ORGANIZING THE DEPARTMENT FOR GENERATIONAL TEACHING & LEARNING OF ENGINEERING KNOWLEDGE

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Abstract

Modern times mean the cybernetic revolution, which is composed of the latent information age, the rising knowledge age, and the future wisdom age. These changes will make current engineers trained only in information obsolete – replaced by computers. Therefore, to prepare engineers for the future, engineering faculty must master knowledge teaching.

Students will be members of the Millennial Generation for the next two decades and will be a blend of self-controlled concrete/linear learners. Conversely, the younger faculty is of the X Generation, which shows strong abstract/random thinking, individualism, and increasing pragmatism with aging. Further, the senior faculty represents the Boomer Generation whose virtues characterize individualistic, spiritual/moralistic, and uncompromising qualities. This clash of generations will be a continuing challenge to the engineering education profession and is a prime subject of this paper.

Traditionally, knowledge is obtained from selected information. Yet, in the knowledge age, a broader interpretation hastens this from a noun to a verb basis. The result is *knowledging,* which will allow the solving of new and different technical problems during the 21st Century. However, *knowledging* is reversible – knowledge decays first to *informatics* then to routine information as information overload floods communication.

Undergraduate engineering must begin *knowledging* by stressing insight, leading to new and improved problem solving throughout the curriculum, culminating with more diversified capstone design courses. However, *knowledging* needs to occur all through the undergraduate curriculum, and such a responsibility will definitely challenge department and college administrators.

The teaching design as explained in this paper represents a reversal of conventional professorial assignments, for the younger faculty, the X Generation, will teach the advanced courses, and the older faculty, the Boomer Generation, the beginning courses. Consequently the students, the Millennial Generation, will be exposed to a unique understanding of engineering education incorporating *knowledging*.

Introduction

The authors have published manuscripts concerning the impact of Generations Theory on engineering education at the ASEE National Meetings in 2002 and 2004 and ASEE Section Meetings

from 2001 onward. These publications position the current generation alignment of the engineering faculty with senior faculty as Boomers, younger faculty as Xers, and students as Millennials. The references describe Generations Theory as it applies to this faculty alignment. In this manuscript, the authors move into the engineering departments and show how the current generational alignment possesses the dynamics to move toward undergraduate knowledge learning instead of traditional information teaching.

Futurists believe the cybernetic revolution of today is occurring in two phases: the information age that hopefully has peaked and the knowledge age that is underway. A century ago, the engineering profession evolved in the industrial revolution and during that time the engineer created and handled scarce but valuable information. Today such information is common. Consequently, today engineers are trained to primarily handle routine information, and the long-range consequences are that the cybernetic revolution with its ever more efficient computers will make engineers redundant or quickly obsolete.

In the past century, engineers utilized information along with analogues to solve problems that were primarily formed from linear mathematics. In the 21st Century the problems will principally shift to the nonlinear mathematical regime that leaves much of the common linear analogs, for instance, superposition, insufficient to obtain required solutions; thus, the creation of acceptable solutions will require the attainment of knowledge for the baccalaureate curriculum that is currently unavailable, if not undiscovered. Consequently engineers will largely be the creators of a growing knowledge base to attack future problems.

Engineers must shift into the knowledge age in order to survive as professionals.[1] Just as the information age eliminated middle managers, engineers may become expendable unless they embrace new learning concepts. For instance, China produces yearly about three times the number of engineers than the USA;[2] however, these are "information engineers," not "knowledge engineers" which in the future will hopefully allow this nation to overcome such a number discrepancy. Thus, this paper is about the early aspects of the knowledge age with accent upon engineers learning knowledge from professors that are teaching information with appropriately added knowledge.

Traditionally, ordinary knowledge is obtained from systematic, purposeful, organized information;[3] contrariwise, higher knowledge is produced by the use of insight and other creative mind processes. The knowledge age, however, requires a broader interpretation of its namesake from a noun to a verb basis resulting in the gerund *knowledging*, which importantly now becomes a process articulating the accumulation of knowledge and allows solving new and challenging technical problems during the 21st Century. However, *knowledging* is reversible – knowledge, once it enters the public realm, decays first to *informatics*, then to routine, public information, thus further escalating information overload.[3]

Teaching knowledge, not just information, is the requirement for the Millennial Generation — the generation in college today and for the next 20 years.[3] These Millennials represent a controlled, dominant, and energetic populous, especially when compared to their predecessors; yet, *knowledging* will not be easy since it represents progressive concepts for most engineering professors teaching in baccalaureate programs. To understand this challenge, one has to observe not

only the expected capabilities of the Millennials but also comprehend the preferences of the previous generations, the Boomers and the Xers, since they will largely be the developers of engineering curriculum and the early, formal teachers responsible for *knowledging*. This paper presents one generational methodology to accomplish this task. With time, other methodologies will naturally evolve.

