Teaching Engineering to Cyber Children

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Abstract

Few engineering educators will argue that the student in the classroom today is different than was the student of as little as 20 years ago. Today's student was wholly raised in the age of interactive graphics, and that has been a central part of their learning process. These students will not learn well, and will not be challenged, using many of the teaching methods of the past. Methods used to teach engineering must change to accommodate the background of the student in the classroom—the student is not going to change. The purpose of this paper is to discuss the learning styles of today's student and begin to propose changes that can be made in the educational process.

Introduction

The process of engineering education is a cognitive process. Cognitive behaviors involve the recall of specific information, the application of that information, and the processes of analysis and decision making (Pophan, *et al.*, 1975). A taxonomy of the cognitive process is shown in Figure 1. Knowledge requires the ability to recall that which has been communicated whereas comprehension requires an understanding of that which has been communicated. Application requires the use of abstract concepts in specific situations and analysis requires a dissection of that which has been communicated. Synthesis and evaluation, respectively, require the organization of a pattern from the separate parts and judgment of the subject against a standard of appraisal (Getzels, 1964). During his or her engineering education, a student should probably be able to grow to the fourth level. The student should be able to dissect the information that has been presented in the classroom and be able to apply that information to new problems in the design office. The last two levels likely will come through the professional maturation that comes with experience.

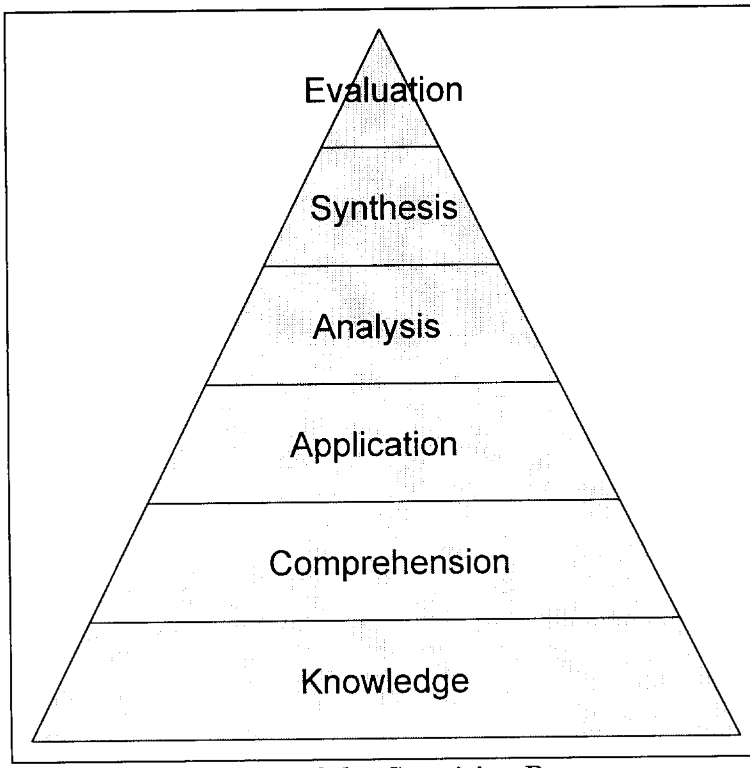

Figure 1–Taxonomy of the Cognitive Process (Goodwin, 1975)

Often-heard comments among engineering educators are: "Students are not as inquisitive as they used to be;" "All students today want is the equation;" and "The students are not willing to work as hard as we did." These comments may be more a criticism of the current educational process rather than a criticism of the students. The students are gaining knowledge, and probably even have some comprehension of that knowledge, because they are able to successfully regurgitate information on examinations and are passing those examinations. That which appears to be lacking is recognition of the need to move on to the next three levels in the taxonomy, or perhaps the lack of motivation to do so.

Regardless, these are the students in the classrooms today and they likely cannot be changed. Today's student is what was referred to on MSNBC "The Site" as cyber-children—children who have been raised completely in an age of interactive graphics, in an age of interactive technology. The teaching methods used to educate these students must change to accommodate the environment in which they were raised. The question, then, is how these students can be motivated to achieve knowledge and comprehension of engineering subject matter and be able to apply and analyze that knowledge.

