AC 2012-3711: TEACHING NON-MAJOR STUDENTS ELECTRICAL SCIENCE AND TECHNOLOGY

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Teaching Non-Major Students Electrical Science and Technology

In recent years, many students in majors other than engineering or science have been expected to take a Science, Technology and Society (STS) course, or the equivalent, to satisfy a component of their general education requirement. Ideally, the STS requirement helps students learn how culture interacts with science and technology, through influences in both directions. In the process, non-major students can also gain appreciation for essential concepts, controversies and current areas of exploration, while developing increased technological literacy for critiquing scientific or technological claims in presentations of various forms. Teaching an STS course, however, requires a very different pedagogical approach than a faculty member may use for a traditional engineering course. Rather than an emphasis on rigorous quantitative problem solving or project planning, non-major students benefit much more from an approach that provides sufficient historical context and biographical details of explorers and their contributions. The instructor should effectively guide discussions on key questions related to selected readings or video presentations, utilize classroom demonstrations to illustrate key concepts, and assign certain mini experiments or projects that help students get a hands-on feel for how things work. Evaluation techniques should fit the course audience. While matching and multiple choice test questions can assess students learning at the lower levels of the New Bloom's Taxonomy related to remembering names, contributions and terminology or understanding concepts correctly, assigning one or more thesis driven papers can serve to assess students' progress in the upper levels of thinking from analyzing and applying to evaluating and creating. This paper illustrates choices made by the author in teaching a non-majors course involving electrical science and technology at Messiah College over the past several years, including samples of assessments measuring student outcomes with the above techniques. The author recommends teaching such an interdisciplinary course for non-majors not only for the pleasure of the experience, but also for the benefits of expanded scholarship that result, both for the students and the faculty member, in the form of newly established interdisciplinary connections. Such connections include understanding diverse viewpoints on technology, recognizing how one fits in the process of developing and guiding technology for society as a whole, and bringing the broader background of biographical and historical precedent into the classroom of the standard engineering curriculum. The paper concludes with some suggestions for future work.

Introduction

The recognized need for Science, Technology and Society (STS) instruction distinct from traditional science or engineering disciplines originated in the latter half of the 20th century, as described by Solomon.[1] Content and approach of STS courses vary widely from one country, university and instructor to the next, but Aikenhead suggests that a common direction is "toward teaching science embedded in technological and social contexts…"[2] Including historical and biographical context brings richer meaning to students studying scientific discoveries and technology inventions, and is consistent with postmodern trends. While authentic context helps reveal sources of bias, STS should also address the nature of science, environmental issues, cultural (e.g. economic and political) aspects of technology and personal values toward helping students find a more informed voice in democratic society.[3] For non science or engineering majors, an STS course has been described for freshman at Frostburg State.[4] For engineering students, using history of technology to understand the impact of solutions has been recently proposed.[5] This paper describes methods of teaching a course for an audience of non-technical upper class undergraduate students who have completed a First Year Seminar course with a college writing component. While STS serves as a common descriptor at many schools, terminology in the field varies; at Messiah College, a Christian college of the liberal and applied arts and sciences, the requirement has been designated as Science, Technology and the World (STW), within the category of Interdisciplinary Studies (IDS). Based on educational literature and the author's own experience in developing effective pedagogy, this paper presents methods and results of teaching an upper divisional undergraduate STW course on electrical science and technology, including ideas for future work.

Where the STW course at an undergraduate school meets a general education (Gen Ed) requirement for all students completing the bachelor's degree, enrollment will likely come from a variety of disciplines. At Messiah College, the Gen Ed STW is specified to serve as "an interdisciplinary exploration of the nature, methodology and scope of science [and technology] with a special emphasis on the interrelationship between science [, technology] and culture."[6] However, engineering, science and certain other departments claim exemptions to the STW for their majors, on the basis of overlapping curriculum that meets those objectives within their own programs. While Messiah College as a whole averages as low as a 13:1 student to teacher ratio overall, STW courses are normally capped at a level of 32 students. From the outset, this instructor has designed the STW course to satisfy an additional writing-enriched requirement, capping enrollment, by rule, at a lower level of 25 students.[7] A class of this size lends itself practically to discussion and written paper assignment management, including commented feedback on rough drafts[8], as suggested here for effective STW instruction. Educators at schools that have larger class sizes should adjust methodology accordingly.

