Ethical Issues Related to Engineering Service Learning

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Abstract

Service learning within engineering education is increasing in amount and visibility. The rapid growth of Engineers without Borders (working internationally), and the EPICS program (working domestically), demonstrate this trend.

There has been much work dealing with the legitimacy of service learning in engineering education. However, there has been less work dealing with ethical issues involved with engineering service learning. While there are ethical issues related to any engineering project, this paper concentrates on ethical issues inherent in the service learning approach. Two of these issues are described below.

One issue is the quality and safety of the design. Objects are being designed by people who are not yet professional engineers. The professors who supervise the work need to be very careful in checking the design to ensure its safety. There is also a legal issue. Many states require that anything designed for public use must be supervised by a registered professional engineer. Many faculty members are not registered and cannot legally supervise such work.

A second issue is how the design relates to the local community. In traditional engineering design the client is clearly identified and the engineer can work with her to make sure her wishes are carried out in the design. Often engineering service learning is done with a local non-profit agency or local government. In both cases they claim to represent the needs and desires of the local community that will be served by the project. The university needs to make sure that this project is really needed and wanted by the people it is designed to serve. Therefore, the project really has two clients, the local agency and the local population to be served. This complicates the design process and raises ethical issues if these two groups are not in total agreement.

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Introduction

Engineering service projects are becoming an increasingly common way to teach engineering. The growth of the EPICS (Engineering Projects in Community Service) program is an example of this[1]. EPICS was founded at Purdue University in 1995 and has now grown to involve 18 universities and some high schools. Other schools, like our own, are not formally members of EPICS but are doing many of the activities that the EPICS program promotes.

One of the issues related to engineering service learning is whether the course is mostly service and not enough engineering. This is, in itself, an ethical issue. If we are offering courses that get engineering credit without doing real engineering, we are being deceitful to our students. This is an issue that many engineering programs have faced as some faculty are resistant to this new way of doing things.

Several papers were presented at the 2007 EPICS national conference that attempt to alleviate these concerns about the real engineering content of engineering service learning courses. Hefzy from the University of Toledo[2] and Zoltowski from Purdue[3] made presentations about how to do service learning based capstone design courses. Budny and Lund[4] from the University of Pittsburgh have written about how to use engineering service projects in first year engineering courses.

Most of the engineering service learning courses mentioned above have involved service projects within poor communities near the college campus. However, international service learning is increasing as well. Kelley[5] has written about service projects in East Africa. The author has reported on a project in rural Western Kenya[6]. The group Engineers without Borders has grown dramatically in the last few years. Professors from Rice University[7] have written about their projects with Engineers without Borders. Part of the motive behind international service learning projects is to help our students develop a global perspective. Pines and Gallant have written about their work in this area at the University of Hartford[8].

Service learning has become mainstream enough to be discussed in a major article in ASEE's Prism magazine[9]. While there may be some local disagreements within engineering programs concerning the legitimacy of engineering service learning, on a national basis there appears to be an acceptance of this approach.

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Why do Engineering Service Projects?

There are many reasons why faculty and students might wish to do engineering service projects. From the students' perspective the opportunity to do a hands-on project where the results can be seen immediately is probably much more enjoyable than a traditional project might be. Many faculty are also drawn to these for the same reasons.

Many people have a desire to be of service to others. This motive can be religiously based or secularly based. Our own university defines service to others as part of its basic mission. Our students have given up significant amounts of time, effort, and money to serve poor people in other parts of the world. This application of appropriate technology in a developing country is very consistent with our university's mission, part of which is:

"to educate men and women for worldwide leadership and service."

At our university most of our service learning to date has been with international projects. These projects are an outgrowth of a student-created service organization. It is loosely patterned after Engineers Without Borders from whom we have learned a great deal.

