-level engineering mechanics courses. Each category of courses presents different types of challenges for the quadriplegic student and the instructor and will be discussed separately. Based on the discussion, two predominant issues will surface: time and process. While the discussion will center on the student and the instructor, I believe the effort of additional entities will be required to significantly improve the process by which quadriplegic students pursue an engineering education. These entities include the educational institution, the federal government, software developers and philanthropic organizations. Additional perspective into the experience of the student was gained because the instructor also served as the student's academic adviser. Some of this perspective will be presented; this is possible because the student granted permission to share the information.

The remainder of the paper will begin with a discussion of the two types of courses and insight gained by advising the student, which will then be followed by a detailed look at the implications for the different entities, the student, the instructor, the academic institution, third-party organizations, and the federal government.

III Freshman-Level Introduction to Engineering and Design

The first course in which the author taught the quadriplegic student was a freshman-level introduction to engineering design and graphics (ED&G 100). This course is comprised of four distinct components: traditional paper and pencil technical drawing, laboratory work, design projects, and an introduction to computer tools. The design projects and the physical laboratory experiments were conducted in groups, and as a result the physical limitation of the student did not require any special accommodation. The compilation of the laboratory reports, done by each student, was accomplished by the quadriplegic student with a word processing program run on a computer which the student operated by using a special mouth-operated pointing and clicking device and voice recognition software. The group design projects were themselves composed of different facets; this allowed the group to allocate the work so that the quadriplegic student was a fair contributor to the overall project. After the classroom was changed to accommodate the special computer station that is required by the student, the introduction to computer tools portion of the course was also straightforward for him. This was a factor, as are all facilities considerations, which required a significant amount of time. However, it is important to ensure that the facilities required by the quadriplegic student are functional on the first day of class. As will be discussed, this is critical given the time struggles faced by the student. While the quadriplegic student did all of the operations that the other students did in the computer tool introduction portion of the class, it was obvious from the start that he could not perform these tasks at the same pace as the other students. This was an issue that the instructor had to deal with.

It was in the area of traditional paper and pencil drawing that the greatest challenges for the quadriplegic student and the instructor lay. The student had wisely chosen to take a course in AUTOCAD prior to taking ED&G 100. Thus he could use this application to complete the drawing assignments. However, all the drawings used in the traditional paper and pencil component of the course had to be converted into AUTOCAD drawings. The drawing assignments are partially completed plates that are commonly used in such courses; in this case they were taken from Giesecke, *et. al.*[4]. This general approach worked well for the student, but required considerable effort from one of the instructor's colleagues. Since the student already knew how to use AUTOCAD, this was the obvious choice of applications; however, the instructor was unfamiliar with AUTOCAD. Fortunately, another instructor at the campus was able to convert the drawings. Without the effort of the other instructor, having the student effectively complete the paper and pencil component of the course would have been much more difficult. It should be noted, although the use of AUTOCAD allowed the student to complete the drawing assignments, the time required to do some of the drawings was several times longer than for a typical non-quadriplegic student. In particular, the labeling of points in the construction of

orthographic views or auxiliary views was particularly time consuming. This would prove to be the first in a long series of lessons about time sinks that would be encountered in the student's performance of technically-oriented tasks.

IV. Sophomore-Level Engineering Mechanics Courses

The second course in which I taught the quadriplegic student was sophomore-level Engineering Statics. Given both my experience with having taught the student in ED&G 100 and also a half a year to think about how to teach statics to this student, I arrived at several conclusions. I was aware of the time consideration and initially concentrated on making sure that the student had a good process in place to solve problems. I wanted the student to be able to have as much control on this process as possible and for him to use the same process to do homework problems as well as to take examinations. I realized the student would be solving the problems using some sort of computer tools. This point is important because I believe instructors must be very careful about what computer tools they expose students to when they are teaching them introductory material. This is because I believe that the use of computer tools must not compromise the students understanding of the basic principles they are being taught. I was able to adhere to the philosophy by not having the student use the same tools that practicing engineers employ, ones which treat basic principles as "black-boxes".

I was surprised to learn that despite having already taken two calculus courses and the first baccalaureate physics course, the student did not already have a problem-solving process in place. Homework and evaluations in those courses had not been accomplished in the same manner that I planned. As a result, the student and I had to develop this process during the semester. This took time, and consequently the student fell behind in his homework. It took several weeks to finally develop a workable process. This process consisted of using AUTOCAD to construct drawings to replace the traditional engineering sketch, and using MATHCAD to solve the problem mathematically. When the process was finally in place, the student began to be successful in solving problems. During the rest of the semester it became very apparent that it took the student at least 2 to 3 times as long as a non-quadriplegic student to solve a statics problem. I believe that this time multiplication factor is mostly related to the process that the student had to use.

