Computer science as a pedagogical discipline continues to advance rapidly, and this advance necessitates frequent revision of the curriculum. One of the fundamental changes in computer science in the last decade is the realization that the context and impact of new technologies need to be taken into account in its design, partly because of the ethical implications of its use, and partly because understanding the consequences of use helps to inform and improve the design. Project ImpactCS was funded by the National Science Foundation in 1994 with the goal to define the conceptual framework, core content, and pedagogical objectives for integrating social impact and ethics into the computer science curriculum.

INTRODUCTION

Computer Science has advanced rapidly in the last several decades, and this advance necessitates the continual revision of the curriculum for an evolving discipline. One of the fundamental changes in computer science in the last decade is the realization that the context in which technology is used must be taken into account in its design, partly because of the ethical implications of its use, and partly because understanding the context of use helps to inform and improve the design [3, 10, 12, 15, 20, 22]. This recognition is included as one of the foundational principles in Computing Curricula 1991 [1, 26], and has been a part of curriculum standards for over a decade [1, 5, 6].

Of the 12 recurring concepts listed in Computing Curricula 1991 that unify the content areas of computer science, six of them (reuse, security, tradeoffs and consequences, evolution, complexity of large problems, and consistency and completeness) are intimately linked to an awareness of the social context in which technology is used and are informed by a social scientific analysis of computing. Since understanding the social and ethical context of computing is now central to the knowledge needed by a qualified graduate of a computer science program, this context must be incorporated into the common requirements for a degree in computer science [1, 5].

The ImpactCS Project funded by the National Science Foundation brought together 25 experts in 1994 from the area of computing ethics and social impact to define the core content and methodology for integrating social impact and ethics topics across the computer science curriculum. Over the course of three years it has addressed major problems that hamper the implementation of across-the-board curricular change: the lack of a well-specified definition of core content and learning objectives and the lack of a strategy for adapting and adopting existing materials that address the core topics into the CS curriculum. To date two reports have been disseminated nationally [16, 21] and a third one is currently being written.

THE CONCEPTUAL FRAMEWORK

The conceptual approach integrates, from the perspective of computer science, the complementary disciplines of philosophical ethics and social science. Based on this integration, the recommended topical areas concur with those listed in Computing Curricula 1991, but we expand on them in both detail and breadth. It is clear that the study of ethical and social issues in computing is interdisciplinary in nature. Ethicists from both philosophy and theology, historians, social analysts, sociologists, anthropologists, and psychologists have all contributed heavily to the research in this area [3].

Instead of requiring CS student to learn from these disciplines by taking separate courses in philosophy and sociology, we propose that elements from these disciplines be incorporated into the core of computer science. Only a conceptual framework that takes into account the interaction of the three dimensions of the technical, the social, and the ethical can adequately represent the issues as they concern computer science in practice. For students to understand the multi-dimensional nature of the problems computer scientists face as they design and implement systems in the world, they must come to an understanding of the ethical and social context of the technology. The intellectual space defined by the three dimensions is summarized in Figure 1. The two dimensions shown in detail are the level of social analysis and the particular ethical issues that arise in technology. A third dimension, technology, is indicated, but not specified strictly in the table. As new technologies emerge, their ethical and social implications can be examined by looking at the various constructs represented in the table.

Each of the ethical concerns, represented by a column in the table, have been dealt with at great length in both popular and academic venues [3, 9, 17, 18]. Each of the levels of social analysis represented by the rows of the table also have a literature associated with them that includes numerous references [14, 19, 24]. The combination of these two dimensions results in such an
overwhelming wealth of research and analysis that it might be difficult to determine where to start. Fortunately, we have a clear rule to help us determine our starting point. What topics, principles, and skills from this array will be relevant to computer science students at the undergraduate level? A fundamental part of any topic to be covered is consideration of issues arising for computer professionals and are often dealt with in codes of ethics [12].

