Creativity in Engineering Education for Higher Student Retention

Dr. Matthew M. Radmanesh
Electrical & Computer Engineering Department
California State University, Northridge
Northridge, CA 91330
818-885-2179

ABSTRACT

Most programs designed to improve student retention are adminstrative programs having to do with orientation, couseling, financial aid and the like. The quality of instruction is not often considered as a critical factor in retention. It is no surprise to find out that the major factor in whether students complete an academic course or stay in college is whether they feel their work is worthwhile or they are having a pleasant experience accompanied by success in learning.

This paper is designed to promote creativity in engineering education through non-traditional methods of teaching and involving the students in the teaching process. As educators a complete knowledge of creative classroom techniques and full awareness of major learning obstacles facing every student are vital if retention of engineering students is of significant importance and practical-minded engineering students are expected to graduate with flying colors.

I. Introduction

Quality in engineering and technology education has always been a major concern for higher education. This has become even more important as we become increasingly technology-oriented as a culture and as an economy. Unless we are able to sustain a leading edge of technical competency by improving our engineering education and its teaching methodology, we may not be looking at a very bright future in engineering growth and acceptability nationally or globally.

In today's highly technology-oriented society, the need for quality education in engineering as well as exciting and retaining student's interest and curiosity in the subject matter has led to intense investigation among many known educators and a great many articles on improvement of quality of engineering education and increase of learning rate has been reported in literature [1] - [8].

This paper attempts to present newer creative teaching methods which have been mostly overlooked by engineering faculty. These novel interactive methods would allow the student to get involved through two-way communication cycle between the class and the teacher. In these methods the student gets transformed from a member of the audience to a participant.

The traditional methods of teaching is based upon the flow of knowledge or information from the teacher (source point) to the students (receipt point) who are passively observing vaguely this flow with a few questions far in between the lecture but otherwise faithfully taking notes sometimes to the excruciating detail. Active participation in the classroom or in the learning process is widely accepted in humanities and particularly in arts and yet is a rare scene in most engineering classes.

Section II briefly describes the goals of engineering educators versus other disciplines. A number of creative and interactive methods adapted for engineering classrooms are presented in Section III. Use of these techniques is intended to increase the student retention and drastically reduce student dropouts. Summary and conclusions are presented in Section IV.

II. Goals of Engineering Educators

We all know that good teaching does make a difference in student learning. This may sound at first obvious but we may be able to recall times when we threw our hands up in the air and blamed student's poor performance on their poor learning habits or their sub-par familial background or weak high school training. In effect what we did was to shift the point of responsibility and causation from teachers to students. However, the fact remains that good teaching does exist and research confirms this observation and adds that teachers do make a difference. This fact can also be perceived intuitively through our own experience as learners. In fact many of us may owe our choice of career to the influence of a teacher who made learning and intellectual work satisfying and exciting for us. Recent research across a variety of colleges and disciplines now attributes a substantial portion of learning to the quality of teaching. Basically, effective and good teachers have some basic understanding of the learning process which they use intuitively and always make the connection between what students already know and what they want them to learn [9,10,11].

One study recently concluded that there was more variability among teachers who taught the same subject at the same college than across courses, departments or colleges. Teachers were clearly the most important factor in the students academic performance and directly influenced student retention or drop-out [12].

The fact that teachers make a difference in student retention is of special significance to engineering educators because the drop-out rate in the sciences is high. For example, only forty percent of declared science majors actually graduate in science and engineering at the end of their senior year. But we may notice that most programs to improve retention are administrative programs concerned with orientation, counseling, financial aid, etc. Surprisingly enough we have not often considered the quality of instruction as a critical factor in retention, and yet a major factor in student retention is a pleasant experience in their studies with good success in their learning of technical materials. So instructional quality can play a major role in student's learning rate and their eventual retention in the subject matter.

What teachers consider their goal varies considerably amongst their particular subjects. For example about 55% of the science and engineering teachers have indicated their primary goal is teaching students the facts and principles of their subject matter which is the goal of only 24% of arts teachers. On the other hand only 3% of science and engineering faculty emphasize "student development" whereas 37% of arts faculty have this as their goal [13,14,15].

Further data and statistics has been collected to show that most engineering faculty considered subject-matter-oriented goals and development of analytic skills essential to their teaching. All these findings indicate that engineering college teachers are teaching their discipline plus a series of academic values fairly well divorced from emotion and personal involvement. In short this teacher's motto is "I teach what I know." Class work and assignments center on mastery of a defined body of subject matter. This type of teacher may be called "instructor-centered" teacher prototype. [16]

The other side of the coin is "student-centered" teacher prototype, who has the motto of "I work with students as people". These teachers believe that motivation, self esteem, self-confidence and the like are integral parts of learning. Majority teachers of basic skills and arts have this as their goal and consider it essential.