As the semester neared completion, it was clear the student was not going to finish the material. Given that the student needed to finish courses that were required for his gaining entrance to his major, I advised him to take a deferred grade in the statics class and finish it when he had the time to devote to the course.

Another characteristic which surfaced while I was helping the student develop good engineering problem solving techniques was his tendency to skip steps. This characteristic, which I have seen in many other students, seemed particularly problematic for this type of student. Given the time which the current process requires the student to solve problems, I could understand his tendency to try and cut corners. However, I believe that the short-cuts contributed to poor

performance on the first examination. He significantly improved the documentation that he put into his problem solutions after the first examination, and his test scores improved markedly.

During the semester in which the student was taking statics, it also became apparent that an electronic text would allow the student to solve problems in a quicker and more independent fashion. In preparation for his taking Dynamics and Strength of Materials the following semester, it was found that neither of the textbooks was available in an electronic format. As a result, permission was obtained to scan the textbooks and provide them to the student in the form of a file. While less desirable than an electronic text, it was an improvement over a standard paper textbook. It is important to note that this required more than a month of lead time and considerable effort on part of the university's support staff.

The quadriplegic student ended up taking a deferred grade in both dynamics and strength of materials. As of the writing of this paper, he had just successfully completed the statics course and was beginning to work on completing the other two courses. The reasons for this student remaining enrolled in these two classes will be discussed, along with other insight gained from serving as the student's advisor.

V. Insight Gained From Advising

At first glance, some of the student's decisions may seem illogical, namely remaining enrolled in Dynamics and Strength of Materials when he had not completed Statics. However, there were reasons for his decisions that need to be understood to fully appreciate the situation. The reasons have to do with three factors: financial aid, entrance to degree requirements and degree status. The first two are of a general nature, while the latter is not. Many of the student's original scheduling decisions related to ensuring that he remained in full-time status for federal financial aid. This requirement is a minimum of 12 credits, and there are no exceptions allowed. This rule, combined with other factors, caused the student to become dangerously overloaded considering the time required to do many of the tasks associated with technically-oriented courses. The other general factor was the need to meet the entrance to degree requirements at the Pennsylvania State University. In order to gain entrance to a College of Engineering Major, a student must, among other things, complete four courses: Calculus I, Calculus II, General Physics: Mechanics, and Chemical Principles with a minimum grade of a C in each course. While taking the Statics course, the student had 14 credits plus an additional 3 credits by correspondence (the required chemistry course). The student became my advisee that semester. When it became apparent that he was overloaded, I learned the rationale behind his decisions. As completing the entrance to degree requirements outweighed other considerations, I advised him to make that his highest priority. This decision contributed significantly to his inability to complete the three sophomore-level Engineering Mechanics courses the semester he began them, resulting in his receiving a deferred grades in each course. In terms of the Dynamics and Strength of Materials courses, the student remained enrolled when a late drop would have been more appropriate only because he had previously used his allotment of late drop credits. This factor would not have been an issue except for the fact that the student was enrolled in an associate degree program, although he was pursing a baccalaureate degree , which allows only

half the number of late drop credits as a baccalaureate degree program. This is not an issue which would generally apply although it was important in this case.

VI. Detailed Implications – Student

The author believes that the most significant concerns for a quadriplegic student pursing a baccalaureate engineering degree are avoiding an overwhelming number of credits and developing good problem-solving skills. The student must realize the additional time that is required for him or her to complete technically-oriented tasks with current technology. No matter what other factors such a student believes is important, taking an unrealistic number of credits can only lead to problems. Second, the student must be willing to develop and use good problem-solving skills. This will likely require that he or she learn to use a new process and include in this process the necessary internal documentation. Despite the time and effort required to develop and use these skills, they are critical to the student's success.

VII. Detailed Implications – Instructor

I believe that the instructor's principal areas of concern when teaching engineering to a quadriplegic student are the student's problem-solving process and how evaluations are administered. Of these, the process is the more difficult to put in place. In addition, since the problem-solving process must be developed while the semester is progressing, the student can easily get behind in his or her homework assignments. The instructor must understand how the student accomplishes each task to be able to provide the most useful technical advice. This requires the instructor to consider all the tasks required for the student to solve problems at the most fundamental level. As discussed above, this may require the use of tools the instructor is unfamiliar with. This, in turn, may require the assistance of other faculty. Furthermore, it is important to understand how the student must accomplish these tasks. Determining how to administer examinations is also important. I believe that in the engineering mechanics courses being discussed, the theory should not be separated from the problem-solving process. Consequently, the student must solve problems as part of the evaluation process. This means a quadriplegic engineering student cannot undergo the traditional 50 minute in-class examination process used to evaluate the non-quadriplegic engineering students. In most, if not all cases, this may be the first time the instructor has had to deal with these issues and there will be an adjustment phase. To make matters worse, in many cases the instructor may not be aware such a student is in his or her course until the first day of class.

