What Makes a College Graduate "Educated"?

A Proposed Curriculum Revision Across Disciplines

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Abstract – Each university has its own understanding of, and definitions for, the critical skills, knowledge, and abilities that are required for a modern college graduate. The University of Tennessee at Chattanooga (UTC) has recently begun an examination of current curricula, and has proposed, as a set of shared educational values, eleven ASK's (Abilities, Skills, and Knowledge), which are viewed as crucial to each student, regardless of major. These principles, which were recently approved at the fall full faculty meeting at UTC, are: communication in a variety of genres and settings; information literacy; intercultural literacy; ethical decision making; inquiry and analysis; quantitative literacy; creativity and creative thinking; critical thinking; collaboration in diverse groups; civic engagement; and integrative and applied learning. [1] This paper explores the relation between the ASK's and the ABET accreditation standards for engineering, the relation between these and skills necessary for engineering practice, and how, or whether, they might be incorporated into an engineering curriculum.

Keywords: Information Literacy, Critical Thinking, Curriculum Reform.

INTRODUCTION

The general education component of a university education can mean very different things at different universities, ranging from a few unrelated courses at some, to a comprehensive set of essential core knowledge and skills that are regarded as absolutely necessary for an educated person at others. The only requirement that the ABET accreditation standards makes on the general education portion of a program is "Criterion 5 (c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives." [2] Thus, it is the responsibility of each university to define for its students what it believes to be the indispensible skill set which is consistent with its goals and vision. However, since general education requirements are not always set by those cognizant of engineering accreditation requirements, there can sometimes be a mismatch between what the university as a whole regards as the appropriate general education standards and what is necessary for engineering accreditation.

The University of Tennessee at Chattanooga is currently involved in an extensive reevaluation of its general education program in order to define what a truly educated college graduate should know or be able to do, and has proposed a set of eleven Abilities, Skills, and Knowledge (ASK's) to be required of each student, regardless of major. While some of these items, such as ethics and communication, are required by ABET and are included in every accredited engineering program, others are not; yet such items as critical thinking and information literacy are essential for the effective practice of engineering. The university currently has a group of "Blue Ribbon" committees addressing these ASK's, charged with developing a set of measurable student learning outcomes for each at freshman, sophomore, junior, and senior levels, but how these would be incorporated into different majors is not yet being addressed. Also, in an era when more and more state legislatures and university administrators are reducing the number of hours engineering programs are allowed to include in their graduation requirements, educators reasonably ask how anything else can possibly be squeezed into already time-crunched programs.

The next section of this paper discusses the correlation between the eleven ASK's and the ABET criteria, how some items which match well to ABET requirements are covered, and how some others may not apply well to engineering curricula. The following section discusses items which are not explicitly required by ABET criteria, but which are

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crucial to successful, responsible engineering practice, and how they can be included in engineering programs. The final section contains concluding remarks regarding this curriculum reform and its implications for UTC's engineering programs.

THE ASK'S AND ABET

The eleven ASK's as originally identified by U.T.C. are

- communication in a variety of genres and settings;
- information literacy;
- intercultural literacy;
- ethical decision making;
- inquiry and analysis;
- quantitative literacy;
- creativity and creative thinking;
- critical thinking;
- collaboration in diverse groups;
- civic engagement; and
- integrative and applied learning. [1]

After their original adoption at the full faculty meeting in September, 2010, each ASK was assigned to a separate "Blue Ribbon" committee personally appointed by the UTC Faculty Senate President. The task given to each committee was to expand the definition of the ASK into the necessary skill set, and define measurable outcomes at the freshman, sophomore, junior and senior levels which, if met, would insure that the students would graduate having the skill, knowledge or ability embodied in the ASK.. [3] However, since the ASK's are meant to define the general education requirements at UTC, since the number of hours in each program is limited by the Tennessee legislature, and since all general education courses at UTC are taken at the freshman and sophomore levels, any outcomes defined at the junior and senior levels would have to be included in engineering major courses. Therefore, it is necessary to examine the constraints already placed on engineering programs by the ABET accreditation requirements, to see if some of the ASK's are automatically met by meeting ABET outcomes, to see if others are not currently being met, but should be, and to identify any that may not be relevant to engineering practice.