These two prototypes show clearly that different goals and beliefs about the nature of the teaching role lead to different teaching methods ranging from heavy emphasis on the lecture for the teacher who "teaches what he knows" to emphasis on exploration and student-initiated discussion for the teacher who "works with students as people" [17].

Due to the nature of engineering subjects and delivery of a great amount of new information to students, and in light of above observations, it behooves an aspiring engineering faculty well to take a mid-spectrum position with regard to the two teacher prototype and create a middle range prototype as a teacher who "helps students receive knowledge as people". In this new teacher prototype, the teacher helps students to learn new engineering facts, design techniques and problem solving ability with the intention of raising their self confidence and motivation in the subject. So his presentations are a good mix of lectures, class discussions and student initiated explorations. And since teaching effectiveness is considered to be an important issue throughout the engineering colleges and universities, it should now be measured by the increase of ability in students to apply the taught material easily.

Therefore the ultimate criteria of good or effective teaching is effective learning. So perhaps we may be able to see that learning depends probably more on the students behavior than on the performance of teachers. So the purpose of teaching can now be more clearly stated as "involvement of students actively in their own learning and to elicit from them their best learning performance".

III. Creative Techniques in Teaching

Teaching today is more like home gardening than like scientific agriculture. Care, attention and experience will certainly result in better crops than neglect. The real intellectual challenge of teaching lies in the opportunity for individual teachers to observe the impact of their teaching on students' learning. And yet, most of us do not use our classrooms as laboratories for the study of learning and presenting creative methods to enhance student's learning.

Learning is not so much an additive process, with new learning simply piling up on top of existing knowledge, but an active and dynamic process in which the connections are constantly changing and the multidimensional structure reformatted. The excitement of learning comes when new connections are made, pulling apart some old connections and making new ones. The point is that new information results in meaningful learning when it connect with what already exists in the mind of the learner.

The learning of a novice is labored and slow not because the novice is less intelligent or less motivated than an expert but because connections between new information and existing mental structure are sparse and there are no mental hooks on which to hang the new information and thus it falls in a heap on the floor, recalled with great difficulty. In a nutshell, this means that an effective teacher should find out what a student knows and teach accordingly [9].

The following subsections describe an ideal model for a learning environment along with several practical teaching techniques which altogether attempt to make the everyday class environment into a more exciting environment packed with sparks of student's interest all engaged in this noble human activity.

3.1- An Ideal Model of a Learning Environment

From a purely scientific point of view, the first and foremost component in any teaching activity is communication whether verbal, written or otherwise. By communication we mean the action of impelling ideas or concepts from source point across a distance to the receipt point, with the intention of bringing into existence an exact duplication at the receipt point. "Exact duplication " causes a complete understanding of that which emanated from the source point.

There are three actual study barriers which prevent an exact duplication of concepts which have emanated from a source point (e.g. teacher, textbook, lecture etc.). The biggest barrier of the three is the "misunderstood terminology or symbol" and there are ten ways that this can happen. So this could be called a "language barrier". There is a definite phenomenon of going "blank" and "forgetfulness" associated with this barrier which if continued over a relatively long period of time will lead to the second phenomenon where the student either individuates self from the subject and develops a mental circuit (to give and receive information with no ability to think with the data) or drops out and quits the subject matter completely. To overcome this deadly barrier, one needs to use a good technical and/or English dictionary to search for and clear these misunderstood words fully as described in the literature [18].

The second barrier is the "absence of mass" which is the absence of the object under study or a representation of it such as a photo, film etc. So this could be called a "mass barrier". The third barrier is the "skipped gradient" where the student leaves out basic steps in the learning process and has serious difficulty with later materials. So this could be called a "gradient barrier".

Therefore, theoretically an ideal learning environment would be having a student who is fully indoctrinated in these three barriers and who has the total self discipline of following the instructions of remedying these barriers promptly when they occur. This ideal scene would consist of the student, a good textbook, several good dictionaries (Technical and English), a complete set of Encyclopedia as a reference, a demonstration kit (to remedy absence of mass) and a quiet and a distraction-free environment.

This ideal scene obviously removes the teacher as an intermediary person between the source of information (e.g. textbook) and the student and should create the fastest learning rate with least amount of confusion and student drop-out and a 100 % retention of data. Since with full awareness of the three study barriers, everything read is comprehended, while the student's interest is kept up and he remains involved and

active in the learning process. Under the "ideal scene" conditions, the drop-out rate would approach zero.