While the STW Gen Ed requirement applies to all students, diversity among STW course offerings provides some freedom of choice to fulfill it, influencing the distribution of major disciplines among students enrolled within a particular class. Perceived relevance to major, informal recommendations and personal preference represent the most likely motivations for their choice. Examples of STW topics addressed at this institution include Appropriate Technology, Biotechnology, History of Modern Science, Religion & Science in Modern America, Scientific Revolution, Plants & People, Eco-Urban Footprints and Exploring Electrical Technology (EET). Such variety is afforded by the freedom instructors have to plan courses reflecting their own interests and expertise, while satisfying a common set of STW objectives. Over the years this author has developed and taught EET, a typical distribution of student disciplines has emerged as shown in Table 1. The classroom presence of students with certain major disciplines has naturally led to developing particular illustrations, emphases and discussion topics based on interests of those particular students.

Rank by population	Disciplines represented by department and/or major (# of students out of 25)			
	2008	2009	2010	2011
1	Art (3)	Business (7)	Art (3)	Business (6)
2	B&R Studies (3)	Crim. Justice (3)	B&R Studies (3)	HD & FS (4)
3	Business (3)	Politics (2)	Mod. Lang's (3)	Music (3)
4	HD & FS (3)	Art (2)	English (2)	Psychology (3)
5	Psychology (2)	10 others (1 ea.)	Business (2)	Comm. (2)
6	11 others (1 ea.)	Open seat (1)	Comm. (2)	Crim. Justice(2)
7			Crim. Justice(2)	4 others (1 ea.)
8			8 others (1 ea.)	Open seat (1)

Table 1. Distribution of disciplines represented by at least 2 or more students in an STW course (Exploring Electrical Technology) in the Fall semester from 2008 through 2011. The following provides major detail associated with certain departments: *Business* includes Accounting, International and Administration, *HD & FS* is Human Development and Family Science, *Music* includes Performance, *Comm.* (Communication) includes Broadcasting, *Art* includes Education and Studio emphases, *B&R Studies* (Biblical & Religious Studies) includes Christian ministries, *Mod. Lang's* (Modern Languages) includes French and Spanish.

This table shows that over these four years, the largest portion (16 %) of student enrollment came from Business, as expected for the department with the most students at this school. Second with 9 % was Art, followed by a tie for third between Biblical & Religious Studies, Criminal Justice, and Human Development & Family Science each contributing 8 %. Psychology was the sixth largest component at 7 %. As a majority of the distribution, these six disciplines make up 56 % of the total enrollment, while several other individual disciplines each contributed 5 % or less, during the past 4 years. The spread of disciplines for other courses like this will differ, but adapting to the specific distribution can help the instructor keep more students actively engaged.

Having identified the background of STS education and its direction, key institutional parameters where this course is taught, and the distribution of students that have enrolled, the next section will describe methods effective to achieve course objectives, and account for this particular audience of non-technical upper class undergraduate students.

Methods

This section describes pedagogical methods used to achieve three of the five particular objectives of the STW course. The three course objectives selected for illustration here, are as defined by the GenEd committee at this institution and adapted to the specific topic of this course. As stated in the syllabus, "By the completion of the course, the students will demonstrate: 1) an enhanced understanding of the relationship of electrical science and technology to other disciplines and relevant ethical, social, cultural, historical and political issues; 2) a substantive knowledge of the essential concepts, controversies and areas of exploration of a specialized topic in electrical science and technology; 3) an ability to critique scientific and technological arguments and claims in oral and written presentations." To show how these objectives are fulfilled, the following two paragraphs will provide overall course layout, approach to the topic, activities assigned and methods of assessment. After that, this section will describe more specific pedagogical choices by the instructor with regard to student audience, classroom management, and topical relevance to the three course objectives.