![Figure 1. The intersection of ethical and social analysis](image)

**THE PEDAGOGICAL FRAMEWORK**

*Computing Curricula 1991* specified four knowledge units under social, ethical, and professional issues within the common CS core requirements: 1) historical and social context of computing, 2) responsibilities of the computing professional, 2) risk and reliability, and 3) intellectual property. However, not much guidance and very little time was allocated (only 11 out of 271 total lecture hours specified by the curriculum) for the implementation of these requirements. Using the conceptual framework shown in Figure 1, we have redefined the core curriculum for ethics and social impact to be expressed as five necessary knowledge units with learning objectives, rather than specific courses, to allow different institutions and programs to package the subject matter in different ways.

A knowledge unit defines a coherent collection of subject matter that is so fundamental to the designated subject area that it should occur in every undergraduate curriculum (1). Frequently the subject matter of a particular knowledge unit is related to other knowledge units in the common requirements and can be introduced within any of several alternative course structures. This is often the case with the knowledge units that we propose in this new subject area designated Ethical and Social Impact of Computing (ES). The five fundamental knowledge units of Ethical and Social Impact of Computing are shown below:

**ES1: Responsibility of the Computer Professional:**
Personal and professional responsibility is the foundation for discussions of all topics in this subject area. The five areas to be covered under the responsibility of the computer professional are: 1) history of the development and impact of computer technology, 2) why be ethical? 3) major ethical models, 4) definition of computing as a profession, and 5) codes of ethics and professional responsibility for computer professionals.

**ES2: Basic Elements of Ethical Analysis:** Three basic elements of ethical analysis that students need to learn and be able to use in their decision-making are: 1) ethical claims can and should be discussed rationally, 2) ethical choices cannot be avoided, and 3) some easy ethical approaches are questionable.
**ES3: Basis Skills of Ethical Analysis:** Five basic skills of ethical analysis that will help the computer science student to apply ethics in their technical work are:
1) arguing from example, analogy, and counter-example,
2) identifying stakeholders in concrete situations
3) identifying ethical issues in concrete situations,
4) applying ethical codes to concrete situations, and
5) identifying and evaluating alternative courses of action.

**ES4: Basic Elements of Social Analysis:** Five basic elements of social analysis are: 1) the social context influences the development and use of technology, 2) power relations are central in all social interaction, 3) technology embodies the values of the developers, 4) populations are always diverse, and 5) empirical data are crucial to the design and development processes.

**ES5: Basic Skills of Social Analysis:** Three basic skills of social analysis appropriate for computer professionals are: 1) identifying and interpreting the social context of a particular implementation, 2) identifying assumptions and values embedded in a particular system, and 3) evaluating, by use of empirical data, a particular implementation of a technology.

An effective way to teach these knowledge units is to provide students with the opportunity to identify stakeholders and ethical issues in concrete situations [4, 25]. In this way they come to realize that technology does not simply "impact" society in a one-way causal chain, but society also influences the shape and development of technology. They also come to realize that the social or organizational setting in which a technology is used influences the way it is used. They are made aware that social relationships have implicit and explicit considerations of power and that those power relationships may shift as a result of the new technology.

Another important idea is that the situations in which a technology will be used, the people who will use that technology, and the uses to which it will be put, are all more varied and diverse than one might first expect. To assess these implications, students are expected to systematically collect and analyze empirical data gathered in a social context.

**DEVELOPING A CURRICULUM**

The amount of time spent dealing with the knowledge units is important - a minimum of 15 lecture hours and 25 laboratory hours of the curriculum should be allocated for this material in order for students to gain an in-depth understanding of the basic elements and skills. In addition, it is strongly recommended that another 10-15 lecture hours be spent on in-depth coverage of topics such as privacy, computers in medicine, computers in education, and computer crime to enable the students to apply the basic elements and skills to real issues (see Table 1).

| Table 1: Minimal Implementation of ES Knowledge Units (KU) |
|----------------|----------------|
| **KU** | **Lecture Hours** | **Laboratory Hours** |
| ES1 | 3 | 6 |
| ES2 | 3 | 4 |
| ES3 | 3 | 6 |
| ES4 | 3 | 4 |
| ES5 | 3 | 5 |
| In-depth Topics | 10 | (optional 5 - 10 hours) |
| **Total Hours** | 25 | 25 - 35 |

The implications of such a time commitment are important within the constraints of a typical computer science curriculum. The strategy chosen by a particular program to implement this new subject area should be pedagogically driven. This content should fit into the rest of the program in an integrated fashion so that the relationship between the knowledge units in this area and the rest of the curriculum is apparent to students. The five knowledge units above can become part of a computer science curriculum in many different ways.

