Engineering for Non-Engineers: Where We Stand at Colleges and Universities

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Abstract
Engineering for non-engineers is being taught successfully at the college level. While this has been done at individual institutions and there is a large community of interest, the practice has not become widespread. Based on the experiences of people who have taught these courses, issues keeping engineering from becoming part of every college student’s education include finding a place for engineering in the general core curriculum, finding faculty to teach the course, rewards for faculty, resources, and course materials. Of these, the critical issue is finding a place in the curriculum. Pressure from outside the academic community is needed to drive changes in university core requirements.

In the 1990s, a push came from the National Science Foundation (NSF) and the National Academy of Engineering (NAE) to make it a national priority to increase the technological literacy of the general public in the United States. Without much fanfare or attention, people at colleges and universities across the United States and beyond have been engaged in teaching non-engineers about engineering for many years. Under different names, people have developed programs ranging from individual courses to minors and even graduate level programs in the belief that all people should know more about engineering and the technology that engineers create and manage.

To be prepared for the future, people need to know something about engineering. While good models have been developed for teaching people about these subjects, it has not become part of the general core curriculum at the college level. This paper will discuss barriers that must be overcome for the practice of teaching every student about engineering widespread.

Introduction
Without much fanfare or attention, people at colleges and universities across the United States and beyond have been engaged in teaching non-engineers about engineering for many years [1,2,3]. While this has been done under different names, people have developed programs ranging from individual courses to minors and even graduate level programs in the belief that all people should know more about engineering and the technology that engineers create and manage. People who know something about engineering are equipped to understand the issues involved when news stories report problems with vehicle ignition switches, water supply systems, cost overruns and schedule delays in military aircraft programs, catastrophic accidents with spacecraft, or other problems with our technological infrastructure. People who produce the news stories, people who propose legislation or sit on juries, and people who vote need to know something about engineering. To be prepared for the future, people need to know something about engineering.

State of the Art
In the 1990s, a push came from the National Science Foundation (NSF) and the National Academy of Engineering (NAE) to make it a national priority to increase the technological literacy of the general public in the United States [4,5,6,7]. In the modern engineered world, a
person needs to know something about engineering to have an understanding of technology. This effort, documented in works such as Technically Speaking [4], led to efforts at two levels. One result of this effort was the movement for STEM (Science-Technology-Engineering-Mathematics) in K-12 education. This has been a very successful effort. Standard teaching materials have been developed, an STEM-based curriculum has been widely adopted, and this has become part of ITEA K-12 educational standards [8].

These efforts also promoted work to include engineering and technology in the curriculum for college undergraduates. At colleges and universities across the country, faculty have developed courses with the goal of teaching undergraduates who are not engineering majors about engineering and technology. While these courses come under different names, they share a goal of educating people about engineering.

This community of college and university educators has a home in the American Society for Engineering Education (ASEE). Over the past two decades, an interest group was formed within the Liberal Education / Engineering and Society (LEES) division, and this interest group grew to the point of becoming a separate division. This division, originally the Technological Literacy Division (TED), recently changed its name to reflect its interest in and promote teaching non-engineers about engineering. Now known as the Technological and Engineering Literacy / Philosophy of Engineering (TELPhE) Division, a primary part of the division’s mission is to promote efforts to teach people who are not engineering students about engineering.

Today, the TELPhE Division of ASEE has attracted a large number of members. Each year, the division attracts enough papers from people who are teaching engineering to non-majors to fill several sessions at the annual conference [9]. The division’s website is a clearinghouse for information on courses and other efforts to teach engineering to non-engineers. The division has hosted workshops for people interested in developing courses or programs in this area and was successful in sponsoring a distinguished lecturer who spoke on areas related to this topic. Members of this division have secured NSF funding for course development and have hosted NSF workshops related to this area.

Papers presented at TELPhE Division sessions show that people across the United States and beyond have developed successful courses with the goal of teaching non-engineers about engineering and technology. People have been successful with many different approaches, including innovative labs where people learn about engineering by taking things apart and building new things, classes and labs based on engineering artifacts, approaches drawing on the history of engineering and technology, on current news items, on readings in science fiction, and on movies. These efforts add up to a foundation for more widespread efforts to teach engineering to non-engineers.