As an overview, this course devotes about two-thirds of the semester developing history of electrical science and technology, and the last third addressing philosophical issues by presenting views of noted authorities across the spectrum from anti- to pro-technology. Types of assignments students complete outside of class include reading required texts, preparing for short tests and writing papers on relevant topics. In class activities include short lectures, video presentations, instructor demonstrations, mini-experiments or mini-projects completed by students in groups, reflective writing and interactive discussion. A variety of activities helps maintain interest and allows for differing modes of assessment.

Assessment in the course consists of a combination of Pass or Fail (PF) checks balanced with fully graded work. The PF category includes: a) study guide question responses associated with required readings, videos or lecture notes, b) reflective writing in response to a specific prompt, and c) completion of steps associated with a mini-experiment or mini-project. PF assessment facilitates instructor time-management, while providing sufficient incentive for students to participate. The instructor can apply a strict or more lenient quality control filter on submitted work, as appropriate. Failed work can be returned to students with feedback on how to resubmit for credit. Fully graded work includes the short tests and written papers. The four short tests during the semester each consist of three parts: matching names, matching terms, and multiple choice questions. Students are given 30 minutes to complete each of these tests. Serving as one measure of course objective achievement, grading these short tests is relatively easy for the instructor to manage. Grading written papers can be much more time consuming, but they act as a valuable outcome assessment of whether these students have creatively engaged with the material, thought critically about it, and made significant progress on course objectives.

While engineering students prepare to solve mathematical problems, use advanced tools in project design, and apply scientific principles, many non-technical students bring a different background that primarily emphasizes reading, writing and speaking skill sets. Thus, oral discussion and written papers better suit the student audience as tools of learning. Oral discussion becomes effective when preceded by a preparatory activity such as one of those in the PF category above, and conducted by one of a variety of organized formats in the classroom. Quality of writing assignments, and hence papers submitted to fulfill them, may be enhanced by a fully developed prompt. A good prompt for the paper should fully describe expectations of the assignment.[9] Expectations include draft deadlines, format including page length, style (e.g., research or persuasive), suggested topic(s) to address, and type of thinking to be reflected in the paper.

For meaningful discussion, and stimulating preliminary thoughts about the selection of a paper topic, the preparatory activity should be selected carefully; one of the best activities to inform and stimulate such good discussion can be a well-selected reading. To fulfill the stated course objectives on the topic of electrical science and technology, the author of this paper suggests several useful works. Some of these readings are full texts specified as required in the syllabus, and other articled or excerpted portions of selected works combined into a required course-pack, edited by the instructor and published in-house on campus after obtaining all necessary copyright permissions. Near the beginning of the semester, while treating the origins of electricity & magnetism for which minimal documentation or published treatment exists, the author assigns students a reading intended to raise questions and get their "critical thinking juices" flowing: *Technology & Religion*[10] defines technology in general, illustrates by some specific examples including electrical ones, and brings perspective from the commonality and distinctiveness of three great religions: Islam, Judaism and Christianity. From the perspective of these traditions, Herzfeld identifies several ethical issues that arise in contemporary applications. Reading Herzfeld's treatment helps students begin to address objectives 1 and 2 as stated above. The instructor typically assigns a study guide to accompany readings like this, with leading questions intended to help students recognize key issues for consideration and further discussion. Since the teaching of any course is a work in progress, the instructor recognizes that the effectiveness of these questions may be further enhanced, and the choice of text will eventually need to be updated to stay current. Thus, these decisions are revisited on an annual basis for potential revision.

