YOUTUBE FRIDAYS:
Engaging the Net Generation in 5 Minutes a Week

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The majority of students pursuing undergraduate degrees are digital natives (sometimes called the Net Generation). These men and women are characterized by being born in the 1980s or 1990s and by having "grown up digital." They have had access to computers and the Internet from a very young age. The ubiquity of laptops, cell phones, digital music players (*e.g.*, iPods), and other electronic devices has this generation plugged into technology continuously throughout a typical day. The advantages enjoyed by technology-savvy students are numerous. The near instantaneous access to course-related information can be used to look up unit conversions, find physical properties, or verify an equation within seconds. The integration of technology in the classroom, *e.g.*, using Tablet PCs to promote student engagement,[2] is almost expected by the digital natives.

There are many technology-driven behaviors that challenge faculty in higher education today, however. For example, the free flow of information has revolutionized how students communicate (and sometimes cheat[3]), including the wide availability of solutions manuals for textbooks that are only intended for instructors. Also, handheld technologies allowing students to send text messages or "Tweet" have contributed to shorter student attention spans. Text messages truncate the English language to a series of abbreviations and "Tweets" are limited to just 140 characters (about the length of this sentence). Myriad books, blogs, and wikis discuss topics related to the growing population of digital natives[4-7]; however, this paper focuses on a simple classroom exercise to encourage students to use the seemingly endless information around them to enhance their college educations.

Active learning is a key component of many different teaching techniques used to engage students.[8] The use of multimedia (*e.g.*, audio, video, PowerPoint presentations) is one way to maintain student interest throughout a class period and during the duration of a quarter or semester. Student participation and even leadership is critical when finding successful active-learning strategies. Therefore, for an activity to truly qualify as active learning, students' enthusiasm is needed.

YouTube Fridays began as a way to show the students about my area of research (rheology of complex fluids) as part of the first class period of Introduction to Engineering Thermodynamics. The fact that a professor is both teacher and researcher is important to emphasize to undergraduate students.

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Seeing the interesting problems their professor works on piques their interest and motivates them to get the most out of their studies. After watching a video of people "walking on water" (actually a pool of corn starch, a shear thickening fluid), the students wanted to know how a corn-starch pool worked and if they could build one.[9] I chose another video, about viscoelastic fluids,[10] the second week of class, and the students wanted to know if there would be videos every week. I consented, on the condition that the students do the work and find the videos and relate them to the course. Thus, YouTube Fridays started its transition from a fun way to start class at 8 a.m. on Fridays (and to bolster Friday attendance) to a quantifiable teaching technique.

IMPLEMENTATION

YouTube Fridays have been piloted as part of two courses (Table 1). Introduction to Engineering Thermodynamics, a sophomore-level class for students in chemical engineering, engineering physics, and civil engineering, was where YouTube Fridays began. A more formal YouTube Fridays pilot was completed the next semester as part of a Material and Energy Balances class, a sophomore-level course for chemical engineering students. The students were required to relate their chosen video to the topic of the course, namely thermodynamics in the first pilot and the field of chemical engineering in the second. The evolution of the topics of the videos and the "new" course material related to the videos will be discussed in the context of each pilot. A section on how YouTube Fridays were evaluated precedes the concluding remarks and summary of how to adopt YouTube Fridays in other courses.

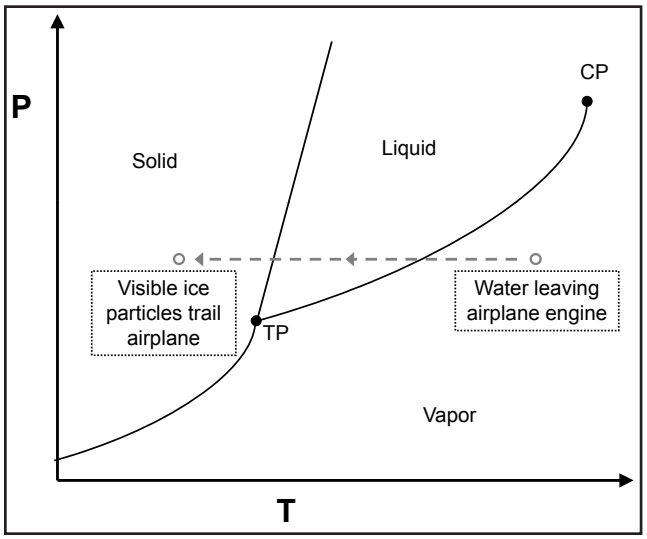


Figure 1. *Schematic of a pressure-temperature phase diagram of a pure fluid. Overlaid points represent the two phases of water present in the videos.*

