Educational Technologies and the Teaching of Ethics in Science and Engineering

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Keywords: instructional technology, distance education, online course, teaching, learning

ABSTRACT: *To support the teaching of ethics in science and engineering, educational technologies offer a variety of functions: communication between students and instructors, production of documents, distribution of documents, archiving of class sessions, and access to remote resources. Instructors may choose to use these functions of the technologies at different levels of intensity, to support a variety of pedagogies, consistent with accepted good practices. Good pedagogical practices are illustrated in this paper with four examples of uses of educational technologies in the teaching of ethics in science and engineering. Educational technologies impose costs for the purchase of hardware, licensing of software, hiring of support personnel, and training of instructors. Whether the benefits justify these costs is an unsettled question. While many researchers are studying the possible benefits of educational technologies, all instructors should assess the effectiveness of their practices.*

Introduction

Educational technologies and distance education began centuries ago with the introduction of the book.[1] Reading a book, a student can learn a subject while separated from the author/teacher in both time and space. The phrase "educational technologies" now refers to electronic information technologies that support instruction.

Educational technologies may be used both inside and outside the classroom. These technologies support both conventional classes and online classes with students in multiple locations. Personal computers, connected via networks, enable instructors and students to access and share information with speed and convenience. Using these technologies, instructors and students can communicate their ideas, prepare documents,

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Paper received, 21 September 2002: revised, 18 October 2004: accepted, 20 July 2005.

disseminate those documents, archive documents on a variety of storage media, and access remote resources such as databases.

When instructors think about incorporating educational technologies into their courses, they should examine possible uses carefully. Incorporating educational technologies is not a simple binary decision, yes or no. Rather, the instructor chooses which functions of the technologies to use, and the level at which each function is used.

Instructors can choose to use educational technologies at relatively modest levels to support effective teaching of ethical issues in science and engineering in colleges and universities. The observations in this essay should also apply to the teaching of ethics in other situations, such as computer literacy classes for high school students and noncredit short courses for practicing scientists and engineers.

Capabilities of Educational Technologies

Many college courses use educational technologies, even as rudimentary as electronic mail, to communicate between instructors and students. The uses of educational technologies can be at three levels of intensity: limited, moderate, and extensive. Limited uses are characterized by one-way communication (at a time) or individual access to information. A course Web site, where the instructor posts the syllabus and assignments, is a limited use. Moderate uses are interactive and collaborative. For example, in chat spaces, students and instructors interact with each other to answer a question, discuss a case, define a concept, or create a text. Extensive uses are immersive and constructive. Multimedia simulations and sophisticated animations are good examples of extensive uses. The term "synthetic environment"[2] refers to educational technologies that offer a rich interface with words, images, and sounds. Using virtual reality technology, instructors can create virtual worlds that students can manipulate in order to see and understand the effects of their changes. For example, students can conduct virtual experiments to understand the outcomes of chemical reactions.[a] Through the Virtual Harlem project,[b] students who study the literature of the Harlem Renaissance can experience its historical context by seeing the buildings and hearing the music of Harlem in New York City in the 1920s.

The boundaries between limited, moderate, and extensive are not strict, and they may change over time. What is considered limited today was state-of-the-art twenty years ago.

From the viewpoint of instructors and students, educational technologies serve five primary functions:

- Communication between students, and between students and instructors
- Production of documents, drawings, and other artifacts by students and instructors
- Distribution of these artifacts
- Archiving of class sessions
- Access via the Internet to special resources

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a. http://www.chm.davidson.edu/ChemistryApplets
b. http://www.evl.uic.edu/cavern/harlem

Within a single course, an instructor can use each function at a limited, moderate, or extensive level, depending on the subject matter, the availability of resources, and the instructor's familiarity with the technologies. See Table 1 below.

	Limited "Web pages" one-way, individual	*Moderate* "Chat spaces" interactive, collaborative	*Extensive* "Synthetic environments" immersive, constructive
1. Communication between students; between students and instructors	E-mail, listserv Voice mail Broadcast audio Anonymous assessment	Electronic conferencing Chat space Online office hours	Real-time video conferencing
2. Production of artifacts by students and instructors	Word processing Charts, diagrams Graphics	Collaborative writing	Animation Video
3. Distribution of artifacts	Syllabus Assignments	Exchange of student papers	Electronic publication
4. Archiving of class sessions	Video of lecture	Analysis of discussion transcript	Speech to text
5. Access via the network to special resources	Links to Web sites Search engine	Online expert/guest Online quizzes	Distributed simulation Scientific visualization Virtual reality

Table 1. Functions and levels of use of educational technologies.

