Teaching the Societal Consequences of Computer Science: New Ideas for Increasing Student Involvement

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ABSTRACT

Almost every university has an upper year course in which students read, discuss and write about the implications for society of advances in computer science. This paper describes our experience updating Waterloo University's version over three offerings of a course that is two decades old. We discovered that students prefer to read material that is current, that overt marking achieves universal participation in discussion and that assignments stressing precise control of short prose improve writing. Most interestingly, we observed students working together to create new ways of learning. These innovations are the result of paying close attention to the strengths, tastes and interests of the students.

CCS CONCEPTS

• **Social and professional topics** → **Computing education**; **Computing education programs**; Codes of ethics;

KEYWORDS

social issues, professional practice, society, ethics, engagment, active learning, class-size, discussion, writing

1 INTRODUCTION

In fewer than seventy years the digital computer has evolved from a laboratory curiosity to an important enabler of technical and social innovation. Students currently graduating from undergraduate computer science (CS) programs will make small and big decisions that determine the shape of tomorrow's society. To help them grasp the consequences of their workplace actions many universities have created upper year courses that examine the impact of widespread computation on society. This paper describes lessons learned while refining such a course, twenty years after its initiation.

Our approach seeks to enable decision making that is technically and socially informed. In forty combined years of experience teaching undergraduate CS the authors have observed the ethical intuitions of most students to be sound, which is to say that, like the average person, they take rights, responsibilities and fairness into account when making social judgements. When their judgements fail, ethics is rarely the problem. Rather, they do not foresee the consequences of possible actions. Thus, in choosing course material and teaching methods we expose students to the ethical, technical and social dimensions of current issues. Doing so, they apply ethical and other social skills to subjects that interest them.

The course has the usual components of active learning—reading, discussion and writing. Allowing the students to choose course topics by voting we found that they prefer to read material that is current, ideally in this week's news. We also innovated to maximize time for in-class discussions and presentations, finding ways to get the entire class participating. Concentrating on the bottom third of the class, we found that unobtrusive but visible marking converted non-discussants into occasional ones, and occasional discussants into habitual ones. Finally, writing is the most difficult problem. We successfully delegated students having problems with grammar to the university writing centre, after which we set goals that emphasized stylistic precision in short writing. We observed improvement in students at all levels of writing.

The next two sections briefly discuss previous work that inspired us and the context in which the course occurred. Then follow three sections that discuss reading, discussion and writing in turn, describing techniques we refined and results in the classroom. The paper closes with a few lessons and suggestions for innovations that might carry on our research.

2 PRIOR RESEARCH

When successful, a social implications course will motivate a lifetime of critical reading, thinking and discussing the impact of present and future technology on our society. We realise, however, that giving a bootstrap from which students can develop is more realistic. To do so we must obtain full engagement of students in the course content.

Thus, taking ethics as an example, we agree with Homkes and Strikwerda [8] that a historical tour of ethical theories is unlikely to benefit our students. Even more, we agree with Pfatteicher [12] that our course should emphasize decision and action over formal framework. We have noticed that our students' ethical intuitions are generally sound, and well-aligned with those of society as a whole. What is missing, as Homkes and Strikwerda point out, is enough knowledge of society and the consequences of technology,

which are strictly unknowable. No course can teach us the ultimate consequences of today's technologies, let alone the future technologies that our students will create and shape.

We thus, in the spirit of Connolly [5], emphasize active learning, teaching students how to reason from decisions to social consequences by asking them to reason about possible consequences of technology in current news. This solves the engagement problem. Our students voluntarily read on-line technology literature; in the course we augment this reading with on-line material that places their reading in the context of present and future society. They engage naturally with topics like self-driving cars or bitcoin. The bootstrap we give them includes tools like critical reading and discussion, not to mention sources of information that discuss the societal implications of technology.

3   THE COURSE ENVIRONMENT

"'Reading maketh a full [hu]man, conference a ready [hu]man, and writing an exact [hu]man.'   –Francis Bacon [1]

Ideally, Social Implications (SI) courses would be unnecessary because society-relevant material would exist in all CS courses, inseparable from technical content [11]. In practice, this is hard to achieve [3, 6]. An SI course economically fills the gap.

We taught three offerings of the course Spring 2014, Spring 2015 and Spring 2017, reworking it each time. This paper primarily describes the final offering, but occasionally aspects of the earlier offerings are described to motivate its evolution. At the outset we set the following goals, based on our prior knowledge of upper-year CS undergraduates.

(1) Most upper-year CS students read technical news and current events daily. We want to widen and deepen their reading and strengthen their ability to interpret it. (Section 4)
(2) Students engage in many meetings, at work and at leisure. We want them to increase the quantity and quality of their contributions to these meetings. (Section 5)
(3) Students write at work and at leisure. We want them to write more easily, stylishly and persuasively. (Section 6)

The details of our class activities are determined by these goals.

In our SI courses, the students were similar to those in other fourth year courses, with a somewhat higher proportion of females, but still a minority (18% in our 2015 offering and 21% in 2017). Most students were in co-op programs. Such students have extensive inside knowledge of industries that employ computer scientists; they have participated in making technical and business decisions, not to mention having observed unattractive sexual politics. The innovations described here owe much to student input.