Pilot 1: The Birth of YouTube Fridays

Introduction to Engineering Thermodynamics introduces basic concepts including units conversion, reading steam tables, the first law of thermodynamics (energy conservation), and the second law of thermodynamics (entropy). During the first few sessions of a semester, the class is split into groups of three or four students (of the 40 total students), which are affectionately called "Thermo Teams"; these teams are primarily used to work problems during class. The active learning exercises of working problems in Thermo Teams constitute approximately half of the class time throughout the semester, and many groups work together inside and outside of class.

The videos chosen by the Thermo Teams covered a range of thermodynamics-related topics; the most popular topics included phase changes and blowing things up. Relating the video to class material solidifies the relevance of thermodynamics to the students. For example, one of the first student-selected videos was a series of clips showing water condensing behind a jet engine (sometimes called a contrail).[11] Concurrently, the students were learning about phase diagrams of pure fluids, especially water. Therefore, at the conclusion of the video, a sketch of a pressure-temperature diagram was placed on the board. The starting condition of the water in the air was labeled (*i.e.*, vapor). The final condition and the independent intensive variable that changed were quickly discussed in teams before the final solutions were sketched on the board (Figure 1). The video and accompanying discussion were a perfect lead-in to the class material for the day.

Using the videos to create quantitative homework problems or open-ended questions (or "Engineering Estimates") is a great way to overcome the perceived irrelevance of textbooks by the technology-centric students. One example video was an at-home experiment performed by two young siblings, estimated to be about 11 and 7 years old.[12] Here, a plate of green-dyed water has a candle sitting in the center. Three

TABLE 1
Outline of the Two Pilots of YouTube Fridays

Pilot	Course (n=number of enrolled students)	Semester	Student-Selected Videos	Written Report	University Course Evaluation	YouTube-Specific Evaluation
1	Introduction to Engineering Thermodynamics (n=40)	Fall 2008	Yes	No	Yes	No
2	Material and Energy Balances (n=55)	Spring 2009	Yes	Yes	Yes	Yes

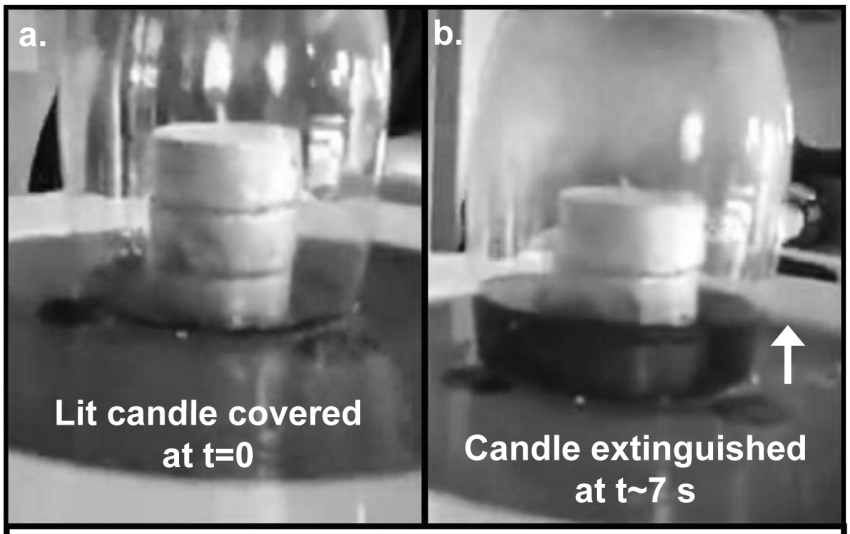
pennies are placed on the plate, the candle is lit (with parental supervision), and a glass cup is placed over the candle. The cup rests on the pennies to allow water to flow in or out of the cup. As the cup was placed over the lit candle, I stopped the video and asked the class what they expected to happen. The overwhelming consensus was that the water level in the cup would rise. The video continued and the class's intuition was proven to be correct. A quantitative engineering estimate problem based on the video (Figure 2) required the students to complete a force balance.