Basic *Knowledging* vs. Knowledge/Information Teaching

Commonly, knowledge is a noun representing facts, but at present it also characterizes a verb representing a process. The Oxford English Dictionary indicates its verb usage evolved from as early as the 14th century. Further, *knowledging*, the gerund of the verb knowledge, means teaching not only the basic information, but also the analysis of that information into knowledge. Yet, *knowledging* is not restricted to this narrow role; as it includes continued successful use of all types of knowledge.

One of the keys to *knowledging* is insight, especially for creating higher knowledge. Insight is divided by the psychology domain into commonly used open-minded processes: 1) Completing a schema; 2) Reorganizing visual information; 3) Reformulating a problem; 4) Overcoming a mental block; 5) Finding a problem analog.[4] Engineers generally make use of numbers three and five; however, advanced *knowledging* potentially utilizes any or all of these processes. In essence, the ability to utilize insight grows with the intellectual capability of the professor and the student.

In the learning process at the baccalaureate level, professors select and reject the information / knowledge to be included in any particular course. This development of course content is performed under several constraints; such as the accredited curriculum, the textbooks available, the time allowed, etc. Yet, what professors typically teach students is information, not knowledge, since it is only gleaned from the available information and thus, in one sense, is restricted to old problems. With the cybernetic revolution, however, most of the problems to be solved by working engineers will be novel problems, often created by new technology or the combination of cross-disciplines. Certainly professors created knowledge previously in their minds, yet they typically do not transmit to students the insights and judgments used in producing the knowledge. Providing students (especially Millennials) the reasons why selected information was included/excluded in course content is a critical part of the *knowledging* process. Useful insights on how experts (professors) differ from novices (students) enhance understanding.[5]

Knowledging is to teach the student the process of creating by judgment the knowledge to solve the given problem. Yet, once this knowledge, which is new to the student, is firmly in place, it now likely reverts to information since it is available for others to use, especially if it appears in communicative form at any time. This now becomes transient knowledge, since it easily reverts to a form of information – *informatics* – defined as previous knowledge when that knowledge becomes widely available to the general public, which is often via modern computers and electronic communication systems.[6]

The traditional four-part cognition emerges under these circumstances to a fifth part producing the revised *knowledging* process:

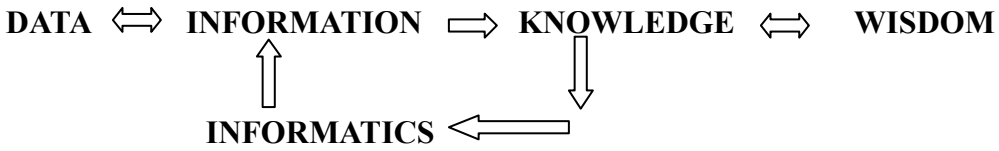

Figure 1: Knowledging; a five-part cognition process.

Here, the delay between *informatics* passing to information is a function of the domain of the knowledge. Engineering as a domain is broken down into a number of fields, such as mechanical, electrical, industrial, civil, chemical, etc. Each field develops its own knowledge, but some potentially reverts to *informatics* as it is transferred over a reasonable time to other fields of engineering.