Many approaches to poverty issues are from a top-down perspective, using governmental policies and spending to try to make changes. Engineering service learning can be part of a bottom-up approach, using technology and social entrepreneurship as tools to make a difference in poor communities. With a focus on service, technology can be an instrument of peace, community development, restoration of human dignity, and the alleviation of hunger and suffering. This happens as these endeavors and their practitioners orient their craft toward an end that has meaning as well as economic profit.

Engineers are not the only people who are trying this bottom-up approach. Non-engineering examples of such an approach to poverty are described in the excellent book[10] by Shannon Daley-Harris and Jeffrey Keenan.

Safety Issues

Nothing that is made can be guaranteed not to fail. Everything that is designed and built has some finite probability of failure. This is because our knowledge is not perfect. Our capability to build to a specific design is not perfect.

As a result of this, an engineer must be very careful to design according to the most recent knowledge and practice in her field. Even if a design is based on the most current knowledge, there is still a chance that not enough is truly known about the situation, and the part/structure may still fail. An ethical engineer should take into consideration the likelihood of failure during the design phase.

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This process is called risk analysis. The purpose of discussing this issue is to make the reader aware of risk analysis, and to encourage him to use it in some form in engineering service learning courses.

There are two separate issues that must be examined. The first one is the **probability** of failure. This is the likelihood that the structure will fail during use. A second issue is the **severity** of the failure. If the structure does fail, how hurtful will that failure be? In many situations the actual calculations of the probability of failure and severity of failure may be rather difficult.

It is possible to plot the severity of failure versus the probability of failure. Every engineering design, can, in theory, be put on this figure. An example of this is shown below in Figure 1. The letters a, b, c, and d refer to specific locations in Quadrants 1-4.

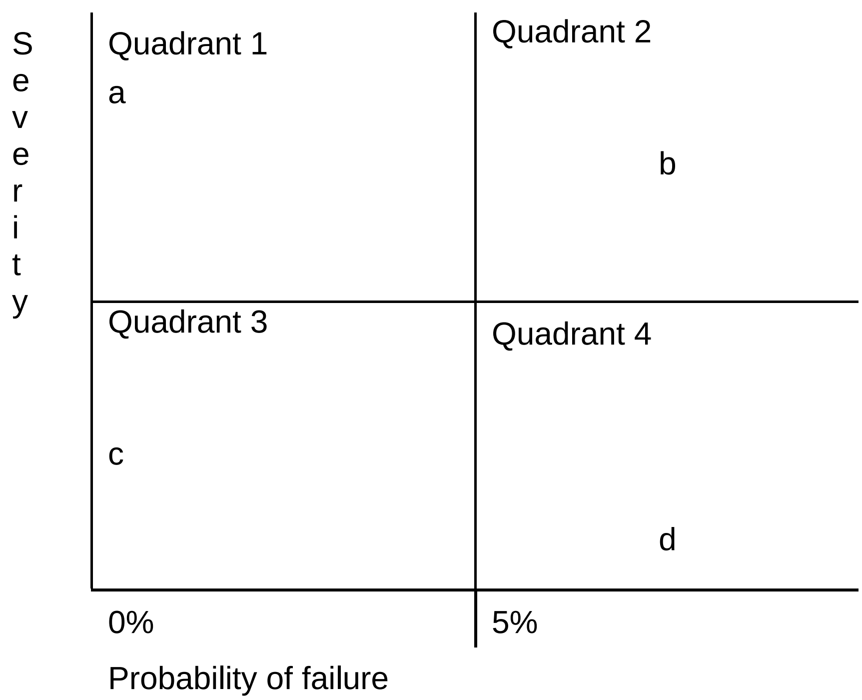

Figure 1—Severity versus Probability Graph

There are four quadrants where a design can be placed. Hopefully it is obvious that the high severity—high probability region is to be avoided at all costs. For example, an engineer would not want to design at position **b** in the above figure. What is considered to be a high probability of failure will vary according to what he is designing.