Overall, the first pilot of YouTube Fridays successfully demonstrated a way to engage students of the Net generation. Videos were used to reiterate recent class material, demonstrate the robustness of the first law energy balance, and even introduce the students to advanced topics beyond a sophomore-level first course in thermodynamics. One such topic was the idea of nucleation. The video involves some young people with a clear glass bottle of beer subcooled to a temperature below the freezing point.[13] They show the beer is still liquid and then tap the bottle on a concrete floor to initialize nucleation. The entire bottle of beer freezes in just seconds to the wonder of the people in the video and the class. (I think many of the students attempted this trick the following weekend.)

Pilot 2: YouTube Fridays and Chemical Engineering

Material and Energy Balances is the first core course in the chemical engineering curriculum at Colorado School of Mines. The Spring 2009 class contained 55 students and groups of five were assigned randomly. The formal YouTube Friday assignment was given during the second week of class. Students were asked to select videos related to chemical engineering (jobs, products, benefits of, etc.). In addition to choosing the video and giving a short oral description in class, the students were now required to complete a short written assignment as well. The written document provides an avenue for the students to analyze their chosen video. The objective of the written report was to address one or more of the following questions: How does the video relate to chemical engineering, biochemical engineering, or large-scale chemical production? What is the chemical reaction involved? How is the chemical reaction or product scaled up? What company produces the chemical(s) in the video? Does the video involve a chemical engineering job you would like to have? How does chemical engineering influence our daily activities? The written document needed to be signed by each member of the group. Overall, the quality of writing and depth of thinking demonstrated was better than I had anticipated.

To give the students an idea of the length (less than 5 minutes) and content of the video, I chose a student-created video titled "A World Without Chemical Engineering" for the first Friday of the semester.[14] The various scenes of the video demonstrate that fireworks, gasoline, cars, mass-produced medicines, etc., would not exist without chemical engineers. Based on the example video, the student-selected topics included blowing things up (again), the difficulty of being a chemical engineering student, and the jobs that a chemical engineer might perform. The mix of information on chemical engineering with humor was common throughout the semester. In total, videos created by chemical engineering students were very popular (including those from South Dakota School of Mines and Technology, Brigham Young University, University of Minnesota, the students in the pilot class at Colorado School of Mines, Tufts University, and Northwestern University). Detailed discussions of a few of the videos demonstrated the basic understanding of the field of chemical engineering and provided a first exposure to more advanced topics that will be seen during the final two years of the students' undergraduate education.



c. Engineering Estimate Problem:
http://www.youtube.com/watch?v=OPBO6D5os0w
After watching the YouTube video, what is the pressure drop (atm) in the cup to make the water level rise?

"Answer"
Force balance: $\Delta P=\rho gh$
$\rho=1000$ kg/m^3 (for water)
$g=9.8$ m/s^2 (on earth)
h~1.25 inch=0.032 m (from Google search on tea light dimensions)
ΔP~0.003 atm

Figure 2. *Screenshots of a video made of an at-home experiment (a. and b.) and the course-related problem derived from the video (c.).*

One of the more humorous videos of the semester also proved to be one of the most instructive of the semester. A video titled "CSTR" is a parody of The Village People's "YMCA" complete with costumed performers and chemical engineering-centric lyrics (Figure 3).[1] While the whole class enjoyed the video and likely picked up one or two facts about CSTRs, the five students who selected the video clearly learned even more, as they wrote a detailed report containing information that was not even in the video. First, the group defined "CSTR" as a continuously stirred tank reactor. Obviously CSTR is not part of the texting vernacular. Next, the basic assumptions of perfect mixing, steady state operation, constant density, isothermal, and irreversibility were stated as conditions needed to understand the function of a CSTR. In addition, current course content was reiterated in the students' write-up: "CSTRs have the same mass flow rate in as out, which is important so that the reactor does not overflow." Finally, the students identified Dr. Scott Fogler as the author of *Elements of Chemical Reaction Engineering*, "a book that we use for one of the classes we must take during our curriculum."