To fully understand the cognition process, clarification of the term "learning" with respect to the terms "knowledge" and "information" is needed. Further, effective application of learning methodologies will enhance and accelerate the *knowledging* process. Thus, the five-part cognition *knowledging* process now transitions to a six-part definition:

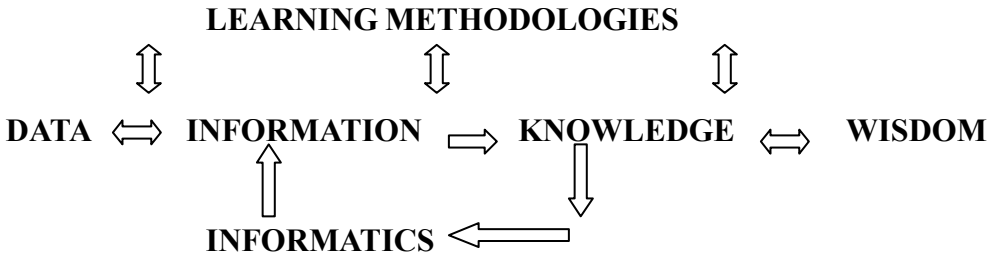

Figure 2: The application of learning methodologies to knowledging; a six-part cognition process.

The relationship of learning methodologies to the *knowledging* process is therefore dependent upon student preconceptions, amount of acquired information, and metacognitive abilities. The relationship is also dependent upon other factors such as teacher expertise, teaching ability, defined curriculum, and learning environment.[7] Further, effective assessment techniques and faculty professional development strengthen the bonds between learning and *knowledging*. Particularly in current times, an important aspect becomes generational preferences.

Generations Theory Synopsis

Knowledging requires more than just a lecturer routinely handling a large class and covering information. It requires a mentor match between a professor interested in presenting information and its relationship to knowledge and students willing and ready to absorb and utilize such knowledge. The current alignment of collegiate personnel presents the opportunity for *knowledging* to occur, as Millennial students are inherently eager to "go the extra mile" and obtain the best education possible. The faculty possesses knowledge and has the ability in the Boomer senior professors to lead the *knowledging* process with necessary and important backing from the

Xer junior professors. Thus, for understanding of *knowledging* in a college of engineering, one must first appreciation the concept of Generations Theory.

The authors have previously published papers about Generations Theory and its connection with engineering.[3,8] However, a brief summary follows to present enough information to make the remainder of this knowledge teaching paper coherent.

The theory of historical generations is a study of the time repetitions of basic social stresses over 80 to 90-year cycles (Figure 3). Each cycle normally has four types of generations; each cycle also has four turnings slightly out of phase with generational changes.[9] Historians Strauss and Howe employ the generational types of Idealist, Reactive, Civic, and Adaptive. These generations follow each other and currently average 17-23 years in length. The 80 to 90-year repeating cycle (or to use the ancient Latin word, saeculum) extends back several centuries.

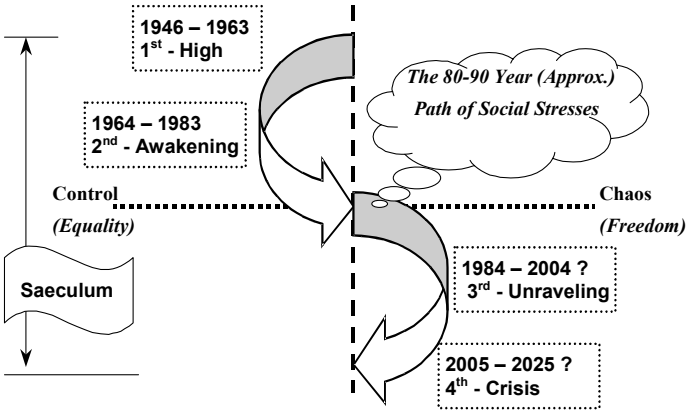

Figure 3: The position of social stresses over a saeculum.

The characteristics of the four Generations Theory types are:

- An *Idealist* generation grows up as *increasingly indulged* post-Crisis children, comes of age as the narcissistic young crusaders of an Awakening, cultivates principle as moralistic mid-lifers, and emerges as wise elders guiding the next Crisis.
- A *Reactive* generation grows up as *under-protected* children during an Awakening, comes of age as the alienated young adults of a post-Awakening world, mellows into pragmatic midlife leaders during a Crisis, and ages into tough post-Crisis elders.
- A *Civic* generation grows up as *increasingly protected* post-Awakening children, comes of age as the heroic young team workers of a Crisis, demonstrates hubris as energetic mid-lifers, and emerges as powerful elders attacked by the next Awakening.
- An *Adaptive* generation grows up as *overprotected* children during a Crisis, comes of age as the sensitive young adults of a post-Crisis world, breaks free as indecisive midlife leaders during an Awakening, and ages into empathic post-Awakening elders.