Other readings and videos on the topic of electrical science and technology fit better into the chronology of an historical approach. Heilbron treats early history of electricity before the invention of Volta's Pile in a well-researched chapter of *Elements of early modern physics*.[11] In this chapter, Heilbron identifies four periods in the era of Early Electrical Science (from 1600 to 1800), framing developments in the study of electricity from haphazard observations often viewed as magic, to establishment of the Scientific Academies, and eventually more systematic quantitative measurement methods enabled by instrumentation in the late 18th century. Since the invention of Volta's Pile represents such a pivotal event in the history of electricity, the instructor shows students segments of the video *Volta & Electricity*[12] well-suited for the student audience due to its detailed description of the historical context and dramatic illustrations of how Volta handled the essential quantities of charge and voltage (i.e., "tension" in Volta's day). Unfortunately, *Volta & Electricity* does not appear to be for sale any longer, and quality of the library videotape version has degraded over time. Thus, shorter video segments now available on YouTube, or *The Ambiguous Frog*,[13] a fascinating account of the Volta-Galvani controversy, may be preferable options for instructors seeking a resource on the topic.

Classroom discussion on Volta & Electricity can focus on several areas: 1) the difference in perspective with Galvani that stimulated Volta's work (controversy as an ingredient of science), 2) characteristics that made Volta the same and/or different from explorers before him, 3) instruments Volta assembled to test his theories about contact electricity, eventually enabling him to construct a working Pile, and 4) recognizing how Volta's Pile improved on the Leiden Jar so as to have such an immediate impact. As a follow up, one of the suggested paper topics students may choose to write a formal paper involves comparing and contrasting Volta's pile to batteries of today. Volta's invention becomes a transition point in the course, leading to the momentous developments of the 19th century, including newly perceived connections between electricity and magnetism, inventions of the dynamo and motor to establish the power industry, and implementation of a practical telegraph, making long range instantaneous electrical communication possible.

Electric Universe[14] picks up with events early in the 19th century, by revealing the personal side of explorers such as Faraday, Henry, Morse, Bell, Edison, Thomson, Maxwell, Hertz and others. Bodanis's text also addresses course objectives effectively by striking a balance between its accessibility for the general reader including biographical details, while treating the scientific and technical aspects with enough integrity to interest uninitiated students in a deeper way. The reader discovers when and where the term "short circuit" emerged, what characteristic of a wire affected by Bell's microphone transmitted the pattern electrically, how JJ Thomson found the electronic particle that Edison missed, what unique property of the electron enabled invention of the semiconductor-based transistor, and why the transistor facilitated a computing revolution. These examples illustrate essential concepts (objective 2). Controversies (also objective 2) include the question of AC versus DC for electric power distribution, the role of Faraday's fields in successful operation of the transatlantic cable, and who got credit for inventions such as the telegraph and the transistor. Each of these essential concepts and controversies in the historical context can lead to related issues in contemporary "areas of exploration" (objective 2). For example, contemporary issues on the forefront related to power distribution include deregulation, smart grid developments, and alternative power sources to alleviate environmental concerns. Moreover, Bodanis introduces claims about the multiple ways electrical technology impacted culture (objective 1). For example, he identifies the particular ways distribution of electric power impacted entertainment, industry, transportation, architecture and home life, and how the advent of radio broadcast brought social unification in multiple forms. Bodanis also describes how applications of transistorized electronics, on the other hand, cut in the opposite direction, giving birth to musical subcultures, a more segmented retail industry, loss of blue collar jobs, increased individuality and instantaneous access to all kinds of specific information. As an alternative to Bodanis, *Electrifying America*[15] details the historical effects of power distribution even more completely, in a way that relates closely to these course objectives. However, its thoroughly researched treatment of the Electrification process and social implications during the late 19th and early 20th centuries can be a little too burdensome for most of these undergraduate students to read fully as a required text. Thus, in recent years, the instructor has given an optional paper topic that students may choose to select, using a library copy of Nye' work, and has assigned only Nye's first summary chapter for the whole class, included with permission in the course pack.