Six of the 11 videos focused on education and jobs related to chemical engineering. Having an understanding of mathematics, physics, chemistry, and biology was mentioned in multiple videos as well as several of the written reports. The difficulty of being a chemical engineering student was ubiquitous and one video was quoted as saying half of the students fail "thermo and diffusion." Another common observation was that chemical engineers are problem solvers. The many sub-fields of chemical engineering are mentioned in the videos and by the students. Most prevalent areas of future need for chemical engineers were clean energy, nanotechnology, and biotechnology. The excellent pay of chemical engineers was mentioned as one reward of the difficulty of obtaining a chemical engineering degree. The problem-solving skills of chemical engineers allow them to pursue other fields such as law, management, and entrepreneurial positions. The central themes of a chemical engineering education and the profession of chemical engineering were certainly covered over the course of one semester. The educational value for the students will be discussed in the evaluation section below.

Since chemical engineering is a broad field and the assignment was open-ended, it was not surprising a subset of the videos were related to chemical reactions and physiochemical changes. Two videos were segments from the show *MythBusters* involving the combustion of non-dairy creamer[15] and walking on a corn-starch pool.[16] The corn-starch pool introduced the students to the idea of non-Newtonian fluids and the concept of shear thickening (also covered during the first pilot course). The report on the corn-starch pool discusses applying a force quickly, which causes thickening, vs. slowly, in which one would sink into the fluid—an excellent