Obviously this theoretical ideal scene is purely an ideal model and yet gives insight into using it as a frame of reference for comparison of all of the teaching techniques presented later in this section.

It should be pointed out that in order to bring this method into the realm of practicality, however, we need a supervisor (and not a teacher) to monitor student's progress and alleviate trouble spots and perhaps guide them to correct sources of information and to make sure that the student is doing the associated actions correctly. Of course, in this version of the ideal method, it is assured that the student is following a prescribed course of action in the form of a checksheet (or a checklist) laying out exactly the required technical materials, experiments and actions. This checksheet must be prepared by an expert faculty in advance.

In summary, this ideal model of a learning scene has the following characteristics:

1. It makes the student actively participate in the learning process.
2. It encourages the student to think for oneself.
3. It makes the student adjust the rate of data flow according to his/her own pace.
4. It provides 100% student retention and zero drop-out rate.
5. It places the student on the road to becoming a critical thinker and gives success as a learner.
6. It gives self-confidence to the learner after a while, to navigate himself out of any confusion purely on own self-determinism and makes learning a lifelong endeavor and joy.

Short of the ideal learning scene (no teacher theoretically), we will now focus on more traditional methods of learning where a teacher is a necessity and will present hereforth several creative teaching techniques where a teacher by using one of these techniques or all in combination can dramatically improve the student's learning rate and retention.

3.2 - Technique #1: Presentation by Use of Variety

Research has shown that an effectively good teacher must possess not only a series of personal positive attributes such as being friendly, enthusiastic, fair, interested, helpful, etc. but also provide an intellectual excitement and interpersonal rapport with the students. This latter is an important feature of a teacher which may have been overlooked often. The teacher of course must be well prepared and well organized but must also understand that he is dealing with a diverse mix of students with a variety of learning styles.

Different perception channels take dominance for different students in the learning process, for example some may be verbal or others may be oral but research shows that majority are visual. This means that if the material is purely presented in writing, it would be better to not only say it out loud and clear but also show it by a diagram or a picture or symbolically by a math formula in order to increase the overall probability of learning in the classroom.

This technique of presenting the same material from different angles and with different perspective for presentation has shown to be very effective and popular with students and they all appreciate this extra step that a teacher is willing to undertake in order to

accommodate their needs. This alleviates in essence the "language barrier" and the "mass barrier" and brings more reality to the subject. It is also interesting to note that educators tend to teach in a way which matches their own learning style, thus by using a variety of presentation styles they overcome this old habit and inevitably improve learning rate regardless of student's personal learning style.

3.3 - Technique #2 Use of Pausing Principle

As a lecture rolls forward, the diverse mix of students each with their own limited scientific vocabulary are bound sooner or later to run into the language barrier. This means that a whole slew of misunderstood terminology, symbols and words would start to accumulate practically right from the beginning. However, if after every 12 to 15 minutes of lecturing, one allows the students a two-minute pause for immediate review with nearby students which is in essence an opportunity to refresh memory and fill in blanks left due to an accumulated number of misunderstoods, research as shown that learning rate has been enormously improved.

It should be stated that during this period the instructor should not receive any questions from students, and actually must announce this fact early on before start of this 2 minute pause. This technique lends itself heavily to the lecture mode of teaching and alleviates particularly the "language barrier" and allows the misunderstood terminology or symbols to be caught up with and clarified. Thus the gaps in knowledge created in the learning process are filled and handled as they occur.

3.4 - Technique #3 Allowing Wait Time for Questions

This technique is based upon a well known statistics that shows only approximately 3.65% of class time is devoted to questioning which boils down to about 2 minutes in a 60 minute lecture. At the end of the one hour one can certainly state that a lot of lecturing took place but no such conclusion can be drawn about student learning.

Professors contribute to the problem of little participation by not spending any significant amount of time asking students questions, or worse yet allowing enough time for the students to answer it even if there is one. In this technique the teacher asks a question, allows about 3-5 seconds and a student may respond but then pauses. Now at this moment if the instructor restrains self from continuing with the lecture or asking another question and just waits some more the student continues and finishes response. By the use of this technique, it has been found that the length and number of appropriate and yet unsolicited responses increased and students confidence in dealing with questions was raised and were inclined to think more speculatively and with higher curiosity.

This technique alleviates all three barriers through question and thus making the student more aware and alert of the subject and sort of "wakes him up" to find out what his confusion are and thus giving him a chance to air them out.