This work has not been limited to individual college courses. Papers presented at TELPhE sessions report successful efforts to develop programs such as college minors [10,11,12].

The TELPhE Division is not the only division of ASEE with an interest in teaching people who are not preparing to become engineers about engineering. The parent division, LEES, retains a strong interest in this area. The Pre-College Division represents people teaching engineering to
non-engineers at the K-12 level. While the First Year Programs division focuses on teaching new engineering majors, they too are teaching engineering to people who are not (yet) engineers. Other divisions including Engineering and Public Policy and Systems Engineers have interests related to this area as well.

Also, efforts to teach the general public about engineering are not limited to educators focusing on college courses or on K-12 education. Museums such as the Science Museum of Boston [13] are active in this area as part of their efforts in technological literacy. The Public Broadcasting System program “American Experience” has produced programs related to teaching people about engineering and has developed an Engineering Map of America [14]. Engineering professional societies have an interest in this area; the American Society of Civil Engineer’s efforts to inform people about our infrastructure relate to educating people about engineering. NASA, the Department of Defense, the National Institute of Standards and Technology, and other government agencies have produced educational materials that are available for all to use. Much can be learned about engineering from the history of technology. The Society for the History of Technology (SHOT) produces material that can be very useful in teaching people about engineering. Museum exhibits are useful here as well. The Smithsonian Institution’s American History and Air and Space Museum, the Air Force Museums in Dayton, Ohio, and at Warner-Robbins AFB in Georgia, the Aviation Museum in Seattle, and the Space and Rocket Center in Huntsville, Alabama, are all good examples. While local and regional science centers such as the Adventure Science Center in Nashville, Tennessee, emphasize programs for K-12, they can be part of broader efforts.

The need for an introduction to engineering and technology to be part of a college education is clear. Today, people in colleges and universities are teaching technological and engineering literacy for non-engineers, and have been doing so for over a decade. These people have come to ASEE and have shared their knowledge and successes with the engineering education community. People who want to develop courses or programs in this area can turn to the TELPhE Division for help, including sample course materials. Useful materials and more are available from other ASEE divisions as well. Resources are also available from engineering professional societies, government agencies, museums, and other organizations.

With all that, why isn’t an introduction to engineering and technology part of everyone’s college education?

Challenges
People are teaching non-engineers about technology and engineering at the college level. Some people have been successful to varying degrees at different institutions. Based on the experiences of people in the TELPhE Division who push to teach non-engineers about engineering, here are some reasons why this has not become widespread at the college and university level. Starting with the most difficult issue, the major issues are

1) Getting a Place for Technological and Engineering Literacy in the Curriculum,
2) Faculty to teach the course, and
3) Rewards for faculty who teach and administrators who support these courses.
In addition, there is a need for

4) Resources and
5) Materials for teaching the course.

Items 1-4 are related to institutional support; with sufficient support from higher levels, these hurdles can be overcome. As noted earlier, item 5 has been addressed up to a point.

Getting a Place for Technology and Engineering in the General Curriculum

The most effective way to put a topic into the curriculum at colleges and universities is through at least one full three quarter or semester hour course on the subject. To enhance the curriculum with engineering, an engineering course for non-engineers has to be developed. At least one faculty member must be available to teach the course, and there must be enough students must take the course to at least meet standards for minimum class size. If the course is to be required for all students, a large number of faculty members must be made available and the faculty must agree on a common curriculum for the course. It is likely that another course must be removed from the university’s core requirements to make room for the technological and engineering literacy course.

Currently, in most institutions with an engineering course for non-majors, the course is an elective. For an elective course, students must be able to use the course as part of their degree program. Students must have enough room for electives and enough interest in taking this course to choose it from other options.

If a university has elective courses in the general university core, this course could be added to the list of electives. It would then compete with other courses for students. If the course is an elective, the most difficult issue is likely to be attracting students. Students will perceive the course as being difficult, and faculty advisors from other areas may not see the value and will urge students to take other electives. For a general elective course designed for non-majors, faculty responsible for the other majors have to be convinced to promote this as a good elective option for their advisees. The name engineering in either the course listing or course title sends a signal to some students that the course may be difficult, and some students will seek what they perceive to be easier options.

