THE ASSESSMENT OF PROPOSED TECHNOLOGIES

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Abstract

As new technologies are introduced at an increasingly rapid rate, it becomes vital that society develop strategies that assess the impact of such technologies on our lives. To address this challenge the Graduate School of Engineering at Santa Clara University has introduced a new course requirement for all engineers. This paper describes the need, and the approach that Santa Clara has taken.

It has long been understood that new technologies often have a life of their own, leading to outcomes, some good, some bad, that were not anticipated by their developers. The reaction to such unanticipated consequences cannot be to pursue no new technologies, as that would have its own unforeseen consequences. Nor is it acceptable to blindly pursue new ideas with no reflection on their possible implications. An effective society must find a middle ground. It is critically important that we reflect on issues that include: stakeholders (present and future), possible consequences that are difficult to anticipate, ethical concerns, and others. Engineers are often in a unique position to address some of these issues.

Santa Clara University has introduced a new set of courses designed to help engineers reflect on such matters so that they can make a positive contribution to the necessary societal debate. The paper briefly describes nine courses and then emphasizes a new course, Societal Issues in Engineering Professional Practice, which has been designed specifically to give engineers an organized approach to technology assessment.

The paper also describes a web site which has been set up to help others in society assess technologies.

1. Introduction

New technologies will have profound effects on the future of society. Some of these effects are of course intended. But others are not intended, and not anticipated. The latter can have an extraordinary impact on society, often far greater than that of the original intended effects. An effective society must find ways to deal with new technologies so that potentially harmful technologies can be banned or inhibited, and potentially useful technologies can be encouraged and accommodated in appropriate ways. This paper concerns an approach to the problem of assessment, and in particular to the teaching of assessment concepts to students of engineering. We stress here that the assessment is that of the technology in question and not of the student outcomes in the course.

While the subject of this paper is technology, as we usually use that term, it should be recognized that all of our human enterprises share the reality that their effects deserve our close consideration and that some of their consequences will be unanticipated. Hence, in a broader sense this paper addresses our efforts in such diverse fields as: medicine, law, legislation, business, education, business, and many more. Neil Postman[1] has spoken to this broader sense of technology in his Technopoly: The Surrender of Culture to Technology. A seminal work by Merton[2] in 1936 also treats of this issue. In a more recent work Steven Gillon[3] explores the unanticipated consequences of social reforms in twentieth century America, dissecting a wide range of topics including welfare, affirmative action, immigration, and campaign finance.

Section Two presents a discussion of the problem of assessment, a task that is necessarily difficult because of problems inherent in attempting to look into any future. In Section Three we consider briefly a set of courses intended to raise the consciousness of young engineers about the relation of their work to society. Section Four describes the development of a course specifically directed toward the assessment of technologies. In Section Five we introduce an Internet site developed to help others assess technologies.

2. The Assessment Dilemma

The process of assessment can be divided into two parts, first, the determination of prospective outcomes that can be anticipated with reasonable accuracy, and second, the attempt to anticipate the unanticipated. The latter problem suggests, of course, a contradiction. If results are unanticipated surely there is nothing to be said of them. We believe that is too pessimistic a perspective. We believe that a systematic analysis of a proposed technology can help us anticipate where it may lead us. This will never be a perfect process, but we can do better than we do today.

This is not the place for a detailed look at the causes of unanticipated consequences. We have dealt with this issue in a previous paper[4]. Nonetheless, a brief summary is appropriate. Dietrich Dorner[5] has identified four features of systems which make a full understanding of any real system impossible. These are:

- complexity
- dynamics
- intransparence
- ignorance and mistaken hypotheses

Complexity refers to the many different components that a real system has, and the interconnections among these components. Many systems exhibit dynamics, that is, the property of changing their state spontaneously, independent of control by a central agent "in charge of" the system. Intransparence means that many elements of a system cannot be seen, but can nevertheless affect the operation of the system. Finally, ignorance and mistaken hypotheses are often a major contributor to the problem. This last of the four is particularly interesting because it is the one that we can do something about. We can take steps to reduce our ignorance and to increase our understanding. The assessment of technology, the subject of this paper, is an approach to formalizing this process.

3. Education for Assessment

In the Fall of 2000 Santa Clara University introduced a new requirement for degrees of Master of Science in the engineering fields. It is intended to focus attention on issues of technology and society, including the assessment of new technologies. This requirement is called Societal Issues in Professional Practice. As the catalog puts it, "The purpose of this requirement is to help our MS graduate students develop a better understanding of the human dimension of their professional work. … Courses that satisfy this requirement will engage one or more of the following topical areas:

- Developing sensitivity to other cultures in the local or global workplace
- Understanding the social impacts and implications of engineering practice
- Understanding the legal issues that impact society and engineering practice
- Understanding the ethical dimensions of engineering practice
- Understanding the environmental implications of engineering practices
- Understanding and developing responsibility for professional service"

To date ten courses have been developed to satisfy this requirement. One of these courses is described in detail in the section that follows.