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This does not mean that high probability of failure will always mean the design should not be made. For example, when a man shaves with a razor blade, there is a high probability of failure (meaning he cuts himself shaving). For many, this probability is somewhere between five and ten percent. Does that mean the blade was designed or built poorly—not necessarily. It means that the user is not always as careful as he should be. Men who shave with razor blades tolerate this high **probability of failure**, because the **severity of failure** is so low. This might be represented by position **d** in the above figure. [In this example, the 5 to 10% probability of failure would be in the high probability of failure quadrant.] In the case of the razor blade, the failure is a small cut that the user has probably forgotten about by the time he leaves for work.

What probability of failure is acceptable depends upon the severity of the failure. The five percent failure rate in shaving (which is willingly accepted) is much higher than the probability of failure a car's axle. If an automobile's axle failed five percent of the time, most owners would be very upset. This is because the severity of the axle failure is so high. [It could result in loss of human life, probably will result in damage to property, and certainly would result in a lot of time wasted trying to get it repaired.] This might placed as position **c** on the above graph. [While the severity is high, the probability is low.]

If the severity of the failure is very high, the designer must make sure the probability of failure is very low.

Once the probability and severity of failure have been determined (or estimated), then the decision as to whether to make the part needs to be made. There may be honest differences of opinion as to what is acceptable risk. However, some risk decisions appear to be based solely on financial risk rather than taking into consideration the value of human life. For example, the Ford Pinto was known by Ford to have a design flaw that could result in a disastrous fire during some types of rear end collisions. They estimated the probability of failure to be rather low, and decided it was cheaper to not make the design changes but be willing to pay off any claims that might occur from the accidents. For details of the Pinto case, read the article in Johnson's engineering ethics book[11].

A separate issue is whether some accidents have such great severity, that the structure should not be built, even if the probability of failure can be reduced significantly. This is the argument that some engineers use when discussing nuclear power. Is the severity of the very small probability accident so great that we should not build such a plant? For example, the probability of failure in a nuclear plant might be represented by position **a**; its severity is very high, but its probability is very low.

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Liability Issues

Liability for design is not something that is always carefully thought through when doing an engineering service design for a non-profit agency. However, our recent experience on a bridge project illustrates the potential for a problem. A group of faculty and students from our university are working on a design of a pedestrian bridge to be build in south eastern Kenya. We have reported on our preliminary work at a conference last summer[12]. About the time we finished our preliminary design a pedestrian bridge failed in Nepal[13]. This bridge was built by a non-profit agency that uses many volunteers to do their design and building. A photograph of the failed bridge is shown below.

Figure 2—Failed bridge in Nepal that had been built by a non-profit agency[13]

This bridge failure shows the importance of ensuring safety in whatever the students design. While the bridge in this example was not the result of a student design, its length is not much longer than the largely student designed bridge we are working on at our university.

It is important that the student engineering service projects be given adequate supervision so that failures do not occur. Some student designs seem relatively simple. However, even something as simple as playground equipment could fail if not designed or built properly.

In addition to the issue of safety another issue that needs to be faced by engineering service projects is one of legality. In many states designing projects for customers outside your university is considered the practice of engineering, which mush be supervised by a registered professional engineer. Many

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university faculty are not registered engineers and may be illegally practicing engineering by supervising projects that will be built in the community. At my previous university we had to change some teaching assignments so that there was a registered engineer working with each student design team.

Community Issues

Even if the probability and severity of an accident can be estimated, problems can still develop if the public does not have the same perception of risk that the engineer has calculated. At the very minimum, our designs need to be acceptable to the local community. Even if we are confident they are safe, the local community needs to be confident they are safe was well.

William Oakes and Marybeth Lima have written an excellent book on engineering service learning[14]. In chapter one of their book, they make the following recommendations concerning the interaction of an engineering service project with a local community[14]. We would like to interact with several of these concepts in this paper

- Think hard about how your problems are defined or framed
- Realize that engineering and technology decisions are value laden
- Realize that engineering itself is value laden
- In engineering, use systems thinking rather instead of linear thinking
- Engineering and technical systems should be democratic

Engineers and engineering students frequently do not seriously think about how their design might impact a community. The social implications of their designs are not one of the criteria that is used to assess its success. This is in contradiction to what ABET requires schools to teach concerning engineering design. Criterion 3(h) states that[15]:

> "Engineering programs must demonstrate that their students attain the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."