The key to Generations Theory is the italicized wording preceding "children" in the first phrase of these generation type explanations, for this early exposure sets the tone for the children's young adult and often lifetime performance. These adjectives are: *Idealist — increasingly indulged; Reactive — under-protected; Civic — increasingly protected; Adaptive — overprotected.*

The dichotomy between social "degree of freedom" and "degree of protection/control" governs the children's empathy toward educational accomplishment as well as their performance in future adult years. A current example is the transition from Civic to Adaptive generations that is occurring after September 11, 2001 — the apparent catalyst for the next Crisis cycle — with the increased emphasis upon safety as society moves to the highest protection status for children. For the morphology of Crisis refer to the Fourth Turning[9].

The common media names for the currently living generations starting with the youngest are:

- Millennial - Civic type with birth years of 1982 – 2003;
- X - Reactive type with birth years of 1961 – 1981;
- Boomer - Idealist type with birth years of 1943 – 1960;
- Silent - Adaptive type with birth years of 1925 – 1942;
- GI - Civic type with birth years of 1901 – 1924.

The generational age location in history is shown in Figure 4.

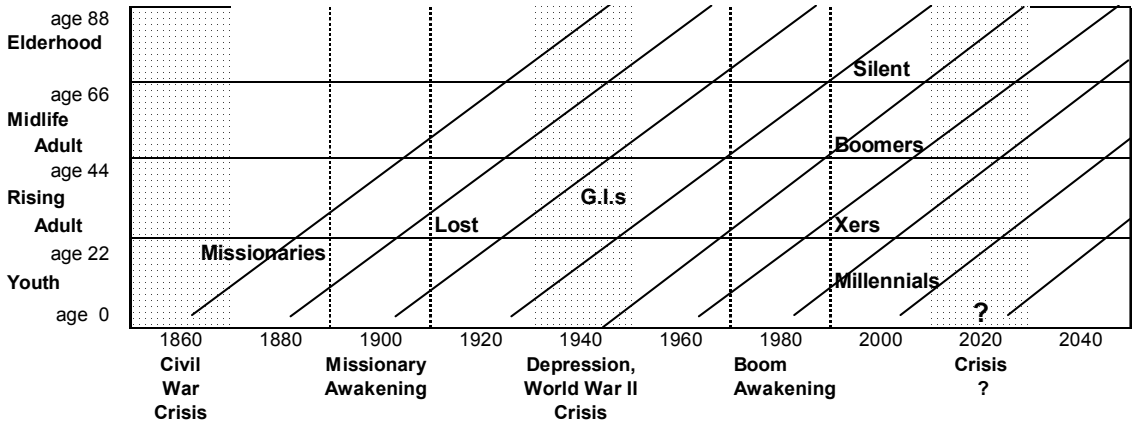

Figure 4: Generational age location in history.

The Millennial Generation (Civic) is our prime concern and its maximum age is 22. This Millennial Generation (Civic) is community oriented and secular in nature; conversely, the Boomer Generation (Idealist), the other dominant type, is individualistic and highly spiritual. The other two types are recessive in behavior and tend to initially follow the behavior of their next oldest generation but by midlife develop their own identity — the Adaptive is secular like the Civic while the Reactive is spiritual like the Idealist.

For the authors' purpose, the sterling learning academic characteristics (socially behaved, concrete/linear learners, and willing to take orders from parents and teachers) of the Millennial Generation (Civic) are significant. These characteristics are important in comparison to the increasingly pragmatic with age actions (strong individualism, abstract/random thinking, entrepreneurial, and "liberal – don't follow the rules" social behavior) of the teachers that are of the X Generation (Reactive). Further, both sets of characteristics are important to compare with the virtues (individualistic, spiritual/moralistic, and uncompromising) of the Boomer Generation (Idealist) that are the senior professors.

The blending of this tripartite of academic characteristics to produce a coherent educational result involving *knowledging* is truly a monumental but worthwhile task.

Using Generational Methodology to Organize the Department

As summarized above there are three main generations involved in current engineering education. The Boomers are professors beyond their early forties while the Xers are the younger professors. The Millennials are the students. Additionally, a few senior and emeritus professors over sixty remain from the Silent (Adaptive) Generation. A pictorial view of campus life for the next twenty years is shown in Figure 5.