An engineering course for non-engineers can be offered as an elective for some majors. For a course designed for non-majors, faculty responsible for other majors have to be convinced to add this course to the list of approved electives. A course on engineering for non-majors is likely to be competing with courses in the major and other courses that have already been established as being important for these majors. The people who will decide on adding this course to the elective list and who, as faculty advisors, will advise students on their elective courses are likely to be offering other elective courses and seeking students for those courses. Even when faculty in other programs support the engineering for non-engineers course, it can still be difficult to attract enough interested students.

For some majors, a course on engineering for non-engineers should be attractive, and advisors in those areas should recommend the course. Education majors who are likely to teach in an STEM
curriculum need a course in engineering. Students in economic history, geography, industrial psychology, business, computer science, and the physical sciences where graduates are likely to work with engineers should be encouraged by their advisors to take such a course. Going beyond a single course, a minor should be attractive to advisors and students alike. Advisors and students in areas that are not related to engineering and technology are far less likely to see the value of this as an elective course.

If all students are to be exposed to engineering as undergraduates, then the engineering course for non-majors must be a required course for all students. A recent trend in state institutions, driven by state legislatures, has been to reduce the number of hours required for a degree. It is not likely that the number of courses required for a degree can be increased. Instead, a course, either from the general university core or from each major, must be cut to make room for the engineering course. Any cuts will be resisted internally by people who teach the course being cut. A course on the required list is there for a reason; the course is thought to be important enough to require for all students. People who think the course to be cut is important will resist efforts to remove that course to make room for the new course.

While other options, such as a mini (one semester credit hour) course could be considered, the structure of the institution is geared for standard three semester credit hour courses.

Recommendation: efforts to develop a widespread program to enhance general education with engineering should be focused on one full, three semester credit hour course with the possible option for more courses in a minor.

Faculty
To offer a course, at least one faculty member must be available and interested in teaching the course. If more than a few sections of the course are to be taught per year, more faculty members will be needed.

It is rare to find a faculty member who does not already have a full time teaching load. If a faculty member is to be allowed to teach an engineering course for non-majors, either the person teaches this as an overload or one or more of their current courses must be assigned to another faculty member. Especially at the start, the faculty member will need time to develop and prepare the course. Even if they draw heavily on work done by others and made available through the TELPhE division of ASEE, they will still need to do quite a bit of work for themselves. They should not be asked to attempt this as an overload. Instead, some of their courses need to be assigned to another faculty member. The department will either need to hire another faculty member or find adjunct (part time) faculty to cover these courses.

In our experience, if only a few sections are needed, a dean or department chair is likely to find someone who would be interested in taking on such a course. Some but not all faculty members would be interested. If a course is to be required for all students at the university, the existing faculty in a department or a college of engineering will not be sufficient to take on the added load of a service course for the entire campus, and more faculty must be hired.

Even if a faculty member is interested and can be freed from other duties to take on this course, it will be different from the courses taught by most engineering faculty members. Based on
successful courses documented in ASEE papers presented in TELPhE sessions, it is likely to have more in common with first year survey courses that introduce engineering than to other, more advanced engineering or engineering technology courses. It is likely to have much in common with history and other university core courses, where the material covered is more qualitative than quantitative and the student’s mastery of the material is gauged at least in part with written work instead of engineering calculations. The course is also likely to have a laboratory component where students may take things apart and may build things.

Once a course is established at a university, it may be possible to augment a small group of full time faculty with adjunct instructors. Retired engineers with the required educational credentials would be ideal candidates. If the course is structured with separate discussion or lab sessions, retired engineers who do not have the credentials to teach as adjuncts may be used as discussion or lab instructors working with regular faculty members.

Rewards - Faculty
A faculty member who is willing to take on the challenge of an engineering course for non-majors may put themselves at risk in the retention-tenure-promotion process. This faculty member would be taking on a service course for non-majors. If the course is required of all students at an institution, then the class sections are likely to be large. In higher education, teaching is expected but not rewarded. Teaching survey courses to non-majors, especially in large numbers, is not rewarded, and may prevent a faculty member from doing other work that would be rewarded. The problems will be worse with engineering faculty. Unlike English or History departments where heavy service teaching loads have long been part of each instructor’s load, engineering does not have a history of teaching service courses. Engineering faculty will have to adjust to teaching large numbers of students who may not be motivated or engaged since the course is not part of their major.