4. An Assessment Course

This section describes a new course ENGR 300, *Societal Issues in Engineering Professional Practice*, which has been developed to help students reflect on the role of technology in society, and more specifically, to learn a formal approach to the assessment of proposed new technologies. The course has three specific objectives:

- To raise the student's consciousness concerning the impact of technologies on society.
- To help the student formally assess those consequences of a technology that can reasonably be anticipated at the time of the assessment.
- To give students some tools, admittedly limited, to help them look "toward" consequences that cannot be anticipated at the time of the assessment.

The first of these objectives is addressed by introducing the class in the initial sessions to examples of technologies that have been developed in the past, and which have led to major impacts on society, some of which were not anticipated. An example is the Internet. It is impossible to give an exact date for the beginnings of the Internet, although the year 1969 is often given as the birthyear of this phenomenon. It was in that year that the Advanced Research Projects Agency (ARPA) set up the first nodes for what would become the ARPANET, which in time evolved into the Internet[6]. The ARPANET was set up to provide for communications among scientists at a number of research institutes and universities. No one anticipated in 1969 that one day hundreds of millions of people all over the world would be linked together by means of this medium.

Discussion of three or four examples of this type sensitizes the student to the matter of social impacts of technologies, anticipated and unanticipated, and prepares the class for an assessment of new technologies. In order to formally address assessment we have

developed a template (Figure 1) that can be applied to example new technologies. The questions should be addressed for the long term as well as the short term.

1. Background: Describe the background and origination of this technology.

2. Description: Describe the proposed technology carefully. What is it intended to do? What resources does it use? What physical processes or properties does it entail?

3. Social Impact: Who are the stakeholders? That is, who stands to gain or lose from the implementation of this technology? Who will benefit? How are the poor affected? Does it bring society together? What effects will it have on employment?

4. Ethical Issues: Is the technology likely to threaten the rights of individuals? Is it a fair technology, that is, does it distribute costs and benefits equitably among the stakeholders? Does it provide for the greatest good of the greatest number? Does it promote the common good? Should we pursue this?

5. Legal: Is the technology legal? Does it promote law? Does it facilitate law-breaking? Does it assist (or hinder) law keeping?

6. Economics: Is the technology economically desirable for individuals, for a region, a country, the world? What is the impact on economic stability? Is it economically feasible?

7. Environment: How does it affect our environment (short term and long term)?

8. Unanticipated Consequences: Review the description of the technology in Number One above. What can this type of technology be used for in general? Can you think of any uses of this technology other than the one proposed here? Are there any historical examples of developments analogous to this one that might serve as a guide to ways in which this technology might evolve? What potential risks are there?

Figure 1. Technology Assessment Template

An example of the use of this template is the case of the **Wireless Communication**:

1. Background

Wireless communication was one of the dominant influences of the twentieth century, beginning with the experiments of Guglielmo Marconi, then tracing a long line through AM and FM radio, television, interplanetary communication, and by the end of the century the ubiquitous cell phone. As the twenty first century begins wireless seems poised to play even more dramatic roles in the life of the community.

2. Description

Wireless communication is a process that allows the delivery of information from one place to another without the need for hardwired lines, such as telephone wires, cables, fiber optics, etc. A simple radio or a cell phone are examples. Communication can be in the form of digital or analog signals. The former can be coded to provide output in many possible forms including data, audio, video, and others. The primary limited resource used is the electromagnetic spectrum that today can support only a limited number of signals before interference effects become unacceptable. Whether new multiple access techniques can be developed that would dramatically increase the number of potential users is not clear at this time. Other required resources are electronic components, which do not presently seem to put an undue burden on the planet's resources.

3. Social Impact

The stakeholders are truly everyone on the planet. In one form or another this technology can be developed at such a low cost that no one need be excluded from it's use, in either a shared or dedicated form. Even if an individual is not a direct user, he or she is likely to feel the impact of greatly expanded global communication.

4. Ethical Issues

Perhaps the primary individual right likely to be impacted is the right to privacy. It is not clear that the privacy of the user can be protected. One might argue that the user makes a free choice about using or not using the technology. But if society evolves to such an extent that the technology becomes essential to a reasonable life, then that argument may not hold. A second question is whether or not the technology is fair, whether it distributes costs and benefits equally among its shareholders. While no technology is ever likely to be totally fair in a world of rich and poor, it seems that this technology has a much greater potential for equal distribution than technologies such as transportation, housing, and food production, just to name a few. The reason for this is in the relatively low cost of production, associated with a relatively low use of resources. A third ethical question is whether the technology provides for the common good. One might have a degree of optimism on that score to the extent that one believes that better communication is good for the community. It is not difficult to think of negative as well as positives ways in which communication can impact society.