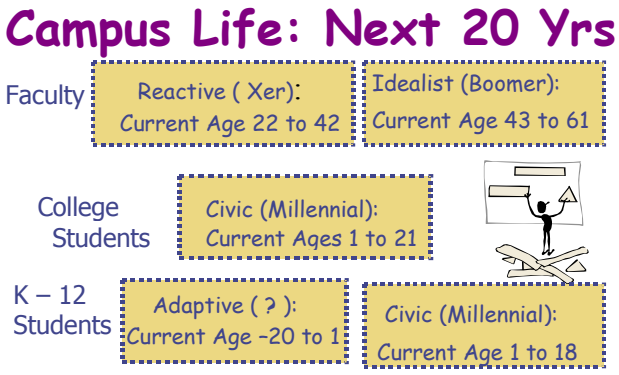

Figure 5: Campus Life the Next Twenty Years

The key to knowledge teaching is recognizing the knowledge aspects of the teaching being performed. Current teaching has mostly information associated with the instructional topic, such as textbooks, references, computer programs, etc. Yet the knowledge aspects of such teaching largely linger in the professors' minds unless a definite stimulant occurs to encourage the transfer of that knowledge to the students. It is the authors' opinion that the recognition of the importance of generational theory as it relates to the knowledge age must become an integral part of the required stimulant.

A dean leads/governs a college of engineering and is responsible for the several departments, which are headed by their own department heads (Chair type designations will tend to complicate the *knowledging* process since they are administrative and not performance responsible). The key to teaching knowledge lies with the department head for it is that person's recognition of the subtle understanding of *knowledging* that will allow its accomplishment. It will be the department head's assignment of which professors teach the various curriculum topics that will spell success or failure of knowledge teaching. And, this is particularly important at the current time, since Millennials will not become faculty members for another decade.

Notice that the above description of departmental leadership is put in terms of responsibility, not administration. Knowledge teaching must have a responsible department head in charge that can and will pick the proper faculty to teach a given course. In addition, department heads must

work with a responsible dean to insist upon hiring the best faculty that can accomplish knowledge teaching. Initially, the current faculty must be employed; however, appropriate professors must handle the key, high knowledge content courses, and the remaining faculty must be assigned to lower knowledge content, but still important, courses. Thus, the dean and department heads, likely both Boomers, must assess the capabilities of the professors making up the teaching faculty.

In order to teach knowledge to Millennials, the faculty teaching requirements should be reversed from the current common order. That is, the Xer faculty should primarily teach the senior, capstone courses since they are time-wise the closest to the ongoing major research results via graduate school where the production of pertinent knowledge is based for the given field. Such capstone courses, however, will involve a team teaching concept utilizing adjunct professors and a Boomer lead professor — ideally this should be the department head. Further, in order to include knowledge instruction in the earlier courses, especially in the students' 2nd and 3rd years, the appropriate knowledge-oriented Boomer faculty members should be the teaching professors, because of their longer exposure to the given engineering field and possession / recognition of its knowledge content.

An important aspect of this reversal in teaching assignments is that professors should not be allowed to choose the undergraduate course they want to teach; they must teach the courses that they can best teach for *knowledging* as determined with the department head. Further, it is the dean's responsibility to appoint knowledge-responsible department heads and not leave selection of departmental leaders to a political type majority opinion of the faculty.

A further *knowledging* aspect is the rotation of capstone courses between Xer faculty members; otherwise, one professor will have a lock on a course for more than two or three years. Further, when an Xer professor begins teaching a new course, that course should not be a basic course, but a secondary (higher level) one utilizing the basic course as a prerequisite. After teaching one or more of these secondary courses, the more experienced professor is assignable to the basic course.

This concept of having the senior, Boomer, professors primarily teaching basic courses while leaving the more advanced courses for the Xers is reinforced by the learning differences in Millennials and Xers. As noted previously, the Millennials are concrete/linear learners who learn well in physical laboratories supporting lecture presentations. Contrariwise, the Xers are abstract/random thinkers where the concept of computer driven virtual laboratories is adequate for their pragmatic teaching style. Consequently, it is the responsibility of the Boomers with their longer exposure to engineering education to teach the basic courses so as to adapt the Millennials to virtual computer simulations by unique hands-on activities where further knowledge experiments can be performed and appreciated.