The reward structure for faculty is geared to research and teaching in the major. In research institutions, research is a primary consideration in tenure and promotion. A faculty member who is focusing on research will want to teach graduate and upper level undergraduate courses in their area of interest. They will be seeking to recruit graduate students for their research programs. When teaching undergraduates, it is in their interest to seek courses at a higher level that are related to their areas of research interest. Even in institutions that put more emphasis on teaching, a faculty member will do better by teaching within their discipline. They will have smaller classes and a larger percentage of their students will be interested in the subject of the course.

A faculty member teaching a course for non-majors may have the support of the department chair and the dean, but will be doing this when they could be putting their efforts into research and teaching majors. When they are reviewed by faculty committees, no matter how much credit they are given for doing good things with the course for non-majors, this will not generate the right sort of publications needed for tenure and promotion. If the course for non-majors is required for all students, they will get some students who are not interested and run the added risk of poor teaching evaluations that may be held against them.
If a faculty member takes on this teaching assignment, they need to be assured of strong support from above in the retention-tenure-promotion process.

Retention-tenure-promotion considerations are issues for junior faculty members. Tenured faculty members, especially tenured full professors, can take on a service course with comparatively little risk. If they are interested and if they can be released from other teaching duties, senior faculty members are good candidates for teaching this sort of course. However, you need a senior faculty member who is willing to take on the sometimes less rewarding task of working with non-majors. One would expect an English professor to prefer teaching an upper level literature course to people with enough interest to be English majors over teaching a first year composition course required of all students. It is likely that senior faculty in engineering would want to avoid teaching a survey course when they could be teaching an upper level course for their own majors.

Rewards – Department Chairs and Deans
If a faculty member is to teach a course for non-majors, then that person will either have to teach the course as an overload or give up another course. If they give up a course, either someone else has to be found to teach the course or the course has to be cancelled. This will not be a problem if the course to be dropped is such that the students can be moved to other sections or if the course is not required, does not attract many students, and can be dropped.

It is more likely that the instructor teaching the course for non-majors will have to give up a course that needs to be taught as well. This creates a problem for department chairs and deans who have to find someone to teach that course. This can also be beneficial if it allows the department chair and the dean to justify a new faculty position.

If an engineering course is to be required of all students, more faculty must be hired. As long as the course is required, this will be beneficial to the engineering program. Programs that do not have courses that meet university core requirements are at a disadvantage. While teaching courses like first year composition or art appreciation may be tedious, it does allow a department to justify more faculty. One measure of department productivity is the number of students taking classes from that department. A university core course can greatly boost a department’s productivity in this area.

Resources
In addition to faculty, other resources are needed for the course. Based on current models, it is highly desirable to include a laboratory component in the course. For that, money will be needed for equipment, supplies, and, unless the class is small, assistants in the lab. Additional lab technicians may be needed; hopefully, undergraduate students could be hired as lab assistants. If the course is either another elective option or is replacing another course in the core, adequate classroom and lab space should be available.

Materials
People have been introducing engineering and technology to non-engineers for some time. Many good examples have been documented and materials are available. Materials developed for first year engineering courses and for K-12 may be used here as well.
What is lacking is a “standard” textbook or equivalent for instructors who are new to the subject or are seeking to produce a standard course for large numbers of students to be taught by different instructors. Models for developing such a standard package of teaching materials exist, but the task remains to put something on the market for colleges and universities.

Resolving These Issues
The most difficult issue will be to make a place in the curriculum for engineering in the general university core. If this is to be done by developing a course (recommended) and there is no room to add a course, then another course must be removed to make room. Understandably, people responsible for the course targeted for removal will resist. Within the institution, the power structure favors the people with the course in the core. They will have a larger faculty due to the core courses and will have the strength that comes from higher measures of productivity. Working from within, it will be all but impossible to add a new course to the core if it means pushing out another course. When working against established interests in the university, even provosts and university presidents can have difficulty making such a change.

Change is far more likely to happen if there is pressure from above. In the case of state institutions, governors, legislatures, or state or university boards of trustees can mandate changes. In private institutions, university boards can insist on changes. There will still be difficulties, but change can happen. In this case, pressure from above will be necessary.