As a reference for the discussion, when most people speak of the ABET criteria, what they first think of is the infamous and ubiquitous ABET Criterion 3 a-k program outcomes listed below: [2]

(a) an ability to apply knowledge of mathematics, science, and engineering

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

One of the ASK's is subsumed in ABET criteria, some match well, some are partially met, and some do not have an obvious application to engineering programs. Others are not explicitly required by ABET, but are, nonetheless, necessary for engineering practice. The correlations between the ASK's and the ABET outcomes is shown in Figure

1. In this figure, black shading indicates complete overlap between ASK and ABET requirements, gray shading represents partial coverage, and no shading indicates no perceptible correlation.

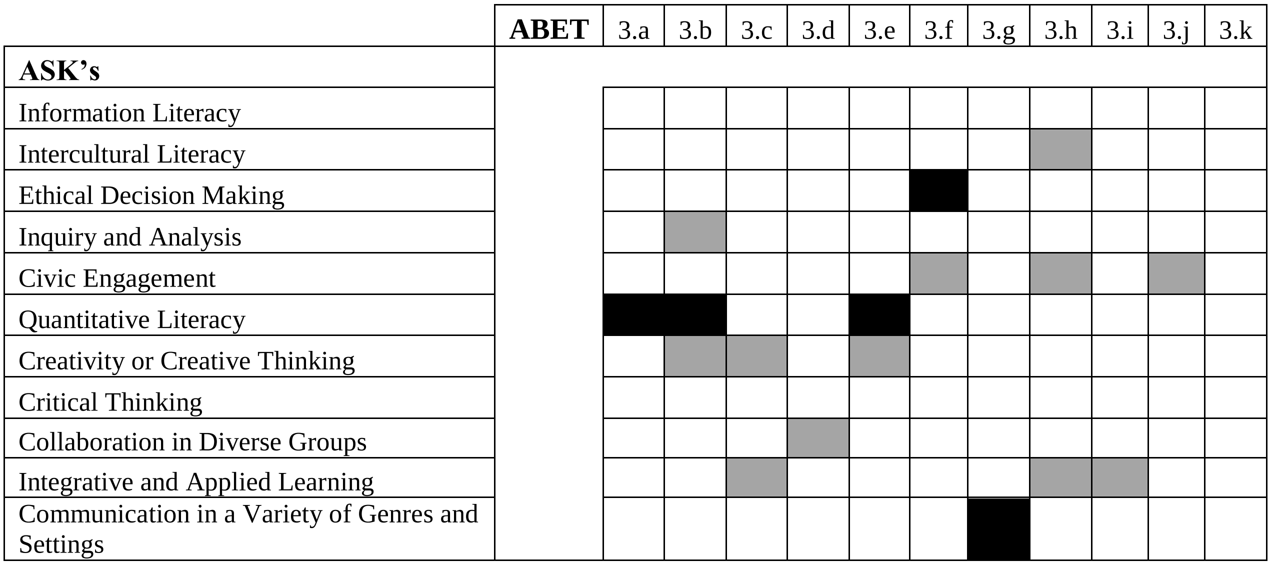

Figure 1. Correlation between UTC’s Abilities, Skills, and Knowledge essentials and ABET required outcomes.

One ASK that is Subsumed in ABET Criteria

One of the ASK’s is quantitative literacy, further defined as “Reason and solve quantitative problems from authentic contexts and everyday situations to create arguments supported by quantitative evidence and clearly communicate those arguments in an appropriate format such words, tables, graphs, mathematical equations, etc.” [4] When the ABET outcomes are examined, at least three, 3.a., “an ability to apply knowledge of mathematics,” 3.b., “an ability to ...analyze and interpret data,” and 3.e.,“ability to identify, formulate and solve engineering problems,” [2] are directly applicable. This, in combination with an examination of the proposed outcomes for this ASK, which even at the senior level only include such items as “use quantitative evidence to support arguments” and “communication of results,” [4] lead the author to conclude that engineering graduates of ABET accredited programs should already exceed this requirement.