The representative course media (both print and visual) identified above remains central, yet some learners respond better to classroom demonstrations and hands-on activities such as provided in the mini-experiments and mini-projects selected for this course. Classroom demonstrations early in the course include methods of static electricity generation and discharge, measurements with an electroscope, Coulomb's Law calculations associated with a pair of suspended balloons, and Leiden Jar storage compared to that of commercial capacitors today. Later in the course, the instructor shows how a hand driven dynamo serves to power a winch, light one or more small bulbs or drive another dynamo in reverse. Shaking a transparent plastic Faraday flashlight illustrates the concept of induction nicely. These demonstrations are usually conducted by the instructor, but may be assisted by a student volunteer. For more student involvement with hands-on activity, the instructor assigns the following mini-experiments in groups of three or four: 1) floating a pre-magnetized nail on water with Styrofoam (as a simple compass) followed by reflective writing about observations of the group and/or compared to other groups, and 2) digital multi-meter measurements of batteries, including an internal resistance calculation. While the mini-experiments focus primarily on observations and measurements, mini-projects require more steps of construction. The mini-projects include: 1) wiring an electric lamp (including socket and plug), and 2) constructing an electronic music circuit. The electric lamp project leads to a demonstration comparing the illumination of a compact fluorescent (CFL) bulb (20 W) versus an incandescent bulb (60 W), using a light-meter. The instructor then leads students through calculations of the expected CFL break-even time based on bulb prices and cost of electricity. This demonstration is easily upgradable to test a comparable LED bulb.[16] While the calculation of break-even time here focuses on electric light sources, the instructor explains that long term economic benefit of other emerging "green" technologies such as the latest electric car[17] can be evaluated in a similar way, an issue that should be of interest to all students, but especially those in Business.

Having described several of the specific choices made in course materials and classroom activities to address electrical science and technology, this section will now address some particulars about conducting classroom discussions, and handling formal papers. With regard to classroom discussions, after a suitable preparatory activity, the instructor provides opportunity for oral participation, often using questions from a study guide, or alternative questions that arise spontaneously. Some options for organizing discussion include: 1) allowing any student in the class to respond to each question on a voluntary basis, 2) assigning one or more questions to each student or group, 3) allowing each student or group to choose a question of preference from the study guide. Each of these options has certain tradeoffs. In the case of option 1, unless the instructor directs students otherwise, more talkative students in the class tend to dominate, while quieter students remain passive. The latter two options can engage more complete student participation, although some students may be prone to hide in a group. When organizing groups, the instructor allows a few minutes of preparation, so students within each group can collaborate with each other, and choose a student to represent the group when reporting to the class as a whole.[18] Students can be asked to organize themselves in groups of their own choosing, or by an instructor's devised method, such as the random distribution of numeric playing cards.[19] The instructor uses a variety of the above methods through the course to avoid excessive routine, and so as to adapt appropriately to the material being addressed. Such discussions address the oral part of Objective #3, assessed Pass or Fail on the basis of preparation and participation.