1. Communication

Educational technologies allow students to communicate with each other and with instructors across time and space: they need not be in the same place at the same time to exchange ideas. They can send and retrieve private messages by e-mail and voice mail. They can transmit documents via fax and as e-mail attachments. They can broadcast messages through e-mail listservs and post messages on electronic bulletin boards. Using educational technologies, an instructor can administer a classroom assessment questionnaire to which students respond anonymously.[3] In addition, an instructor can hold online office hours so that students need not travel to the instructor's location.

Students and instructors can discuss ideas using electronic conferencing software or in chat spaces, either synchronously (all students present at the same time) or asynchronously (students log in multiple times over several days). In a threaded discussion, students post a sequence of statements on the same topic; each statement responds to a previous statement in the thread. Part of the table of contents page for a threaded discussion and an example statement appear in Figure 1 overleaf.

Figure 1

Digital Divide Catherine Patel 21 Mar 2005
    Re: Digital Divide Bob Ramirez 29 Mar 2005
    Re: Digital Divide Barbara Wong 29 Mar 2005
Equity Issues Cary Rosenfeld 21 Mar 2005
    Re: Equity Issues Laurel Nilsson 22 Mar 2005
        Re: Equity Issues Molly Stearns 28 Mar 2005
Copyrights Catherine Patel 21 Mar 2005
    Re: Copyrights Bob Ramirez 29 Mar 2005
Internet Plagiarism Monica Harrison 21 Mar 2005
    Re: Internet Plagiarism Andrew MacDonald 24 Mar 2005
    Re: Internet Plagiarism Sandra Gilroy 24 Mar 2005

Figure 1(a). A small part of the Web page with the table of contents for a threaded discussion in a course. Each underlined phrase is a link to another Web page with the author's contribution. (Based loosely on http://cops.uwf.edu/lkcurda2/disc115_toc.htm, accessed August 27, 2003, with names and titles changed)

Re: Digital Divide
From: Barbara Wong
Date: 29 Mar 2005
Time: 21:54:33 -0600
Remote Name: 128.162.105.73

Comments

Although the typical student has access to a computer in the home, students from poorer families usually do not. At the elementary school where I teach, when I ask who uses a computer in the home, only students from wealthy and middle-class families have access. Because computers offer many opportunities for learning, I think all students should have computer access. Some schools allow students to check out computers and software to use at home.

Figure 1(b). The contribution of one student in the threaded discussion (Based loosely on http://cops.uwf.edu/lkcurda2/_disc115/000000dc.htm, accessed August 27, 2003, with data changed and comment paraphrased).

Discussions on electronic bulletin boards and electronic conferencing systems differ qualitatively from discussions in classrooms. The pace is slower, and participants have more time to compose thoughtful statements. Whereas the traditional classroom favors the verbally assertive extrovert, the chat space seems to favor the reflective student. Participants are more likely to share personal information in an electronic forum than in a traditional classroom.

With current technologies, electronic discussions omit nonverbal communication, such as vocal tones and visual cues. It is more difficult for a participant to express emotion in text than in person. Without visual cues, the instructor cannot rely on students' body language and facial expressions to determine whether they are attentive,

satisfied, or confused.[4] According to some educators, however, women and minority students may contribute more successfully in electronic forums because their gender and ethnicity are less evident.[5]

In courses on ethical issues, students benefit by discussing concepts and cases actively, and the instructor should structure these discussions. For instance, the instructor can require that a student post a statement before the student can access other students' statements, so that each student must think about the material before responding to other students' ideas. The instructor can organize synchronous and asynchronous small group discussions by creating separate chat spaces. The instructor can also organize formal debates and role-playing exercises. In sum, the instructor can use educational technologies to implement the same pedagogical methods that would be used in teaching ethics in a conventional classroom.

2. Production

Educational technologies allow students and instructors to produce artifacts. Students use office software to write and revise papers that incorporate tables, charts, diagrams, and figures. Nowadays, students' documents may go beyond text and graphics. To demonstrate their learning, students may collaborate with each other to construct Web pages with text, images, and links. They can create and edit animations and videos. By the end of this decade, video may become the new literacy.