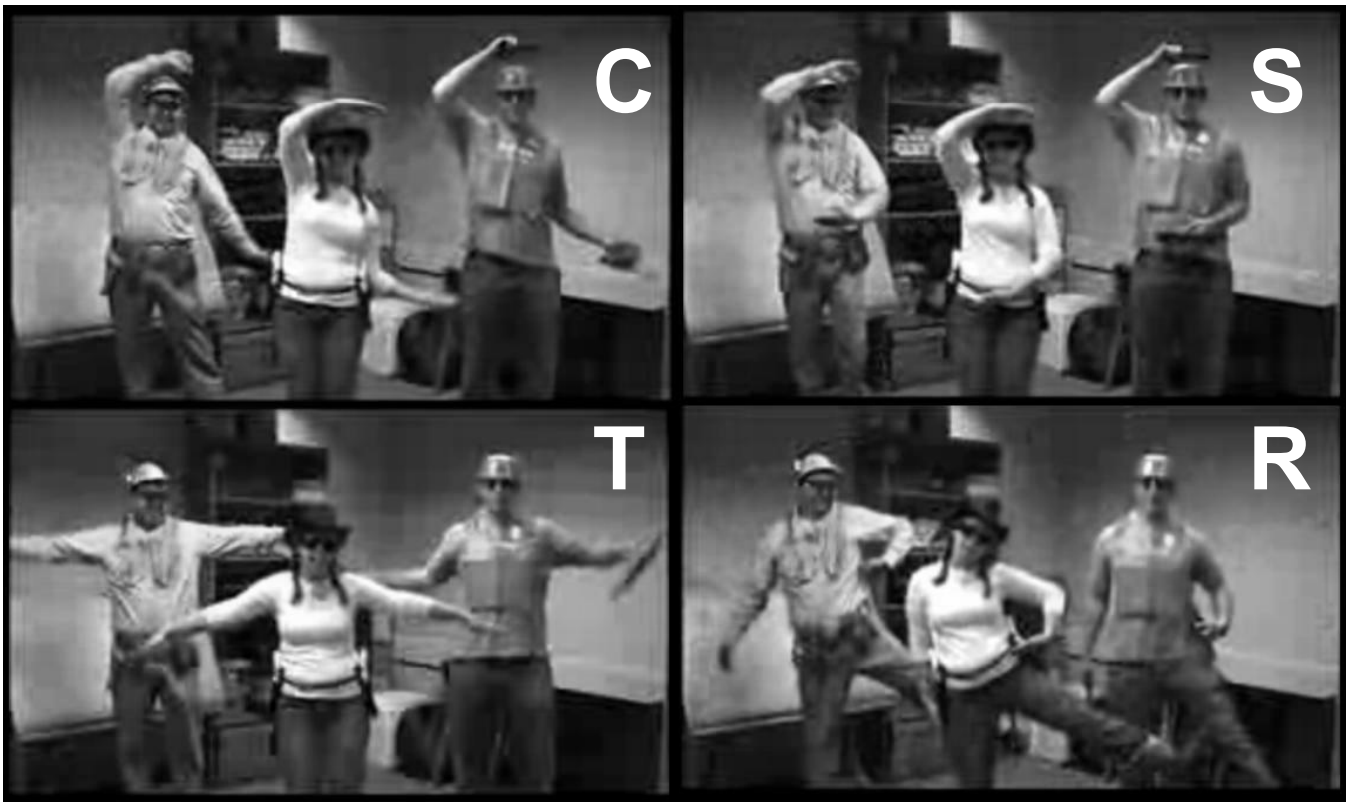


Figure 3. *CSTR hand/body motions (parody of the song "YMCA").[1]*

example of kinetics (another advanced topic covered later in the curriculum) outside of a reaction engineering setting. The concept of kinetics was also prevalent in a video of a recorded lecture contrasting the rate of reaction and the heat of reaction. During the middle of the semester, a group of students in the class took the initiative and made their own video and posted it to YouTube.[17] The enthusiastic group naturally chose to find a chemical reaction that would blow something up. The group mimicked other videos on YouTube by combining toilet bowl cleaner (*i.e.*, concentrated hydrochloric acid) and aluminum foil. The reaction created hydrogen gas. First, a plastic soft drink bottle was destroyed by the reaction in less than a minute. Then, a Nalgene bottle was used as a sealed reactor. The bottle did not explode; the top was simply blown off. The students' report noted the different strengths of two "plastic" bottles and the need for safety measures (venting) when producing aluminum chloride on an industrial scale. Overall, the breadth of chemical engineering was captured in the videos and a significant amount of critical analysis of the videos was included in the written reports.

EVALUATION

The assignments were graded at the conclusion of both pilot courses, and the points were added to the participation/web-based quiz portion of their grade (5% of total grade for the semester). Overall, the selection and discussion of the video contributed between 0.5 and 1% of the semester grade. During the second semester, the grading rubric was broken down into four categories: 1. length and content appropriateness of the video; 2. video provides new and/or interesting information about chemical engineering or being a chemical engineer; 3. length and content appropriateness of the written document; and 4. the written document addresses one of the questions in the assignment or related information. With few exceptions, the students did an excellent job selecting appropriate, interesting, and entertaining videos. In the future, a peer-review component will also be added to the grade. The peer evaluation will hopefully circumvent the problem of just one or two of the students (out of groups of four or five) completing the assignment. I expect more uniform participation throughout the semester with the peer review component making up 20% of the assignment's grade.

After the first pilot, feedback was collected via comments on the back of the university's course evaluations. One student commented that YouTube promoted his learning. The curious statement "YouTube Fridays FTW!" appeared in the written comments on another student's evaluation; as someone with no text-messaging experience, I went to class the day after reading the evaluation (which was from the previous semester) and naively asked the students what the statement meant. A Google search defined FTW as "for the win." The students, after laughing at their professor for a minute, assured me that FTW is a very positive statement, basically saying that YouTube Fridays were great.

In addition to the university's course evaluation, a one-page evaluation of YouTube Fridays was given at the end of the second pilot. The evaluation was completed during class and the students' names were required. The multiple-choice section allowed for four levels of response. Two free-response questions and an area for additional thoughts/questions/comments/concerns completed the evaluation form. The assessment of students' opinions, both positive and negative, will lead to a more student-centered activity in future semesters.

Overall, the students gave YouTube Fridays favorable remarks, which are summarized below. The evaluations should be taken in context. The goal of pilot 2 was to introduce the students to chemical engineering and what chemical engineers do, which was very successful based on the written reports and the data collected from the evaluations. YouTube Fridays were not designed to improve their learning of material and energy balances during pilot 2, which also was corroborated by the evaluations.