This last factor prevents careful consideration of the issue of electronic textbooks, since textbooks must be chosen months before the class begins. In addition, modifications in the physical facilities may be required to allow the student to function effectively in class. If these issues are not resolved prior to the first day of class, they will contribute greatly to the time pressures felt by the student.

VIII. Detailed Implications – Academic Institution

The academic institution's primary responsibility in this educational process is to facilitate the students' ability to take courses despite their physical limitations. In many cases this requires changes to physical facilities. In the case of a quadriplegic student this may well go beyond just providing standard wheelchair access. In the case of the student discussed here, access for a special wheelchair that has the student in a partially reclining position was needed. In addition, a computer station that used the mouth-operated pointing and clicking device was required. Furthermore, when electronic textbooks were not available, it was necessary to electronically scan a regular textbook and provide the result to the student.

I believe that academic institutions need to be very proactive in preparation to accommodate such physically-limited students. This will require the institution to prepare the facilities so they are in place and functional the first day of class. In addition, advance notice should be given to the instructor so he or she can prepare to deal with the special circumstances. This includes the issue of textbook selection. Although I do not have survey information, I believe most academic institutions currently are not prepared to provide the advance notice to allow this process to proceed as efficiently as possible.

IX. Detailed Implications – Software Development & Philanthropic Organizations

As discussed above, the process used to do technical drawing and solve engineering mechanics problems with computer software is time consuming. The process of solving engineering mechanics problems is particularly poor because it requires the cutting and pasting of pieces from several different programs. It is very important to note that similar problems do not occur with widely used general purpose software programs, such as spreadsheets and word processors. It is clear that better software could be developed, although the market for such software would be very small; consequently, the economic incentive to develop such software is absent. As a result, this is an ideal situation for a philanthropic or governmental organization to facilitate the development of better software tools.

X. Detailed Implications – Governmental Organizations

Thus, governmental organizations could contribute to the development of software to facilitate the ability of quadriplegic engineering students to perform technical tasks associated with obtaining an engineering degree. Perhaps more importantly, in the opinion of the author, the federal government should reconsider its criteria for making financial aid decisions for quadriplegic engineering students. As has been discussed, it requires quadriplegic engineering students a minimum of two to three times as much time to perform many technically-oriented tasks as students that do not have the disability. As a result, it is not reasonable to expect such students to be able to succeed if they take the same course loads as non-quadriplegic engineering students. While I realize this represents a major change in the current criteria used to award financial aid, I believe this change is in line with my understanding of the intent of the Americans with Disabilities Act.

XI. Financial Aid Clarification

It should be noted that financial aid is available for students who are not in full-time status. However, full-time students are generally eligible for more aid than part-time students. One of the purposes of this paper is to present information that suggests that using a different criterion when making financial aid decisions for quadriplegic engineering students may be justified.

XII. Acknowledgement

I believe it is critical to recognize the determined efforts of quadriplegic engineering students. The ultimate goal of this paper is to improve the process these students must use in order to pursue a baccalaureate engineering degree. In particular, the author acknowledges the student he has had the privilege to interact with, Mark Marusiak. I also greatly appreciate the contribution of Mark Matusky of the DuBois Campus of The Pennsylvania State University who, as described in section III, graciously translated the drawing assignments into AUTOCAD.

XIII. Summary

The author's experience in providing engineering education and academic advising to a quadriplegic baccalaureate engineering student has been discussed. The lessons learned about the difficulties associated with such students taking technical courses in their first two years have been outlined. The experiences presented are analyzed to provide constructive suggestions for all entities involved in the process. These include the student, the instructor, the academic institution, software developers, and philanthropic and governmental organizations.

Bibliography

1. Henderson, C., *2001 College Freshman with Disabilities: A Biennial Statistical Profile*, American Council on Education, Washington, DC, 2001.

2. LaPlante, M., P., *Disabilities Statistics Abstract No. 16: Health Conditions and Impairments Causing Disability*, Disability Statistics Rehabilitation Research and Training Center, Institute for Health & Aging, School of Nursing, University of California, San Francisco, CA, May 1996.

3. Anon., *Statistics on Spinal Cord Injury*, Spinal Cord Injury Program, Washington University, School of Medicine, St Louis Missouri, http://www.neuro.wustl.edu/sci/statisti.htm.

4. Giesecke, F., Mitchell, A., Spencer, H., Hill, I., Dygdon, J, Novak, J., *Engineering Drawing: Problem Series 1*, Prentice-Hall Inc., Upper Saddle River, NJ, 1997.

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