Although ethics cases are usually written as text, many students have visual learning styles. Thus, instructors can use educational technologies to present images from real cases, such as a diagram of the Union Carbide plant in Bhopal and a photograph of the Citicorp Center in Manhattan. Instructors may also show video clips of cases. Students can use educational technologies not only to write and revise conventional papers that analyze cases and codes of ethics, but also to create videos to dramatize real or fictional cases. An assignment to create a video promotes student motivation by giving students freedom and responsibility, and it appeals to visual learners.

3. Distribution

Educational technologies allow the perfect replication and rapid dissemination of artifacts. Instructors can easily post their syllabi and assignments on course Web sites. An instructor might also post electronic versions of copyrighted materials with password protection, so that only students enrolled in the course can access them. (Educational technologies pose new challenges to copyright laws that are too numerous to consider here; see the article by Carol Twigg.)[6]

In a course on ethics, students can submit reading journals and analytical papers to instructors electronically. Students can quickly and easily exchange their papers with other students for peer editing and critique. Educational research suggests that students devote more effort to papers that other students will read than into papers that only the instructor will read.[7]

4. Archiving

The storage function of educational technologies allows students and instructors to save their work for future reference. An instructor can store video of a lecture electronically so that students can view it later online. Furthermore, an instructor can archive a class discussion conducted in an electronic forum. An archive can be especially useful for an ethics course because an instructor can analyze the transcript of the discussion afterwards to evaluate the quality of each student's contributions.

5. Access

Educational technologies allow students and instructors to access special resources that are not available locally—provided that they have appropriate equipment and sufficiently fast and reliable Internet connections. Students who are not resident on campus may access resources offered by the university. Both resident and nonresident students can access information stored in special collections or databases held at other institutions.

Resources may include online quizzes that are graded automatically and immediately. Automatic grading is especially helpful in large enrollment courses. With immediate feedback, students determine quickly whether they understand factual material, and whether they can solve closed-ended exercises with fixed answers.

Resources can include special visualizations or virtual reality spaces, available locally or at other institutions, to which the instructor has arranged access. A visualization resource shows the student a model of a physical process such as a chemical reaction.[a] A virtual reality space gives the student the illusion of moving through a physical environment, under the student's control; for example, the Virtual Harlem project[b] provides the sights and sounds of the Harlem Renaissance as if the student were walking along the street. Usually, to access these resources, the student does not need any special hardware or software, just recent versions of Web browsers that run applets and VRML (Virtual Reality Modeling Language) code.

Special resources may include subject matter experts, although a single expert cannot respond to thousands of students studying the same subject at the same time. On occasion an expert might participate as a guest in an online class.

For a course on ethics, the student can use the Web to access materials at the Online Ethics Center for Engineering and Science,[c] the National Institute for Engineering Ethics,[d] and other organizations. Using the searchable collection of codes of ethics maintained by the Center for the Study of Ethics in the Professions at Illinois Institute of Technology,[e] students can compare the codes of different organizations and professions, and they can examine how codes evolve over time.

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a. http://www.chm.davidson.edu/ChemistryApplets
b. http://www.evl.uic.edu/cavern/harlem
c. http://www.onlineethics.org
d. http://www.niee.org
e. http://www.iit.edu/departments/csep

With educational technologies, students can access a deluge of information, but the instructor is still essential. Because information on the Web varies in quality and reliability, an instructor must help students select, understand, interpret, and criticize that information. In addition, an instructor must exercise professional judgment in evaluating the student's mastery of knowledge about ethics and the student's skill in moral reasoning; professional judgment cannot be automated. Because significant ethical problems are open-ended, students' responses to these problems are generally not amenable to automatic grading.

Some Uses of Educational Technologies

Educational technologies can be used to duplicate traditional pedagogies, such as delivering a video of a lecture to remote students several hours after the lecture occurred. As Tom Creed[8] put it, however, "technology amplifies bad pedagogy." Instead, technologies should be used in pedagogically sound ways appropriate to the subject and to the students, to promote intellectual engagement. Linda Harasim and her colleagues[9] assert that educational technologies facilitate a shift from instructor-centered to student-centered instruction, from individual to collaborative learning. They claim that students should no longer be passive recipients but become active participants. Educational technologies do support multiple active and cooperative learning methods, although these pedagogical methods do not require electronic technologies.