Students fulfill the written part of Objective #3 by completing assigned formal papers. The General Education committee at this institution specifies for any Writing Enriched course that students must submit at least 10-15 pages of finished draft writing, including at least one preliminary reviewed draft, to achieve the goal of helpful intervention.[20] For the purposes of this course, the instructor distributes the total finished page requirement into three assignments, the first specified as 2-4 pages in length (worth 10% of course grade), and the other two 4-6 pages in length (each worth 15%). In this way, collectively, the page length requirement has been met, and given a substantial portion (40%) of the course grade credit. The papers are each assigned using a prompt that includes all the elements previously described, including a list of the instructor's suggested topics relevant for that stage of the course, striking a balance between all students on same task versus all students having complete freedom of choice.[21] To specify the type of thinking expected in each paper, the instructor uses progressively increased levels of Bloom's Taxonomy--New Version[22] for each of three papers during the semester. For example, the first shorter paper emphasizes Remembering and Understanding levels (e.g., definition, classification, description, discussion, explanation and selection), the second paper specifies Applying and Analyzing (e.g., illustrating, interpreting, comparing, contrasting and distinguishing) and the third highlights Evaluating and Creating (e.g., arguing, defending, judging, developing and formulating). Having students illustrate thinking at the highest levels of Blooms Taxonomy fits the style of the third paper, since it is specified as a persuasive one in which the student must argue a position on the appropriate use or non-use of a contemporary technology. In reviewing each draft before the final, the instructor makes some written comments that are unique to the individual student paper and other numerically coded comments about issues common to many students. The numerically coded comments are identified by a key given along with the draft when it is returned to students. Sequencing paper assignments[23] helps students refine their research content, and sense coherence in the progression of their work that parallels the intended development of subject mastery. The written part of Objective #3 is assessed primarily by the grade on each of these papers, but also to an extent by the grade on three short essays assigned as a part of the final exam. Assessment of papers by the instructor is based on an analytical rubric[24]distributed to students with the syllabus, including areas of Focus (20%), Organization (30%), Content (30%) and Mechanics & Style (20%).

Having addressed the pedagogical methods used to achieve the three highlighted course objectives in this section, the next section will provide some sample outcomes of students as a measure of the extent to which they have fulfilled these objectives.

Results

To assess fulfillment of the course objectives stated in the Methods section, this course utilizes PF class participation activities, informal reflective writing exercises, formal paper assignments, tests and a final exam. In addition to these graded mechanisms, ungraded class discussions were held frequently to help stimulate students thinking in the direction of the objective stated above, by asking factual and more penetrating discussion questions and soliciting opinions from among students so as to expose both common ground and controversy.

The instructor uses class participation activities such as study/discussion guides on videos and assigned readings to evaluate student participation and engagement with the material on a basic level. Generally, most students in the class complete the participation activities, thus make progress on the objective, since many of the activities are designed specifically to address interdisciplinary issues. A few students due to absence or negligence fail to complete the class participation activities, thus generally making less progress on course objectives, and consequently lowering their class participation grade. Of the class participation activities, one closely related to Objective 1 requires the students to draw a diagram showing all the major disciplines represented by students in the class, including scientific and technical ones, if any. After discussing some examples, students realize the variety of different perspectives that exist in these relationships between disciplines, as aspects of culture that relate to electrical science & technology.

Of the formal paper assignments, all of the suggested topics from which students choose require some literature search to provide adequate historical background as context for the issue. One paper topic that specifically develops interdisciplinary awareness along the lines of the stated objective involves addressing social factors that influence the Digital Divide.[25] Although the Digital Divide is an optional choice of the first paper assignment, the third paper, a persuasive one, requires the following three approaches for full credit: 1) addresses how the specific electrical technology of your choice acts as an influential agent ON and/or BY other aspects of culture which you identify, 2) traces the specific electrical technology back to its original, and 3) evaluates positions advocated by noted authorities across the spectrum of pro- to anti-technology. Because the presence of approaches 1 and 3 as stated above is evaluated as a part of the grade on Paper #3, it can serve as one measure of Objectives 1 and 3 as stated in Methods.

Table 2 shows that the average percentage grade on Paper #3 over these years was 87 (B+). Students do reasonably well on the average, with a few excelling and some less than adequate. It should be noted that these grades are better than otherwise due to the process-writing approach, in which students submit a first draft for the instructor to read, comment and return, enabling students to make revisions prior to final submission. Grades on Paper #3 measure combined objectives, however, rather than individual ones.