Five multiple-choice questions were ranked on a scale of "strongly agree," "agree," "disagree," or "strongly disagree." The questions focused on whether YouTube Fridays promoted learning new things about chemical engineering and jobs for chemical engineers, the effectiveness of videos vs. websites, and the value of the class time throughout the semester. The students' responses are summarized in Table 2. An ~80% posi-

TABLE 2
Students' Percentage Responses to Five Survey Statements at the End of the Second Pilot Course

Statements	Strongly Agree	Agree	Disagree	Strongly Disagree
I have a better understanding of the field of chemical engineering from participating in YouTube Fridays.	11	69	20	0
I know more about the jobs available to chemical engineers from participating in YouTube Fridays.	9	73	18	0
YouTube videos teach me more about chemical engineering than websites about chemical engineering.	7	32	61	0
I think it is valuable to use 5 minutes of class time each week (~3% of total class time) to watch YouTube and not cover class material.	24	56	18	2
I think YouTube Fridays helped me learn the material in ChEN 201 this semester.	0	18	71	11

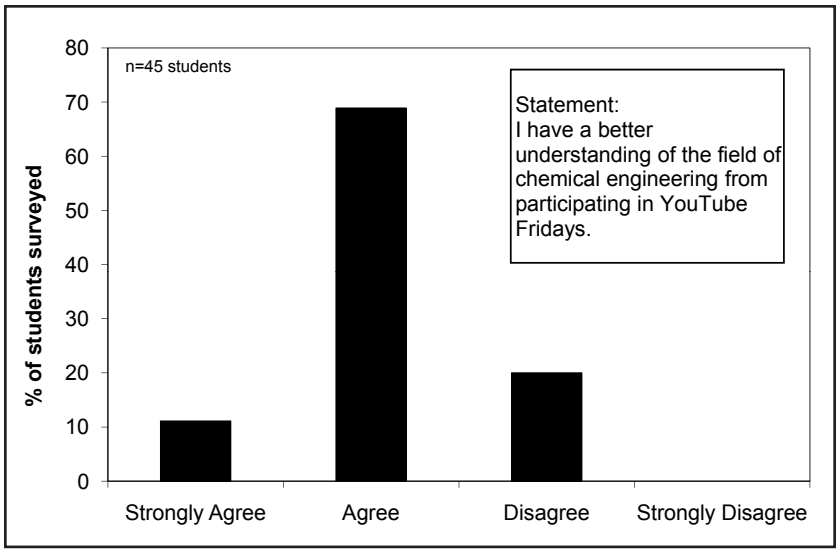


Figure 4. *Sample of the assessment data from Material and Energy Balances course (pilot 2).*

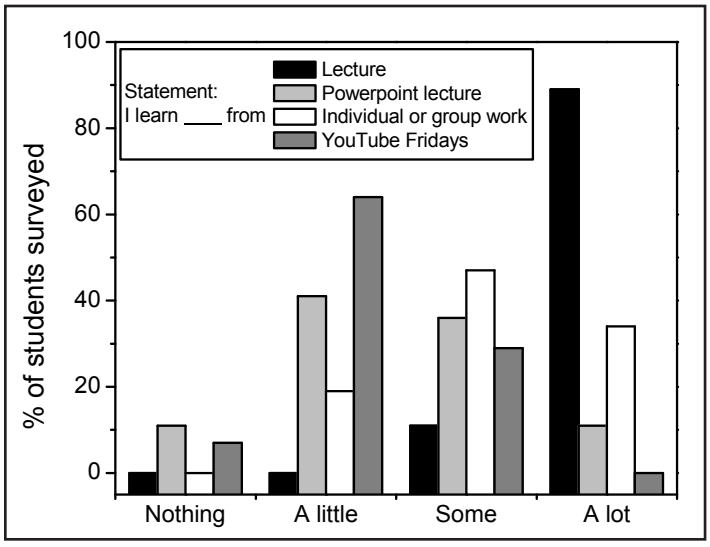


Figure 5. *Evaluation data from Material and Energy Balances course (pilot 2).*

tive response ("agree" or "strongly agree") was reported for learning about chemical engineering, learning about chemical engineering jobs, and using a small fraction of class time for YouTube instead of class material (Figure 4). The students believed, however, that they learn more about chemical engineering from websites (*e.g.*, <aiche.org>, <chemicalengineering.org>) than from watching YouTube videos.