The purpose of this paper is to discuss the learning styles of the cyber children. Further, its purpose is to suggest changes that can be made in the engineering classroom to support these learning styles so as to educate cyber children in the principles of engineering. The purpose of the paper is not to discredit the manner in which engineering has been taught in the past. The engineers educated with those methods have made significant accomplishments. The methods, though, may need to be changed because the background and upbringing of the students in today's classroom is different than it was as little as 20 years ago. The personal computer and interactive connectivity have been a primary contributor to that change and can be utilized effectively in education.

Traditional Learning Technology

When investigating the differences in learning styles between students of the past and students today, one must investigate the technology available in the past. This includes the technology that was available for the students, the technology that was available for use in instruction, and the technology that students used as part of their academic study.

For the first 75 years of this century, the tool most commonly used by engineering students, and by most engineers, was the slide rule. Some mechanical calculating machines were available in design offices, but were not readily available to students. Hand-held calculators were not available until about 1975. Because extensive computations were cumbersome and time-consuming, even with hand-held calculators, parametric studies and "what if" problems were not often used—there simply wasn't time available. Students learned by working different relatively closed problems to gain a grasp of the information presented in the lecture.

Prior to the 1950's, television was not readily available, if available at all. Students were forced to visualize in their mind the situations offered by radio and books. There was very little animation available to help understand engineering principles. By the 1960's television had become a common appliance in most homes. The change began for students to watch an animation prepared by others rather than develop their own visualization.

In the 1960's and 70's computers began to have some use in engineering, and to some extent in engineering education. Graphical presentations were very limited, but computers could perform calculations quickly and enabled parametric studies and open-ended problems to be assigned. For the most part, though, these solutions required some programming and lengthy turn-around time Although available, computers were not extensively use in the undergraduate educational process.

The most dramatic change in available technology occurred about 1985 with the ready availability of the personal computer and the associated graphics. Over the next ten years the development of the personal computer was dramatic, and the capability for graphical presentation and animation of data was phenomenal. Students began spending considerable time looking at graphical interpretation of data—interpretation prepared by others—and playing games. While doing so they continued watching television.

Traditional Engineering Education

The traditional approach to engineering education is quite difficult to define because there are many variations on the same theme and exceptions can always be cited (Nelson, *et. al.*, 1996). When looking at the broad spectrum of engineering education, though, there are certain commonalties in a majority of the classrooms.

The general classroom format is an instructor in front of the room presenting material to students sitting in chairs viewing the lecture and taking notes. Thus, they primarily learned via the auditory modality. Gardiner (1994) reports that the lecture method results in students retaining less than 20 percent of what they were taught one week after the lecture.

These lectures begin and end at prescribed times. During the lecture a certain element of the course material is presented and demonstrated. Visual aides used to augment lectures typically included chalk and blackboards, and perhaps overhead projectors. The chalkboard is the predominant medium used for instruction. Other visual supports included textbooks and handouts. When computers are used as part of the presentation, their role is basically that of an electronic chalkboard; the full capabilities of the technology are not being used.

The emphasis was on delivery of course content by the instructor talking to a group of learners. Students were expected to learn by listening, and, at the same time, take careful notes of important points. They were also expected to learn via visual means by reading textbooks, outside references, and their notes.

Thus, students were forced into learning some course content by listening and some by reading. Little effort was expended in delivering course material via a student's preferred learning modality or in assisting a student to integrate auditory and visual material.

Except for times of direct question and response, this is a passive learning environment. The student is not an active part of the learning experience in the classroom. Further, because the learning approach within a course is not varied, all students are expected to learn at the same rate and in the same manner.

In many respects the goal of the present system is delivery of information by the instructor and regurgitation of that information by the student, rather than the assimilation of knowledge (which is learning). Using this approach, education is being mass produced very much like General Motors or Ford mass produce automobiles.

Today's Learning Styles

Two variables have appeared in recent years that dramatically affect today's students' learning styles. The first of these is educational technology with its rich capability for visual representation (Kaha, 1990). Today's students have grown in a society that depends heavily on television and multimedia for information. They have learned to learn by visualization, with less emphasis on learning by listening. To a great extent, though, the visualizations used are visualizations prepared by others—the student is not an active participant in the process.