	STW class average grades on Paper #3			
	2008	2009	2010	2011
Grade percentage	87.7	86.5	88.7	86.6
Standard Deviation	6	8	7	6
Sample Number	25	23	25	23
Did Not Submit	0	1	0	1
Total in Class	25	24	25	24

Table 2. Average grade statistics on Paper #3 for classes of students in Exploring Electrical Technology during the fall semester from 2008 through 2011. Nonsubmissions have been removed from sample statistics, as indicated.

To illustrate student written work more explicitly, three anonymous thesis statement samples from the final draft of Paper #3 in Fall 2012 are selected and critiqued here. Although the thesis statement cannot serve as a sufficient measure of overall paper quality by itself, it does act as a necessary element of focus, organization and persuasion. Author #1, a business major states, "Hybrid cars have a rich history, impact culture in many ways, and have sparked a debate about whether gas or electric cars will dominate in the future." While this statement addressed the right kind of issues for the assignment, more specificity could strengthen the claim; for example, will the paper argue that the hybrid is both more environmentally friendly and cost effective than purely gasoline powered cars? Author #2, a Human Development and Family Science major suggests, "Although cell phones have become a more popular and convenient alternative for human communications worldwide, they will erode face-to-face relationships unless people realize that they need to take more time away from their cell phones. They can try and balance their cell phone time better." Author #2 makes a substantive and specific claim, but should combine the two sentences into a single sentence thesis statement. Author #3, a psychology major proposes, "Despite the concerns about [Electroconvulsive Therapy] ECT, from its early development to its new found use as a means to treat major psychological disorders, the positive results of ECT on the brain far outweigh side effects and negative views associated with treatment. Author #3 frames a developed persuasive argument, but could strengthen the claim with the caveat that positive results occur for patients with extreme forms of depression, and may not be warranted otherwise.

As a somewhat less subjective measure, a few sample multiple choice items (out of 25 total) indicative of knowledge associated with course objectives are selected from the final exam. The first of these examples involves a question drawn from *The Big Switch*.[26] On the test, item #3 is stated as follows: "In *The Big Switch*, what role does Carr say electrification played in American Society?" Table 3 below shows the results. Three out of every 4 of these students chose the best response which is "Educational requirements of white collar jobs increased, extending the need for public education beyond elementary level, and making higher education much more common." This claim makes an explicit connection between electrical technology and education in America, related to Objective 1. Though the outcome of student performance on this item may be satisfactory, it reveals less about how many students understood or agree with the connection Carr claims than how many listened and participated actively in class when it was discussed or studied their notes before the test.

In the next two examples, questions are drawn from *Electric Universe*. Item #17 is stated as follows: "Which of the following is UNTRUE about the social effects Bodanis suggests occurred as a result of the transistor?" The best response was "mass communication by broadcast radio and TV became less specialized." This illustrates an explicit connection with mass communication culture, illustrating Objective 1. However, as indicated in Table 3, while three out of every four students chose the best response in 2009, only one out of two chose wisely in 2011. This significant drop in performance deserves some further analysis by the instructor. The second of these examples is a completion repeated from a previous test. Item #23 states, “According to Bodanis, social effects that occurred as a result of the distribution of electric power in Edison's day included…" The best response was "entertainment after working hours in amusement parks at the edge of cities that led to social mixing including marriages across traditional boundaries." This claims an explicit connection with entertainment and social traditions, again illustrating Objective 1. While two out of every three students chose well, those who missed it may have been distracted by other choices that looked correct, or exhibiting test fatigue.

Final Exam Multiple Choice Item #	Fraction of best responses	
	2009	2011
3	18/24 (75%)	18/24 (75%)
17	18/24 (75%)	12/24 (50%)
23	16/24 (67%)	16/24 (67%)

Table 3. Fraction of students out the the class size who chose the best response of selected multiple choice items on the Final Exam in the fall semester of 2009 and 2011.