Another set of questions investigated the students' perceived learning from four major classroom teaching styles. The responses to these questions were ranked "nothing," "a little," "some," and "a lot" (Figure 5). All of the students said they learned some or a lot from lecture at the board and ~80% feel they learned some or a lot from individual or group work in class. The efficacy of using PowerPoint slides as a pedagogical method received very mixed response. Finally, 42 out of 45 students stated they learned a little or some from YouTube Fridays. The response of learning "a little" or "some" seems appropriate since the activity only consumes 5 minutes of class time per week.

The final multiple-choice questions asked how many times the student accessed my website to find the videos shown in class. Only eight of the 45 respondents said they visited my website to watch the videos from class again. This response may be deceiving as I have had several inquiries from students about re-watching the videos. The website of the current and past videos will be given on the assignment at the beginning of future terms. The course website (*e.g.*, within Blackboard) will be used instead of the faculty's personal laboratory site.

The free-response questions of the evaluation asked 1) for one fact about chemical engineering the students learned from the video their group selected, and 2) for one other fact the students learned about chemical engineering from YouTube Fridays. A sampling of the responses (Table 3) demonstrates the students' affinity for YouTube Fridays. The most common written comment centered on the diversity of chemical engineering and the jobs chemical engineers do (60% of the class). Other common responses reiterated the exciting future chemical engineers have with the global energy, water, and pollution issues. The extreme difficulty of being a chemical engineering student was also mentioned several times. The need for better sound equipment on which to hear the videos (beyond the laptop's speakers) was also mentioned several times. Overall, the written feedback was overwhelmingly positive toward having YouTube Fridays as a "break" from normal class time.

A few reflections from my perspective will improve the activity in the future. The written assignment needs to state that the video cannot repeat videos on the list from all past semesters, or the content may become stale (as was the case some weeks during pilot 2). YouTube lists related videos right on the screen as you are watching a video. For a small fraction of the videos selected, the video chosen for the subsequent week came from this list. The students of the Net generation, however, seem to pride themselves on originality when selecting videos. In addition, the open-ended nature of the topic each semester may need refining at one or two points during a semester. For example, instead of chemical engineering as the open topic for the entire term, focus on three topics such as chemical engineering jobs at the beginning of the semester, material/mass balances and

reactions in the middle of the term, and energy balances at the end of the semester.

CONCLUDING REMARKS

YouTube Fridays only take a small fraction of class time and are an effective way to engage the Net generation and to expand the content of the course in a dynamic way. The organization and execution of this activity are summarized in Table 4. All of the student selected videos from both pilots are included on the author's faculty webpage.[18] Technology in the classroom will continue to change in the coming years and YouTube will become obsolete. The ability to integrate "new" technology that is readily assimilated by current and future generations, however, is necessary to continually engage the increasingly technology-savvy student.

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TABLE 3
Samples of Written Comments from Students Upon Completion Of Pilot 2

I "heart "YouTube Fridays.
ChemE's make bad "gangster" raps.
YouTube Fridays were very valuable and helped to give a reason for some people to come to class on Fridays.
I've learned that mixing chemicals can cause dangerous explosions.
Good to work in groups so we can meet the other students in our class.
That chemical engineers are able to go into many different fields, and most people don't know what a chemical engineer does on a day-to-day basis.
The whole group summary thing was not really helpful because one person usually did it.
I learned that there are a lot more careers available for chemical engineers than I thought there were.
I learned that chemical engineering is such a broad field (and people often devote their degrees to other work).
MEB (Material and Energy Balances) can be difficult and watching these videos helps to remind us all why we are going through this. It shows our future worth.
More work than it needs to be—very hard to get four people together (when) you don't know/trust (them at first).

TABLE 4
Summary of Implementing YouTube Fridays for a Semester (16-week) Course

Week 1	Show a video appropriate for the topic of the semester, form groups of three or four students, distribute assignment with timeline, expectations, and grading rubric.
Weeks 3-15	Watch videos once per week. Collect written reports.
Weeks 15-16	Grade all videos and reports. Collect student feedback.
Post-Semester	Reflect upon previous semester's activity and plan refinement and improvement of the activity for future semesters.