ASK’s that Match Well with ABET Requirements

Two of the ASK’s seem to be directly analogous to ABET criteria. “Communication in a variety of genres and settings” has been defined by its assigned committee to include such skills as incorporating appropriate context and purpose, use of genre and disciplinary conventions, and proper uses of sources and evidence. [4] This ASK is directly correlated to ABET criterion 3.g, “ability to communicate effectively.” [2] Although ABET doesn’t require that its outcome be expanded to include all of the skills currently being considered by the committee, the intention of the ASK and the ABET requirement appear to be identical, and demonstration of satisfaction of one should satisfy the other as well.

The other ASK which appears to be a direct match to the ABET criteria is “ethical decision making,” which has been further defined to include recognition of ethical issues in a complex context and consideration of ethical implications of alternative actions. [4] Both ABET 3.f ,“an understanding of professional and ethical responsibility,” and the inclusion of ethics as an example of the type of realistic constraints that must be included in design in 3.c., [2] show strong connections to the ASK and the outcomes delineated in the work by the committee.

ASK’s that are Partially Met by Engineering Curricula

There is one ASK, “collaboration in diverse groups,” for which no further information exists, and for which no outcomes were defined. This was due to the inability of the assigned committee to agree on what constituted “diverse groups,” and their unwillingness to accept that “diverse” would, in the context of discipline-related courses, have to be defined in different ways for different programs. [5] However, this ASK can be at least partially mapped to ABET 3.d, “an ability to function on multidisciplinary teams.” [2] While a typical definition of diversity might be more likely to include such items as gender and ethnicity, different engineering disciplines do have significantly different educational backgrounds, leading to different methods of approaching problems and different patterns of thought. Thus, the ability to work well in multidisciplinary groups is related to some extent to the intent of this ASK, and at least partially fulfills it.

An ASK which is partially covered by ABET requirements is creativity. This has been extended and defined by the assigned committee to include problem solving, innovation, synthesis, and engaging in independent, creative solutions based on prior course materials. [4] It could be argued that this would make an excellent definition for engineering as a whole. It is also closely related to ABET 3.b., “an ability to design and conduct experiments, “ 3.c., “an ability to design a system, component, or process to meet desired needs within realistic constraints,” and 3.e., “an ability to identify, formulate, and solve engineering problems,” all of which contain aspects of creativity as defined by the committee. The requirement in ABET criterion 5 that an engineering curriculum culminate “in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints” (colloquially known as the “capstone project”) is directly applicable to this ASK. Also, the definition in the criteria of engineering design as an iterative process which optimally converts resources, and builds upon knowledge of mathematics, science, and engineering to create an item to meet needs and constraints [2], could be interpreted as the very essence of creativity, as applied to the engineering discipline.

Another ASK which can be interpreted as relating to the engineering design process is integrative and applied learning. This has also been defined by its committee to include synthesis, as well as effective application of knowledge to complex, real-world problems, and independent application of knowledge to new situations in order to solve difficult problems, all of which are related to the ABET criteria discussed in the previous paragraph. In addition, the defined outcomes at the senior level for this ASK include “envisions a future self that has developed through past experiences,” and the definition includes a requirement for “individual reflection and self-reflection. [4] Both of these are applicable to ABET criterion 3.i., “a recognition of the need for, and an ability to engage in life-long learning,” as lifelong learning necessitates the skills embodied in the ASK. Finally, the ABET 3.h. criterion which indicates that engineering graduates are expected to understand the global and societal implications of engineering decisions [2] would also require the ability to deal with real-world problems in a variety of contexts and the “integrative” aspects required by this ASK.

The ASK of inquiry and analysis has defined senior outcomes including “design/implement a research project,” “organize and collect data,” and “analyze and interpret data...to provide logical conclusions.” [4] These are very closely related to ABET 3.b., “an ability to design and conduct experiments, as well as to analyze and interpret data,” which must be demonstrated in every accredited engineering program. [2]

ASK’s that Appear Less Applicable to Engineering Curricula

There are two ASK’s which are not so easy to relate to engineering accreditation criteria, but which may be partially fulfilled in technical curricula. The first of these is civic engagement, further defined as “Recognize a responsibility to make a difference, by developing the knowledge, skills, values and motivation to advocate, promote and pursue engagement in the community.” [4] While this is not directly met in the ABET criteria, several of the accreditation outcomes are relevant in this area: 3.f, “an understanding of professional and ethical responsibility,” 3.h, requiring understanding of “global, economic, environmental, and societal” impacts of engineering solutions, and 3.j., “a knowledge of contemporary issues.” [2] A knowledge of contemporary issues and an understanding of how engineering solutions affect our world and society are tools which are necessary for true civic engagement, while it could be argued that professional and ethical responsibility of engineers would imply an element of civic engagement. This link could be strengthened by requiring that the engineering capstone projects discussed above include an element of civic engagement; however, this might prove impractical, as it would place a constraint on problem definition that could be hard to meet in small universities or those located in rural areas.