The final two examples of multiple choice items are drawn from classroom demonstrations performed by the instructor. Item #7 states, “As demonstrated by [the instructor], a hand driven dynamo…” The best response was “works just like a motor in reverse.” In Fall 2011, 21 out of 24 (88%) of the students picked this as the best response. Item #18 states, “Based upon the comparison of the fluorescent versus incandescent light bulbs demonstrated by [the instructor] in class, including additional calculations, one can conlude that…” The best response was “the additional cost of a fluorescent bulb may be justified by lower operating cost.” In 2011, 23 out of 24 (96%) of the students picked this as the best response. These results indicate that students were able to successfully recall these “essential concepts” as one measure of Objective 2. While the high performance on these items may be due in part from remembering the demonstration, these questions were also repeated from a previous test.

Perhaps a more direct measure of how well Objectives 1 or 3 were fulfilled by students involves two short answer essay items on the Final Exam. The first question was based on a quote cited from Responsible Technology as follows,[27] "Monsma identifies technology as having an all encompassing influence on culture, and a powerful element in shaping it. What example of electrical technology, and/or its development, can you cite to support (or contradict) this view? Why?" The average score among all students on the essay was 5/6 (83%) in 2009 and 4.5/6 (75%) in 2011. The lower scores in 2011 may reflect stricter grading rather than lower student performance. Nevertheless, the results show that a majority of students had at least an acceptable ability to respond critically to this open ended question, using knowledge gained from course material illustrating connections between electrical technology and other aspects of culture.

Summary & Conclusions

This paper has presented methods of teaching a course on Electrical Science and Technology for upper divisional undergraduates based on guidelines in the literature and experience of the instructor. Appraising the distribution of disciplines represented by students in the class helps the instructor engage students more effectively, by adapting illustrations and emphases of course content to those present.

As the faculty member and students become more aware of each other's major disciplines, they grow as a community in the process of establishing interdisciplinary connections, an overarching benefit. New connections here can take the form of better understanding of various viewpoints on technology, where common ground exists and/or where controversy arises, facilitating more informed communication between disciplines on important issues. Furthermore, certain students get a better picture of where they can fit with a non-technical major into the process of technology development, in real world project applications. At this author's home institution, such students have many opportunities to actively engage in multidisciplinary project work through the Messiah College Collaboratory for Strategic Partnerships and Applied Research.[28] Collaboratory project work includes both voluntary and credited activity, in a cooperative effort between students and faculty inside and outside engineering. Faculty professional growth from teaching such an interdiscipinary course also can include discovering opportunties to bring historical, social and value-based context back into the engineering classroom, to supplement the technical content with a more human side, as this author has done.

To enable students to achieve the course objectives highlighted in the Methods section here, several quality readings have been suggested relevant to Electrical Science and Technology, the details of which are included in the Bibliography. Specific classroom demonstrations have been suggested that may be of interest to instructors teaching a similar course, as a model or as a stimulus for creative alternatives. Methods of discussion and handling formal written papers have been described, including references to the literature especially on the latter for more information. Sampled assessment shows some results, indicative of how well students at this institution have fulfilled three of the course objectives, and useful for continuous improvement by the instructor. While pass or fail assignment can gauge participation, and multiple choice test questions can measure knowledge, oral discussion, written essays and graded papers perhaps serve as the best indicators of outcomes relative to the objectives, for non-technical students at the undergraduate level, as they involve the most creative synthesis and critical thinking.

Future Work

Several opportunities exist for the future, for this author and others, by extending the work with a more in-depth analysis of the pedagogical strategies described here. The relative benefits of each learning activity might be explored on the basis of measured students outcomes, whether new or already employed, and from the point of view of students as expressed on a course evaluation survey. The relative value of hands-on versus instructor-conducted demonstrations may be considered by comparing the observed experience in a course such as this, with the broader experience reported in the literature. Finally, it would be revealing to explore in greater depth what ideas students have about the relationship between electronics and society before taking a course such as this, identify the source of potential influences, and determine how those ideas have changed afterwards. Having students take a pre-course survey, as well as the post-course survey they already take, might be effective in gauging these attitudes.

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