Technologies should be used in ways that reflect good pedagogical practice. Susan Ko and Steve Rossen[10] and Rena Palloff and Keith Pratt[11] present numerous examples of pedagogically effective uses of educational technologies. Arthur Chickering and Stephen Ehrmann[12] emphasize that uses of educational technologies should comport with the famous Seven Principles of Good Practice in Undergraduate Education:[13]

1. Good practice encourages contact between students and faculty, because frequent contact with faculty strengthens student motivation
2. Good practice develops reciprocity and cooperation among students, because collaboration increases involvement in learning
3. Good practice uses active learning techniques, because students learn best when they talk and write about academic ideas, relate new ideas to previous experiences, and apply these ideas in their lives
4. Good practice gives prompt feedback, because students benefit from independent assessment of their knowledge and skills
5. Good practice emphasizes time on task, because students learn more efficiently when they focus on assignments
6. Good practice communicates high expectations, because students rise to the level of faculty expectations
7. Good practice respects diverse talents and ways of learning, because different students learn in different ways

To illustrate four of these principles, presented below are four pedagogical techniques that employ educational technologies at the moderate level to enhance the teaching of ethical issues in science and engineering.

1. Time on Task: Segmented Case[14]

A long case on conflict of interest (e.g., "Golfing"[15 (pp.316–317)]) is divided into segments. Each segment includes some text and a short video clip. After reading the text and watching the video, the student answers a few questions before gaining access to the next segment. After some segments, the student chooses from alternative actions that lead to different continuations. Upon answering questions for the last segment, the student may read commentaries written by experts.

The segmented case assignment illustrates the principle of time on task. Each segment of the case demands the student's attention and response. Each segment can motivate the student to continue by piquing the student's curiosity about the outcome.

2. Prompt Feedback: Just-in-Time Teaching[16]

An instructor posts several short cases that illustrate potential instances of plagiarism in research.[17] Accessing these materials remotely, students read the cases and respond to questions about them before 8:00 a.m. on the morning of the class. Students vote on which cases represent unethical behavior, and their votes are tallied by the computer system automatically. The instructor reviews the students' responses to the questions and adjusts the classroom presentation to respond to specific misunderstandings. The just-in-time teaching technique illustrates the principle of prompt feedback: soon after students make their choices, the instructor responds to their choices.

3. Active Learning: Dyadic Essay Confrontation[18]

Students in a bioengineering course read about the Björk-Shiley heart valve case, examining photographs and diagrams on the Web.[f] Each student formulates a question about the case and writes a response. Students take their laptop computers to class. At the beginning of the class session, students are organized into ad hoc pairs, and within each pair, the students use wireless network links to exchange questions. Each student writes a response to the question formulated by the other student. Students compare their own and their partner's responses to the questions, and each student submits both documents (one written before class and the other written in class) to the instructor electronically.

The dyadic essay confrontation illustrates the principle of active learning in the classroom. Students do not sit passively through a presentation of the case, but instead they actively respond to a question from another student, and in pairs, they compare their responses. Students can write longer, more detailed essays on laptop computers than by hand.

f. http://www.me.utexas.edu/~uer/heartvalves

4. Cooperation Among Students: Anonymous Role-Playing in Groups[19]

The instructor divides the students into six groups and assigns to each group a character in a case (e.g., the public key cryptosystem case).[g] The characters must negotiate an acceptable solution to an ethical problem. The instructor could provide each group with some additional information about its character that other characters do not know, so that students would experience a realistic negotiation, i.e., one without full information. The role-play is held during a synchronous online class session. Throughout the role-play, students within each group exchange ideas in a private chat space, and the group's spokesperson posts publicly the statements made by the group's character. All postings are identified only with the name of the character. After the role-play has run for an hour, students engage in an open discussion of the issues raised by the case.

The role-playing in groups technique illustrates the principle of cooperative learning. In small structured groups, students interact with each other to prepare questions and responses. Each group has a spokesperson, and other students may take specific tasks such as timekeeper and facilitator.