3.5 - Technique #4 Corroborative or Group Learning to Promote Critical Thinking and Problem Solving Ability

In this technique the teacher presents a series of observations about a scientific puzzle related to the subject matter and asks the students to participate in solving the puzzle by analytical reasoning and use of inductive and deductive logic to arrive at the correct

answer (s). This helps the students focus on problem solving as a skill which can be learned. It also increases student's awareness of the processes that they themselves use to solve problems and eventually promotes critical thinking in participating students.

After a while, the students quickly grasp the six steps of the critical thinking ladder which are: 1) knowledge, 2) comprehension, 3) application, 4) analysis 5) synthesis and 6) finally arriving at the sixth stage which is judgment and evaluation. At this last stage, the student has the ability to think critically with the data and can have an "opinion" on the subject matter. In his mind the data is very fluid and he can use the data effectively for his everyday applications with no confusion.

Effective problem solving is essential for success in Engineering and life in general. Instructors should plan and use specific teaching strategies to improve student's problem solving skills on a gradient and should create tests and testing procedures based on these six stages in order to arrive at a high level of skill. The sixth stage of critical thinking ladder could be called the valuable final product of a teacher as a professional and should be at the top of his/her priority or goals list, if bright, able and practical minded graduates are desired.

3.6- Technique #5 Classroom Assessment Techniques for Student Feedback (The One Minute Paper)

Classroom assessment by definition is a simple method for collecting feedback, early and often, on how well our students are learning what we are teaching. The purpose of classroom assessment is to provide faculty and students with information and insights needed to improve teaching effectiveness and learning quality. Student's responses to classroom assessment techniques are usually ungraded and anonymous.

There are many classroom assessment techniques and the simpler ones have been used far more than those that are more complex. The most popular one is the "one minute paper" (also called the minute paper) which has several version each for different classroom needs. The one minute paper lends itself easily as an assessment tool for checking student's knowledge, recall and understanding usually administered at the end or beginning of a lecture or discussion as a wrap-up (or warm-up). One minute paper can also be used to assess what students have learned from a lab session, field trip, homework assignment, videotape, exam, etc. Minute papers can be used frequently in courses that regularly present students with a great deal of new information and because it is quick to administer and easy to analyze, it is suited for any size class.

To use the minute paper, an instructor stops class two or three minutes early and asks students to respond briefly to two questions 1) "What was the most improtant thing you learned during this class?" and 2) "What important question remains unanswered?" Students then write their responses and hand them in. One variation is to use only half of the minute paper by simply omitting one of the questions. Another variation of this procedure is to abbreviate these two questions into one by asking "what was the muddiest point in ____?" Faculty analyze the feedback gleaned from classroom assessments and use it to make adjustments in their teaching. They also share that feedback with their classes in order to help students improve their learning strategies and study habits [14].

It should be understood that effective assessment is part-and-parcel in teaching and learning. It forms an intrinsic part in any educational activity and reinforces and furthers the teaching and learning goals it focuses on. In a broader sense of the word, any time a teacher gets a feedback in any way or form (verbal, written, visual, etc.), he is assessing his teaching effects upon the students and this data must be used effectively to enhance the quality of teaching. Every teacher does this to some degree but one minute paper provides an irresistibly clear feedback easily and quickly.

IV. Summary and Conclusions

This paper is designed to promote creativity in engineering education, through non-traditional methods of teaching and involving the student in the teaching process. A great deal of energy of every student and faculty alike get consumed in combating "study barriers" or "learning obstacle" and yet it seems that these have been left unknown to faculty and students. These actual study barriers along with a series of innovation and creative techniques in Engineering education have been discussed in order to increase student's learning rate and thus exciting and maintaining the student's interest in Engineering subjects fully.

This paper has intended to present an ideal model of a learning environment. This ideal scene of learning turns out to need no teacher and yet the student is required to be highly knowledgeable in recognizing the three study barriers and be responsible for his own learning and should be very self-disciplined in detecting and quickly remedying learning obstacles when they occur. This method has a lot of positive aspects and yet to make it practical the teacher's role should change to a supervisor, a task setter, a classroom manager or administrator who only helps the students when they are in trouble or have collided with one of these three study obstacles, and to check to see if they are doing the required actions correctly.

Short of this ideal scene, the more usual teacher-student classroom scene can definitely be sprinkled with a lot of classroom creativity to retain and excite student's interest and turn him/her into a problem-solver, a critical thinker. Five techniques presented in this paper each one separately or in combination if used in the classroom, will enhance the quality of education greatly and will give it a significant lift toward approaching the ideal scene of learning where retention is high and drop-out rate close to nil.

As educators, a complete knowledge of creative classroom techniques and full awareness of these learning obstacles are vital if retention of engineering students, as well as bright and practical-minded Engineering graduates, is expected to come to fruition in the classrooms or at graduation.