Ignoring societal impacts is also a violation of most engineering codes of conduct. For example, the National Society of Professional Engineers (N.S.P.E.) states in their code as the first fundamental canon of engineering practice[16]:

> "Engineers shall hold paramount the safety, health, and welfare of the public."

The practice of engineering is value laden. This is an important point in Oakes' discussion, but this perspective is not unique to him. Steven VanderLeest has also written about this[17] topic. Engineers use computers to do much of their work. This has led many engineers to only solve problems that can be solved using computers. Problems that are not easy to solve using computers may be ignored. This may be good for many of the specific technical portions of the

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design, but computers are not able to analyze the needs and wishes of the local community.

Oakes suggests[14] that the practice of engineering service learning should be done in a democratic way. This does not mean that everyone votes on everything. It does mean that the local community gets input into the decision making process. This includes not only what topics to design but also how the design works. If the design works in a culturally offensive manner, it will not be used.

This local involvement has another issue with which the engineering project must deal. Frequently the project is done for a local non-profit group which is acting in the name of the community. Care should be taken so that the faculty member makes sure the community itself really wants this project to be completed.

Two examples from international projects at our university will be used to illustrate this point. The pedestrian bridge in Africa that we are working on is being done with a non-profit called Bridging the Gap Africa[18]. Before they will work on building a bridge it must first be requested by the local community. The local community must also commit to help build the bridge and agree to maintain the bridge. This ensures that the bridge is something that the local community wants to have. An example of community involvement in building the bridge is shown in the photo below.

Figure 3—Building a bridge over the Sand River in Western Kenya[12]

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Another example of involving the local community is in the projects we plan to do in 2009. In early January 2008 the author visited with several groups in Rwanda. We identified several projects where the local people have already requested our help. One example of this is the Sonshine School near Ruhengeri, Rwanda. This is an excellent school that was originally created largely to teach kids who were orphaned in the 1994 genocide. At the school they now teach many other children as well. They have needs for purifying their water. Currently the workers boil it in wood charcoal based stoves, which takes a lot of work and pollutes the kitchen area. There are also problems with electricity. The school's source is not stable and very expensive. Teachers and students are trying to use computer labs and need a better source of cheap electricity that is also stable. A photograph of part of their school is shown below in Figure 4.

Figure 4—Sonshine School near Ruhengeri, Rwanda

Our work for the above project will be based upon specific requests from the people who need help. There would not be any issue of community buy in to the project. We still will need to work to make sure our designs are safe and sustainable by the local people.

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Conclusions

Engineering service learning is an exciting way to involve our engineering students in real world projects that meet real needs in communities. This can be in a community close to campus or one 8,000 miles away.

There are several ethical issues related to engineering service learning in a university. The first ethical issue is whether or not this is a legitimate use of the engineering curriculum—is this real engineering or just a feel good service activity? The answer from the literature appears clear that this can be legitimate engineering education. While the engineering education community as a whole has accepted engineering service learning, this does not mean that all engineering professors have accepted it. There may be some local opposition in universities to adopting such a program.

There is a real issue of engineering liability and safety. For some projects this may be simple to ensure, however, for many this is not so simple. This means that the students' work needs to be constantly checked by the faculty members in charge of the course to make sure that it is safe. Depending upon your state, this may also mean that the instructors of senior design be registered professional engineers.

If an engineering service learning project is to be successful, it must have the support of the local community. The support of a local non-profit group acting in the name of the community may not be enough. This does not mean that the community must be 100% in support of the project, only that there is a large consensus that this project is important. Involving the local community as much as possible in the building and maintaining of the project is also important.