If a course to bring engineering and technology into the general core is added, issues such as finding faculty, adding new faculty lines, and ensuring that faculty who teach the core course are given due credit for this in the retention-tenure-promotion process can all be resolved. Additional funds will be needed, especially at the start. With a potential market, textbooks and other teaching materials will be developed.

Recommendations
To add engineering to the general education of college undergraduates …

1) Promote the addition of an engineering course for non-majors to the university core requirements. This needs to be promoted at the highest levels (governors, legislatures, and state boards for state institutions; governing boards for private institutions) as mandates from above will be needed to change university core requirements.

2) The course should be a full three credit (quarter or semester) hour course.

3) The course should include laboratories as well as classroom time. The lab portion may require an additional credit hour.

4) While teaching engineering, the course should incorporate a broad view of technology as well.
5) Institutions should start with an engineering and technology elective course in the core. Once the course is established and enough faculty are available, the course can become a requirement for all students.

6) As a starting point, baseline teaching materials, including a textbook, need to be developed. Work already done in this field can be used to quickly develop this baseline.

Why Do This?
The need for every citizen to know something about technology and the engineering behind it is clear. A college education should contribute to meeting this critical need for students and for society.

While some college students have the good fortune of being able to take a course designed for non-majors in engineering and technology, most do not. Those who do not are getting a college education that does not cover a critical area of human knowledge. No matter what their major, technology and the work of engineers will have a great influence on every college graduate’s life. To serve their students, colleges and universities must do more to include engineering and technology in the general core curriculum. This need has been recognized at the K-12 level, and STEM has become a cornerstone of primary and secondary education. A college graduate needs this as well and, as with other subjects, a college graduate needs to know this at a level beyond K-12. Engineering and technology needs to be part of their college education.

Including engineering and technology in the general core curriculum will be beneficial to the college or university. Doing so will be clear evidence that the institution is keeping its curriculum current and meeting the needs of its students today and into the future. This should be attractive to students, their parents, and to others who support the institutions. For state institutions, a move in this direction should be viewed positively by legislators and governors.

As noted in Technically Speaking [4], the need for people to have a better understanding of technology and engineering has been recognized as a national need. By including these topics in the university core curriculum, colleges and universities will clearly be contributing to meeting this need in our society.

Examples
Some specific examples are available to illustrate the ways in which engineering literacy courses can be integrated into the undergraduate curriculum. The broad nature of engineering facilitates alignment of engineering literacy courses with institutional opportunities. At Union College engineering faculty teach engineering literacy courses as offerings in the required second-year-seminar at Union [15]. The objectives of this college-wide seminar series include an opportunity to do independent research in a focused topical area. Examples of courses include Pervasive Computing and Nanotechnology. Some engineering programs have been successful in establishing courses that meet university general education requirements. Norton and Bahr [16] offer a course called Materials: Foundations of Society at Washington State University. This course satisfies the universities’ “Tier III” general education requirement. Tier III courses must
provide a high level of discussion and research in a general education area, but do not require pre-requisites in the course area. At Bucknell University engineering faculty members Thomas Rich and James Baish engaged non-engineering students through an honors college offering called “Designing People” [17]. This course introduces liberal arts students to the engineering design process. At Eastern Washington University electrical engineering faculty member William Loendorf and colleagues offer a course called Technology in World Civilization [18]. The course fulfills the University’s International Studies graduation requirement. Through interaction with actual historical technological artifact (or replicas), the course explores a historical perspective of the development of technology in a global context by tracing the interconnected events and cultures in which technology developed. These examples illustrate the resourcefulness of engineering faculty in taking advantage of local institutional circumstances to offer courses with engineering content for non-engineers.

Summary
Many people have developed courses that add engineering to the general education of college students. This has been done with varying levels of support at individual institutions. For this to become part of every college student’s education, barriers must be overcome that require pressure from above. The foundation necessary to develop materials and courses exists. Changes in university core requirements, support for faculty, and resources are needed to make the practice of teaching every student about engineering widespread.

Bibliography


9. https://www.asee.org/search/proceedings - For lists of papers at each annual conference from 2011 to 2016, select the conference from the list and search for the Technological and Engineering Literacy / Philosophy of Engineering division. For earlier papers go to ASEE PEER and search for technological literacy.