Future Technologies

Information technologies will continue to improve in many dimensions:

- Functionality - creating and displaying multimedia
- Bandwidth - delivering larger quantities of information quickly, such as real-time video
- Density - storing larger amounts of information on smaller devices
- Reliability - more robust systems that operate without crashing
- Security - resisting intrusions, ensuring confidentiality and integrity of information
- Ubiquity - connecting from everywhere via wireless links

For example, future software tools will simplify the production of videos.

It is pointless to debate which particular technologies best support education because the technologies will continue to change. As technologies change, courseware materials may become obsolete. In any case, the content of the materials must change as scholarship advances and student populations change. After all, education should not be dispensed in inert prepackaged modules for mass audiences.

How can instructors keep up with changing educational technologies? Surely if students can learn to use educational technologies, so can instructors. College and university faculty should be role models of life-long learning. Faculty members learn new knowledge through their research projects, but they should also learn new ways to teach, using educational technologies. There is no substitute for systematic, ongoing, individually crafted, continuing education for instructors—i.e., faculty development.[20] Fortunately, gaining a modest competence with educational technologies in order to

g. http://www.onlineethics.org/edu/roleplay/6001.html

use them at a limited or moderate level is no more arduous than learning to use a program for e-mail or word processing.

Costs and Benefits

Continual changes in technologies require continual replacement of computers and networking equipment. These replacement costs include not only the costs of hardware and software but also the costs of technical support personnel to install, maintain, and upgrade systems, and to train users. As pioneers in online education have discovered, the costs of educational technologies can be substantial for both institutions and students; different educational institutions have made different levels of commitment to investments in educational technologies. The costs of these technologies may hinder the participation of the economically disadvantaged in contemporary society. Because educational technologies allow multiple institutions to share resources, however, the cost of developing a sophisticated resource could be distributed over many users.

Another cost of educational technologies is faculty time, not only for preparation but also for delivery of classes. Because educational technologies promote extensive interactions between students and instructors, an online class should be smaller than a conventional class in the same subject—a course with online discussion should have a maximum of about twenty students. Thus online classes of high quality are likely to be costly.[21]

The costs of educational technologies may be justified for place-bound students who would otherwise need to relocate to pursue their educational goals. Do the benefits of educational technologies justify the costs for other populations of students? It is unclear whether educational technologies are more effective than traditional techniques in achieving instructional goals. Research studies on the effectiveness of educational technologies have been inconclusive. The literature to date suggests that no matter what technology is used, there are no significant differences in student learning outcomes.[22] Some technologies not intended for education, such as word processing, may improve learning, however.[23] Research on the effectiveness of educational technologies continues, both by individual researchers and by institutes such as the Center for Applied Research in Educational Technology.[h] Research articles are published in scholarly journals such as the American Journal of Distance Education[i] and the Journal of Asynchronous Learning Networks.[j] For a comprehensive directory of resources, see the Distance Education Clearinghouse.[k]

Pedagogical research is needed on the effectiveness of educational technologies for moral learning. The effectiveness will likely depend on the specific functions and levels of use of the technologies, the subject matter, and the characteristics of the students. Instructors should systematically assess the effectiveness of the educational

h. http://caret.iste.org
i. http://www.ajde.com
j. http://www.ajde.com
k. http://www.uwex.edu/disted/home.html

technologies that they use in achieving desired outcomes—both cognitive and affective—in their own courses with their own students.[3, 24]

Conclusions

Today education is both "face-to-face" and "face-to-interface." Instructors can use different functions of educational technologies at limited, moderate, and extensive levels to support the teaching of practical ethics. Instructors should use these technologies in imaginative ways, not merely to duplicate conventional pedagogies, but to promote intellectual engagement. Instructors should assess their effectiveness in achieving educational goals.

Educational technologies provide convenient ways for instructors and students to access and share information. But information, by itself, is not knowledge. The difference between information and knowledge is education.[1]

Acknowledgments: In preparing this essay, I benefited from illuminating discussions with Lanny Arvan, Chip Bruce, and the participants in the Web-based Ethics Curriculum Workshop sponsored by the National Science Foundation and hosted by the Association for Practical and Professional Ethics at Indiana University, June 10–11, 2002. I thank Bob Marine for references to the research literature.

This work was supported by the National Science Foundation under Grants SES-0138309 and SES-0225156. The views, opinions, and conclusions of this essay are not necessarily those of the National Science Foundation or the University of Illinois at Urbana-Champaign.

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