The second variable that has—or should—affect students' learning styles is a better understanding of how learning occurs. In the past 20 years cognitive psychologists have advanced significantly the understanding of how learners perceive, process, store and retrieve information (Embretson, 1995; Jarman and Krywaniuk, 1978; Waldrop, 1987). These understandings have led to a new learning paradigm where the instructor's emphasis should be on the learner's capacity to effectively process information presented through different sense modalities. This change should lead to dramatic alterations of the instructor's role as was previously suggested.

A Question

Studies conducted at Antioch College and elsewhere "found no significant differences in learning between students working independently (no classes) and those who attended classes of various types" (Bugelski, 1971). Further suggested was that,

> *"The instructor's main function . . . no longer is to impart his knowledge and his enthusiasms in lectures to students . . . rather, his function might be first, to suggest in a syllabus the resources—books, journals, films, recordings, projects, etc.—helpful for an understanding of the objectives, methods, and subject matter of an area."* (Bugelski, 1971)

This study seems to suggest that the students were learning in spite of the instruction in the classroom. Despite this study, which is now almost 30 years old, very little was changed in the classroom, in particular the engineering classroom.

When these studies are conducted, they are primarily based on textbook knowledge, the first level of the taxonomy in Figure 1. Given the learning technology that was available until about 20 years ago—about the same time that students began to lose their dedication to their studies—is it possible that students were not much different before than they are today? Perhaps, with the change in available technology, instructors are now able to find the "holes" in the educational process that heretofore were not obvious. Because computations are easier to perform, instructors are now better able to evaluate a students comprehension of the material and their ability to apply that knowledge to new situations. On the otherhand, perhaps the need to perform their own visualization of systems offset the inability to perform extensive "what-if" computations and they did have the comprehension that was assumed.

The answer to these questions is certainly not clear. An answer may not even exist. Nevertheless, because of the technology that is available today, and because of the changes that have occurred in learning styles, engineering educators have the challenge to:

1. Cause the student to be an active participant in the learning process,

2. Facilitate the ability of the student to develop a sound comprehension of the material through the visual modality,

3. Develop the means, through engineering analysis and design, to evaluate a students comprehension of the material and their ability to apply that knowledge.

Achieving these challenges will have an impact on engineering education and the role of the instructor.

Changing Role of the Instructor

With students now learning primarily through visual representation and with increased awareness of how learners cognitively process information for understanding the instructor's traditional role must change dramatically in order to be optimally effective. At least four role changes are apparent. The first must be an acceptance by instructors of the need to change from an emphasis on faculty teaching styles to student learning styles, and from classroom teaching to student learning. The focus must become how students learn, not how faculty teach (Guskin, 1997).

The role of the instructor will change from being the primary source of knowledge to the mechanism through which the student seeks knowledge. This changed perspective will in no respect diminish the importance of the instructor or the interaction of students with the instructor. Instead, interaction will be increased as the instructor becomes a resource and becomes more involved with students individually. The instructor will become a motivator and challenge the student to individually achieve their full potential.

The second change must be a re-structuring of the learning environment in order to make more effective use of technology (Charp, 1997). This change will involve structural changes in the classroom; curricular up-dates; increased expectations of achievement; and constant faculty development efforts.

Third, instructors must become familiar with the literature on student learning and use such understanding as the basis for instructional strategies and delivery. No longer will content knowledge be sufficient. Engineering faculty must understand how students learn and present course material according to students' learning styles and capabilities.

Fourth, instructors must emphasize active learning, using technology, peer tutoring, cooperative learning groups, more immediate feedback, and other such instructional techniques to foster student understanding (Carlin, 1997). Involving students more actively in the learning process, as opposed to lecturing at them must become the hallmark of teaching cyber children.

This will require a corresponding change is the measurement of progress. Progress should be measured in terms of comprehension and the ability to apply acquired knowledge rather than in terms of course content, semester hours completed, and grades. Further, a student gaining knowledge must be separated from a student being able to perform in the workplace. Colleges and universities are in the knowledge business. Engineering offices are in the performance business. The knowledge and comprehension which engineering faculty help a student obtain, though, should enable him or her to learn to perform in the workplace. Nevertheless, because universities are in the knowledge business, somehow knowledge and comprehension should be measured rather than ability to synthesize and evaluate systems. These two things are significantly different and the latter is acquired with experience.