The ASK which appears most problematic for engineering programs is intercultural literacy, requiring that students “Reflect knowledge, skills, and attitudes to engage others meaningfully, to place social/economic practices in historical and political context, to put culture at the core of learning and to adapt empathetically and flexibly to unfamiliar ways of being.” [4] While it can certainly be argued that some level of intercultural literacy would be required in order to meet ABET criterion 3.h "to understand the impact of engineering solutions in a global, economic, environmental, and societal context," [2], do any engineering programs "put culture at the core of learning?" Although the application and context of engineering may be different in different cultures, an examination of the ABET accredited engineering programs in other countries such as Mexico, India, Germany, and Qatar show that the essence of the curriculum is the same in each, although the cultures which house the programs are very different. This would seem to contradict the ASK requirement that culture be the core of learning. Some of the outcomes defined by the committee at the junior and senior levels, which would have to be included in upper division engineering courses, include "relativize cultural values" and acquire "new knowledge of culture and cultural practices," [4] which do not have an easily identifiable tie to engineering disciplines and would be very difficult to incorporate. More thought is necessary as to whether this is desirable to require of all university students, and if so, how it could be related to technical fields.

The remaining two ASK's, information literacy and critical thinking, are not explicitly required by ABET, but appear to the author to be essential for successful, responsible engineering practice. These are discussed in the following section.

CRITICAL SKILLS FOR ENGINEERS

As French psychologist Jean Piaget stated:

> The principal goal of education is to create [people] who are capable of doing new things, not simply repeating what other generations have done – [people] who are creative, inventive, and discoverers. The second goal of education is to form minds which can be critical, can verify, and not accept everything they are offered... We have to be able to resist individually, to criticize, to distinguish what is proven and what is not. So we need [students] who are active, who learn early to find out for themselves, partly by their own spontaneous activity and partly through material set up for them; who learn early to tell what is verified and what is simply the first idea to come to them. [6]

Information literacy and critical thinking are inextricably linked, and are essential for all education, including that in engineering programs. The UTC definition of information literacy is for the student to "know when information is required and be able to locate, evaluate, and simultaneously extract and construct meaning in an effective and responsible manner," and critical thinking is portrayed as "a habit of mind characterized by the comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating an opinion or conclusion." [4] It is clearly not possible to perform "comprehensive exploration of issues" without acquiring and examining the appropriate information, and equally impossible to "extract and construct meaning in an effective and responsible manner" without the skill and practice of critical thinking. These are both particularly important to the practice of engineering, where the failure to acquire, recognize, and critically evaluate information can lead to loss of life.

One example of a case in which failure to secure sufficient and appropriate information, and misuse of existing information, lead to loss of life was the February 1, 2003 disintegration of the space shuttle Columbia on re-entry into the earth's atmosphere, resulting in the death of all aboard. After exhaustive investigation, NASA issued an extensive report, giving as the cause of the break-up, the damage to heat shields caused by foam breaking away from the shuttle and striking protective tiles on take off, leading to shield failure on re-entry. However, contributory causes to the incident included the following:

- A number of previous, similar foam strike incidents, and their effects, were not considered.
- Management took the position that since there were no perceptible negative consequences from foam fragment strikes in previous launches, although such foam strikes were documented to have occurred, the probability of significant negative consequences from the Columbia incident were negligible.
- After video of the take-off indicated a foamstrike, engineers requested additional information, such as flyover video and the possibility of a space walk to have astronauts examine the damage. However, these requests were ignored, as they did not follow the correct "chain of command."
- Software was used to simulate the foamstrike incident and predict damage to the heat shields; however, the assumptions made during software development included only small fragments that were not consistent with the Columbia situation, leading to erroneous conclusions.