5. Legality

Wireless communication can obviously be used in illegal ways. There is no question that it can facilitate crime. (For the academic a particularly interesting form of crime lies on the near horizon. It will shortly become possible for a student taking a test to communicate with a fellow student or for that matter with anyone in the world, by one form of wireless communication or another. Some classes have already banned the presence of PDA'a since one student can "beam" a message to another student across the aisle.) On the other hand wireless communication has great potential for enhancing the effectiveness of law enforcement.

6. Economics

Enhanced communication would seem to have great potential for economic gain. It has the potential for facilitating economic growth in general, making business more efficient and more effective. To the extent that communication can become an effective substitute for travel it has great potential for saving both capital and natural resources. Substitution of wireless for hard-wired communication infrastructures can lead to significant savings. Many underdeveloped nations may well be able to bypass the development of the hard-wired phone systems that characterized the twentieth century.

7. Environment

Wireless communication has the potential to impact the environment in many ways. On the positive side the substitution of communication for travel could have an enormous impact. Wireless systems might also be used to monitor environmental conditions in remote or inaccessible regions, providing alarms or early warnings of deteriorating conditions. On the negative side, while wireless communication systems themselves appear to have a relatively benign impact on the environment, they might well encourage growth in other areas that have more serious impacts on the environment.

8. Unanticipated Consequences

Wireless communication is used today for sending information in a variety of forms from one place to another. To think about possible new uses, unanticipated uses, good and bad, we might think about fundamental human activities, such as: food, shelter, transportation, health care, education, law, religion, sports, entertainment. Most of the things that will develop in the future, which we cannot anticipate today, will be in one of these sectors. What needs do these activities have? What capability does wireless communication have? What other technical capabilities are developing in parallel with wireless communication that might combine with wireless with synergistic and unanticipated results? How might societal needs, wireless communication, and other technologies come together? Space does not permit us to think about each of these. Let's concentrate on just one, health care. Suppose that health sciences came up with ways of monitoring continuously the condition of the body by means perhaps of implanted or ingested micromonitoring devices. Could a wireless communication system then be associated with this monitoring system in such a way as to transmit continuing information to a health analysis device that might monitor ongoing conditions, such as cardiovascular health, blood pressure, caloric intake, etc, and also provide early warning of impending traumatic events such as strokes, heart attacks, and others? What other basic human health needs come to mind that might be addressed by an enhanced wireless communication system?

This has been an example of the kind of analysis that we ask our engineering students to do. The point here is not to predict the future. The point is to ask our students to reflect on their enterprises and the impacts that those enterprises may have on the communities of tomorrow. If in the process they are able to make their enterprises more effective contributors to society then we have accomplished our goal.

5. An Internet Assessment Site

Santa Clara University has established an Internet site to facilitate the assessment of proposed technologies. The URL is:

http://sts.scu.edu/students/techassess/

The user will find the template in Figure 1 on this site, along with explanations or comments on a number of the questions found in the template. In addition there are a number of links to papers and other resources that may facilitate the assessment process.

6. How have students used the Assessment Tool?

The assessment tool, referenced in the URL above, has been used in Santa Clara University's ENGR-300: "Societal Issues in Engineering Professional Practice". The initial offering of the class was during the Winter quarter of 2001. Students were exposed to eight different areas of technology: Biotech, Communications, Databases, Energy, Exploration, Medicine, Microelectronics, and Transportation; and used the assessment tool to evaluate each. Each class session covered one of these areas. The classes usually had a guest lecturer, a recognized expert in her/his field, who gave a 45 minute overview of the topic. The class professor, Neil Quinn, then used the assessment tool to lead the students through the questions to evaluate the technology area for about one hour. Each student was then given a weekly assignment to prepare a brief overview of a particular slice of the technology discussed and then utilize the assessment tool to evaluate it. The weekly student assessments are located at:

http://cseserv.engr.scu.edu/NQuinn/ENGR300/WeeklyTechnologyAssessment/

In addition to the weekly papers, students were each assigned a major research paper. The purpose of the research paper was to allow the student to describe in some depth a specific area of technology of their choosing, and assess its societal impact.
The student research papers are located at:

http://cseserv.engr.scu.edu/NQuinn/ENGR300/ResearchProjects/

Throughout the course, students have evolved a sense of societal responsibility in the execution of their duties as engineers. The goals of the class have been met.

It is interesting to note that students who showed little understanding of technology assessment in the beginning of the course were able to step outside of their pure engineering mindset and assess its societal consequences by the end of the course. This observation is most rewarding to the instructor.

7. Conclusion

We consider it clear that anyone involved in the development of a proposed technology is obliged to take into account those consequences that can be reasonably anticipated. On the other hand it is also clear that no assessment can ever anticipate the unanticipated.

Still we believe that appropriate reflection on the possible paths that a technology might follow is possible, is at least in some cases useful, and is required of a responsible society. We have described in this paper a formal process to facilitate this assessment process for proposed new technologies.

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