If the goal of instruction is student understanding and the ability to generalize knowledge to new situations, the instructor's role must change. The instructor must move from being a deliverer of content to facilitating students' capabilities to effectively process instructional material through a number of cognitive transformations. Measurement of the ability to think critically, though, is significantly more difficult than measuring raw knowledge.

Modifying Engineering Education

The last issue discussed above, shared responsibility for the total education, will require a different approach to engineering education—it will require a true partnering of engineering education between industry and the university. Very often engineering educators say "We need to be providing the engineer that which industry wants" and industry says "An engineer should be able to design and make me money the day he or she hits the streets." This is not realistic, even though universities often claim to be doing so. All students do not work in the same industry after graduation and do not remain in that industry their entire career. Students knowledgeable in the design of offshore platforms probably will not be effective designing buildings until they have gone through a relearning process.

This is really the crux of the change. Through universities and industry working as necessary partners in education, seasoned and very skillful design engineers will result. The universities will enable a student to achieve a solid founding in the principles of engineering science, analysis, and design. Industry then acquires this individual and enables him or her to apply those principles to widely varied design problems, under the direction of a senior engineer, and thereby become a highly qualified design engineer.

Another modification to the engineering classroom is the incorporation of computer-aided learning with extensive graphics and animation. Specifically, the change is the type of software that is available and the way that software is used in the classroom. The focus on the use of computers in the classroom—or more broadly, in the learning process—must be directed toward enhancing the students learning and comprehension of the subject matter through the visual modality. The focus should not be on enabling the students to solve larger problems more quickly.

This brings up the issue of what software is appropriate and how it should be used. There is not a single response to this query because what is appropriate in one course may not be appropriate in another course. For example, commercial analysis and design packages may be appropriate in a capstone design course, but most faculty will agree that such software is likely not appropriate in an introductory analysis course. The fundamental question to be asked is "Does the software enable the student to obtain a better understanding of the course content using their preferred learning style?". Content in this context is the fundamental principles that are to be learned and applied through study in this course. The ability to successfully execute software and generate large quantities of data is not necessarily the acquisition of knowledge.

Proper software for use in the classroom likely will require development. (Hopefully this software would then be universally distributed through the Internet to avoid duplicate development efforts.) Despite development efforts in the past, there is not much instructional software available for students working on personal computers. Effective software for use in the classroom today will have several significant attributes. These include:

- Modules directed at specific content with sufficient problems and problem variations to provide virtually unlimited drill for the students,
- A graphical interactive user interface that can operate effectively on the class of personal computer owned by the typical student,
- Animated demonstration and interpretation of system response,
- Immediate feed back regarding progress made by the student,
- Ability to interpret mathematical expressions typed by the student, and
- Ability to interpret alternate correct solutions and assist a student when "all hope is lost."

Development of course software incorporating these attributes is not an insignificant development effort. It does provide two benefits, though, for students when they are taking the course and in later courses for which the information is a prerequisite. These are faculty independent, supplemental, self-directed practice of the principles developed in class. This will enable the faculty to spend more time with the principles of the solution and less time repetitively working problems for the student; through the interactive nature of the software the student has become an active and integral part of the process. Secondly, the software will provide self-directed remedial work for students in later classes when the early principles have become "dusty."

Conclusions

The student in the classroom today is different than was the student of as little as 20 years ago. Today's student was wholly raised in the age of interactive graphics and that has been a central part of their learning process. These students will not learn well, and will not be challenged, using many of the teaching methods of the past. Methods used to teach engineering must change to accommodate the background of the student in the classroom—the student is not going to change. The purpose of this paper was to discuss the learning styles of today's student and to suggest changes that can be made in the educational process.

Teaching today's student, and development of the resources that are necessary to do so, will require significant effort on the part of the faculty. This effort must be recognized and rewarded in the tenure and promotion process. Faculty must be encouraged to develop the tools necessary to meet the challenges of today's student.

The authors have one final thought regarding the use of computers in education. The computer is a very powerful tool for use in the educational process. Because of its power, the computer can wreak havoc if it is used incorrectly. Its use must be defined and absolutely must have a specific and beneficial role in the process—it should not be used just because it is trendy and fun. It certainly should not cause the student to become an unthinking partner—to simply become an unthinking manipulator of data. Rather, the computer, through properly developed educational software, should cause the student to actively think about the concepts presented and to actively pursue assimilation of that knowledge.

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