At the minimum it means the addition of another 3-credit required course in the curriculum. A weakness of such a course is that it requires that only one faculty member will be familiar with the material. Fortunately, many good model syllabi and textbooks exist for such a course [2, 7, 8, 9, 11, 14, 17, 18, 19, 24].

Teaching the ethics and social impact strand can also be accomplished by incorporating a set of modules into other computer science core courses [23]. This approach will work if there are enough faculty members committed to including the material as a significant part of their computer science courses. This means that a social and ethical impact module should be incorporated into many of the traditional undergraduate computer science courses such as introductory programming, data bases, programming languages, operating systems, artificial intelligence, and software engineering. Another approach is to include several of the knowledge units into a "capstone course," a senior level project course emphasizing skills and knowledge required to become a responsible computer professional [13].

The integrated approach requires more effort on the part of the curriculum committee to make sure that all the knowledge units are covered in sufficient depth. The best way to implement these requirements, however, is to use both strategies, a required course and integration of material into other courses. If only one strategy is possible, the integration of social and ethical issues into existing courses is the preferable option because it helps the student to understand the connection that exists between technical, ethical and social problems.
The Importance of Lab Work

Computer Science is fundamentally a lab-oriented discipline. Most courses incorporate laboratory work in one form or another. Because our emphasis of ethical and social issues in computing is on computers in the context of their use, we encourage instructors to incorporate modules from this content area into the lab work in their courses. This can be accomplished in several ways.

First, the technical courses in database design, human computer interaction, operating systems, and algorithms can incorporate examples that include an ethical and social analysis as part their lab work. These range from the simplest inclusion of real-world ethical material in a programming example to requirements that senior projects provide a social and ethical impact statement with their work. Many other areas of computer science are woven into the curriculum in this manner and gain their strength from repeated and varied emphasis. Ethical and social issues can and should be scattered through the laboratory curriculum in a similar manner.

Secondly, the concentrated course in ethical and social issues in computing can require that students not only consider the issues, but apply the lessons learned in simple exercises and major projects. These goals can be accomplished by requiring students to participate in small groups for weekly discussion sessions. They can also be assigned the task of conducting a social impact analysis (SIA) of computer technology used in some office, company or social service agency. First proposed by Shneiderman in 1990[25], the SIA has shown to be a very effective vehicle to enable students to gain experience in assessing the impact of a particular computer implementation in a real-world setting with real stakeholders.

The value gained from such exercises comes from connecting the abstract principles and skills with real-world examples the student can understand and appreciate. Laboratory work like this makes ethical and social issues in computing less like preaching and more like thoughtful application of practical skills. Numerous other examples of classroom exercises and modules to be incorporated into the other CS core courses are currently under development as part of several ethics and social impact projects.

(Note: See http://www.seas.gwu.edu/seas/ImpactCS)

CONCLUSION

The work of the ImpactCS Project provides a useful and coherent conceptual framework to integrate the ethical and social issues in computing for undergraduate students of computer science. It provides instructors and students with a context for considering these issues. The second report of Project ImpactCS provides learning objectives and practical strategies for implementing a tenth subject into the computer science curriculum so that undergraduate students of computer science will receive a well-grounded presentation of the ethical and social issues in computing. We have significantly extended the previous requirements in this area.

It is the intention of the Project ImpactCS Steering Committee that this tenth subject area will replace the section in Computing Curricula 1991 entitled Social, Ethical and Professional Issues (SP) and will become the standard for future implementations of the computer science curriculum. It is our hope that this new definition of the subject area will also become part of the standards in the accreditation process for computer science programs in the future.

REFERENCES