• "...management--including Shuttle Program, Mission Management Team, Mission Evaluation Room, and Flight Director and Mission Control--displayed no interest in understanding a problem and its implications." [7]

While it can never be known whether the outcome of the Columbia incident would have been different if the correct information had been obtained and had been critically interpreted, the report clearly shows that errors of information literacy (failure to acquire all of the necessary information, misuse of information sources, and failure to correctly interpret information) and failures in critical thinking (forming opinions and conclusions without comprehensive exploration of all of the relevant issues, events, and ideas) contributed to the catastrophe.

Furthermore, although the result of failures in these two ASK's have such great potential consequences for engineers, it has been the observation of the author in previous studies on information literacy and critical thinking [8, 9, 10], that some engineering students at UTC perceive their own proficiency in these areas as being much greater than objective assessment would indicate. For example, although 97% of the seniors surveyed considered themselves average or above at electronic searches for data, only 4% correctly identified the appropriate professional database which would have been the correct source to search for information on a technical engineering topic, with 22% identifying Wikipedia as the best source, and 56%, Google search. Also, in evaluating information quality, 2/3 of the seniors surveyed failed to correctly identify what constituted a "refereed" source, and Figures 1 and 2 show their responses to questions on reliability of sources (Figure 2) and how they would select information to include in a paper (Figure 3). [8]

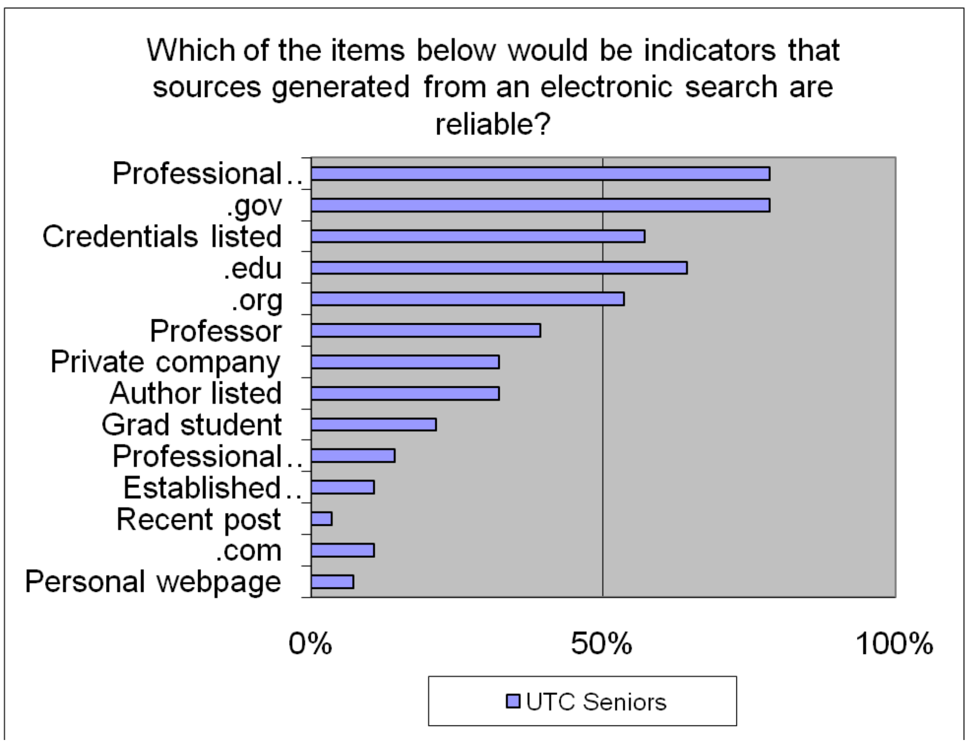

Figure 2. Student responses to indicators of relatibility of results from an electronic search [8]

Examining the figure, it is evident that students considered professional journal results and anything from .gov sites as equally reliable (79%), with over 50% considering anything with author's credientials listed, anything from a .edu website, and anything from a .org website as reliable. (Sum is greater than 100%, as students were told to pick all choices that applied.)

From Figure 3, one can see that given an assignment for a paper on ethics in a technical discipline, 86% would select information from reliable sources, but 34% would select information based on whether it agreed with the student's own viewpoint, 28% would include information because it was easy to find, and 21%, "cool photos."