Examples were provided that show how non-profit agencies can involve the local community in ways that benefit both the project and the local community.

References

[1] EPICS national web page, epicsnational.ecn.purdue.edu/public/conferences/conferences.php
[2] Samir Hefzy, John Jaegly, Christian Smallman, *Developing a Successful Engineering Capstone Senior Design Course Using Service-Learning*, presented at the 2007 EPICS conference, San Diego, May 2007, on the following web site:
epicsnational.ecn.purdue.edu/public/conferences/files/2007_National/A1-Hefzy.pdf
Author: Mohamed Samir Hefzy, John Jaegly, Christine Smallman
[3] Carla Zotlkoski, *Using Multidisciplinary Service-Learning to Meet Capstone Requirements*, presented at the 2007 EPICS conference, San Diego, May 2007, on the following web site:
epicsnational.ecn.purdue.edu/public/conferences/files/2007_National/A1-Zoltowski.pdf

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[4] Dan Budny and Laura Lund, *Benefits and Challenges of Service Learning for Freshman Engineers*, presented at the 2007 EPICS conference, San Diego, May 2007, on the following web site: epicsnational.ecn.purdue.edu/public/conferences/files/2007_National/C4-Budny.pdf
[5] Benjamin Kelley, Walter Bradley, and Brian Thomas, *Student-Aimed Appropriate Technology Engineering Projects in Kenya*, presented at the ASEE Gulf Southwest Conference, Baton Rouge, 2006, in CD based proceedings, no page numbers.
[6] Jordan, W., Ballard, B., Morton, A., Sanders, B., and Wakefield, J.K., *Implementing a Service Learning Engineering Project in East Africa*, presented at the Gulf Southwest Regional Meeting of A.S.E.E., South Padre Island, TX, March 2007. In CD based *Proceedings* (no page numbers).
[7] Ross Gordon, Alex Gordon, and Philip Bedient, *Rice University Engineers without Borders: An Exercise in International Service Learning*, presented at the ASEE National Conference, 2006, Chicago, in CD based proceedings, no page numbers.
[8] David Pines and Brian Gallant, *Providing Engineering Students a Global Perspective through a Project for Developing Communities—Lessons Learned at the University of Hartford*, presented at the ASEE National Conference, 2006, Chicago, in CD based proceedings, no page numbers
[9] Jeffrey Selingo, *May I Help You?,* ASEE Prism magazine, Summer 2006, pp. 41-45.
[10] Shannon Daly-Harris and Jeffrey Keenan, **Our Day to End Poverty: 24 Ways You Can Make A Difference**, San Francisco, CA, Berrett-Koehler Publishers, 2007, 216 pages.
[11] Deborah Johnson, **Ethical Issues In Engineering**, Prentice Hall, 1991, pp. 175-185.
[12] Jordan, W., Parker, H., Eppink, J., Hemmen, S., McGhee, R., and Eberhardt, M., *Building Bridges for a Better Future: "Bridging the Gap"*, presented at the Annual Meeting of the American Scientific Affiliation, Edinburgh, U.K., August 2007.
[13] See news report at the following web site: www.msnbc.msn.com/id/22393428/
[14] William Oakes and Marybeth Lima, **Service Learning: Engineering in Your Community**, Great Lakes Press, St. Louis, 2006, 323 pages.
[15] ABET criterion retrieved on 2/8/08 from ABET web site: www.abet.org/forms.shtml#For_Engineering_Programs_Only
[16] NSPE code retrieved on 2/8/08 from the NSPE web site: www.nspe.org/Ethics/CodeofEthics/index.html
[17] Steven H. VanderLeest, "The Built-in Bias of Technology," *Proceedings of the 2004 American Society for Engineering Education (ASEE) Conference*, Salt Lake City, Utah, June, 2004.
[18]Bridging the Gap Africa web site: Hwww.bridgingthegapafrica.org/H

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