There are many creative methods for adapting Millennials with unique hands-on activities and more will evolve as time passes; however, one current potential proposal involves notebook computers rather than only large lecture-style computer screens. Thus, when Millennials reach the advanced courses, they will have evolved a system of learning that allows them to grasp the Xers teaching style while still encouraging their professors to include more knowledge content.

Again, note that this teaching methodology depends upon the Boomer senior professors successfully performing their important responsibility with the basic courses.

Yes, this is a description of an efficient *knowledging* bureaucratic system. Departments must adapt to knowledge teaching if baccalaureate engineers are to survive in the knowledge age and not be largely replaced by information handling computers. The *knowledging* process must be efficient for current society cannot afford an elaborate inefficient use of limited monetary resources. The process must be responsible to survive as a viable and pragmatic bureaucratic organization.

In this era of *knowledging*, the preeminent person to be named dean of engineering is a leader/administrator that has performed in the best, responsible manner for a number of years. It is not the academic vice president's selection of a "hot" research person as dean. Consequently, a college of engineering must reform itself from primarily a 20th Century research organization into a body whose prime responsibility is to perform the best undergraduate teaching in the rapidly changing 21st Century. Understanding budgetary constraints and using the concept of specialization that is inherent in modern society, the research activities of a college of engineering may need to evolve into a division of engineering research, and consequently many professors will have joint appointments with this and a regular academic department. This arrangement may additional require the use of "matrix management" and entrepreneurial methodologies used in some corporate-like organizations.

The preceding paragraphs have described the faculty situation of Boomers and Xers. Moving onto the Millennials as students involves further considerations for their makeup favors group activities, rather than the individualistic nature of the previous students, the Xers.[10] Millennials will study together and generate group questions to ask their professors, and as time passes and these Millennials become more advanced students, such questions likely will involve knowledge topics. Certainly if the lower level classes are taught by knowledge-conscious Boomer professors, these students will develop such a knowledge-inquiry rational. Such questioning will bombard the Xers as 4th year teachers, and the result is that these Millennials will exploit the minds of these Xers searching for generally hidden knowledge. Further, the Boomer faculty will have to teach the Millennial students and the Xer faculty teamwork and facilitation concepts. When this is successful, the teaching of the knowledge age will be well underway for the early 21st Century.

Now move further into the future. The above description of a bureaucratic organization for the undergraduate program in colleges of engineering goes against the common norm. Today such a program is more tailored toward an independent faculty — especially the Xers — that has a bigger voice in the teaching schedule than that suggested above. And this type of faculty program will largely return in about a decade when the Millennials begin to finish graduate school and take engineering professorial positions, for they will be well versed in the knowledge age and well understand *knowledging*. Further, as the current faculty reorients itself to this knowledge age and becomes more attune to the concepts and experiences of knowledge teaching, the bureaucratic nature of the college of engineering will relax in intensity and a better teamwork approach will evolve toward undergraduate education.

Future Knowledge Teaching

When future multiple decades are considered, then various scenarios are possible. One such is the periodically discussed five-year undergraduate program in engineering with much emphasis upon knowledge acquisition in the final two years. A modification of this five-year program is possible to better handle transfers from two-year community colleges. An additional aspect of this five-year program allows a general engineering degree after four years with a specialty occurring in a give engineering discipline during the final year. Further, under some conditions, students may graduate with a baccalaureate in general engineering and a master's degree in some engineering specialty after five plus years. The extra time is for completing the required graduate requirement, such as a thesis.

Another future aspect represents a cross-discipline approach where engineering information and engineering know-how are blended with a field from a non-engineering domain. Some apparent examples are Chemical and Biological Engineering, Agriculture and Food Engineering, Electrical and Medical Engineering, and, Industrial and Health Engineering.[11] The type of ordinary knowledge that is obtained from systematic, purposeful, organized information represents using the ability of engineers to expertly manage multiple aspects of information and then appropriately combine them utilizing insight to produce problem-solving knowledge. Such cross-domain engineering programs can represent a vital transition for engineering as it scholastically modifies itself for the knowledge age of the 21st Century.[12]

As time passes in the upcoming decades, additional new and better *knowledging* techniques will develop allowing the Millennials to succeed in their quest for engineering knowledge. Look for the members of ASEE to lead the way.

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