Although the dataset on which this information is based is small (students in one semester of the engineering senior capstone design course), it still provides an indication that at least some engineering students at UTC need additional education and practice in the areas of information literacy and critical thinking. Some ways in which each can be incorporated into engineering programs, including full curriculum reform, dedicated courses, and inclusion in existing courses are discussed at more length in the author's previous papers, with examples of semester-length assignments that can be added to existing engineering courses [9,10].

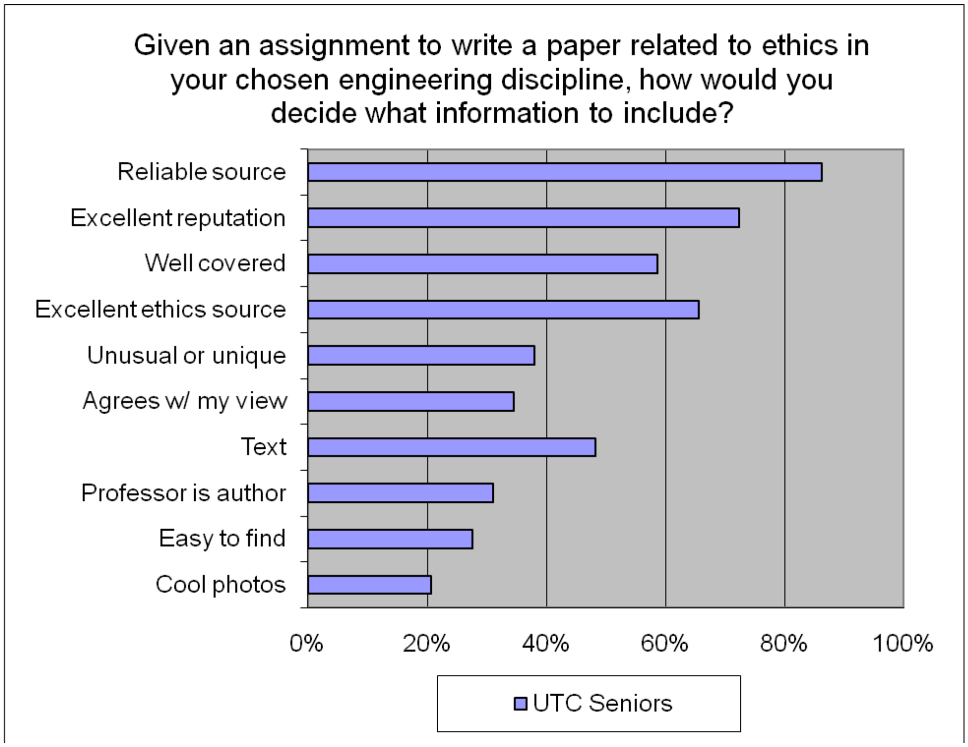

Figure 3. Student responses to ways they would select information to include in an engineering paper [8]

Because of concern and previous work in these areas, the author gladly agreed to serve on the UTC committee addressing critical thinking outcomes, and would welcome the opportunity to continue to investigate and develop ways in which both of the linked areas of information literacy and critical thinking can be better incorporated into existing curricula. Thus, although these final two ASK's are not actually required by accreditation criteria, the author would strongly support their inclusion in UTC engineering programs, and even the consideration of future incorporation into ABET accreditation criteria.

CONCLUDING REMARKS

The eleven general education abilities, skills, and knowledge areas approved by the UTC faculty for all programs have been discussed and defined, along with a discussion of how each fits with engineering accreditation criteria. Seven of the ASK's, communication in a variety of genres and settings, ethical decision making, inquiry and analysis, quantitative literacy, creativity and creative thinking, collaboration in diverse groups, and integrative and applied learning, have been shown to be at least partially included in existing requirements, with some being totally covered. Two, civic engagement and intercultural literacy, have been shown to be less well-suited to engineering curricula, and have questions remaining as to how they could, or should, be included in engineering programs. The final two, information literacy and critical thinking, are not included in ABET standards, but are arguably essential to effective and responsible engineering practice, and, in the view of the author, need to be more strongly emphasized in existing engineering programs at UTC and elsewhere.

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