Our students' experience may sound unusual, but is increasingly common as universities offer programs that combine CS with an area of application. Many newly-designed programs like data science, bioinformatics and computer gaming, require students to take SI courses. At the same time, co-op terms and internships are increasing in CS undergraduate programs. Thus, our particular student mix is likely to be common in years to come.
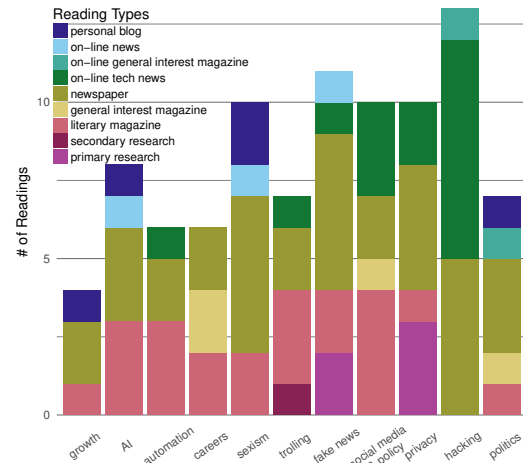

Figure 1: Provenance of the readings for each topic.

4   READING

On-line reading provides the content for discussion and writing. The usual source of reading for SI courses is a collection of essays, either a textbook or course notes. Textbooks for engineering ethics courses are available [7]; course notes can be created. Both have a relatively long lead-time. A more immediate source is on-line material, which can be made available in hours.

Unread readings are useless. To discover the topics students wanted to read we organized the readings of the first two offerings into twenty topics sized for one topic a week. Then in the first week we asked students to examine the readings for each topic and tell us their preferences. Topics offered and chosen can be reviewed on the websites for the 2014 and 2015 offerings [2]. The topics chosen were concrete and in the news, such as social media and career, or current, such as privacy & security in 2014 (Edward Snowden) and bad guys in 2015 (corporate misbehaviour). Abstract topics, such as libertarianism or government regulation were rejected. We thus incorporated the important readings from abstract topics into the context of the concrete topics chosen by students. Under these conditions students eagerly accepted the readings.

Relevance of technology changes rapidly: in 2015 the negative effect of social media on mental health was news; in 2017 it was still true, but no longer news. In 2017, confident that we understood the students' tastes, we chose the topics ourselves. The most engaging topics, as measured by participation scores were trolling, privacy and politics (Figure 2). All had been in the news within the preceding few months; two of them, trolling and politics, were new in the 2017 offering.

The main sources of news and analysis articles were:

- recognized on-line sources, such as *Ars Technica* and *Bloomberg*,
- the web sites of established newspapers, such as *The New York Times* and *The Guardian*,
- the web sites of literary journals such as the *New Yorker* and the *London Review of Books*, and
- the web sites of general interest magazines, such as *The Atlantic* and *The New Republic*

Other sources of articles were research journals and blogs.

Table 1: Primary articles for the 2017 offering for each of the 11 topics, ordered by week as in Figure 1. The proportion of the primary article in the week's reading is also shown.

Primary Article Link	Source	%
Why Growth Will Fall	New York Review of Books	35
A.I. Versus M.D.	The New Yorker	40
Secret Lives of Content Raters	Ars Technica	34
The Economics of Luck	Bloomberg	11
Reflecting on...	Personal Blog	16
Schadenfreude	London Review of Book	36
B.S. on Big Data	The New Yorker	33
Uses and Gratifications	UbiComp paper	33
They Know	New York Review of Books	22
Why hack?	$n + 1$ mag	10
War Goes Viral	The Atlantic	50

Figure 2: Raw participation mark by topic

Figure 1 shows the provenance of the 100 readings from 2017, which were spread over eleven topics. In total they comprised 138,124 words, the equivalent of a significant book. We chose them from almost a thousand on-line articles. At normal reading speed it should take a student about sixty minutes to read everything for a given week, and we expected students to read everything twice.

Each set of readings has a primary article, usually giving an in-depth analysis of the societal relevance of the topic, either a long form article from a magazine or newspaper or a research article. Table 1 gives links to the primary analysis article for each topic in 2017.

Frequent mention of articles in the discussion indicated that the average student read most of the readings. Further evidence that students were engaged by the readings came from student suggestions of articles to be added to the reading lists. Finally, in seeding the discussion the instructor described news from the previous week that bore on the topic, such as Travis Kalanick resigning as CEO of Uber the week before we discussed sexism in 2017 or the Supreme Court of Canada handing down an important decision extending privacy rights in the week we discussed privacy in 2014. The ease of finding such examples indicated the currency of the readings.

The biggest challenge in reading is finding material that will be read eagerly, meaning relevant to students' personal and professional lives, similar in fact to what they read habitually. Naturally, we chose readings from sources beyond the limits of usual undergrad reading, hoping to introduce students to sources they would continue to read.

5 DISCUSSING

Because students learn to discuss by discussing we give it as much time as possible: three lectures are given at the beginning of term, to organize the course and overview its day-to-day procedure. These lectures are insufficient for communicating course expectations fully, so detailed instructions are given on a publicly available website [2]. In organizing discussion, we are faced with two problems. First, the students who discuss most eagerly are those who need
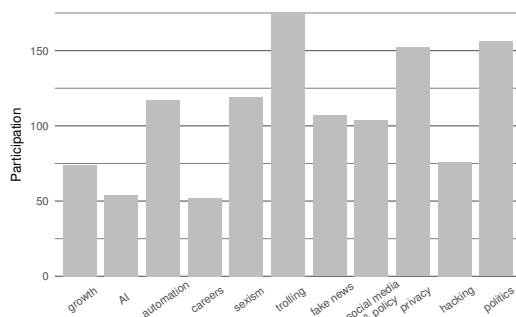
practice the least. Second, fifty students is too many for general discussion.

Our solution to the latter divides the class in half. One half meets on Monday, the other on Wednesday, giving two *small group* discussions. (The whole class attends the Friday lecture for a student-led discussion described below.) Eye contact is essential for effective discussion: from instructor to student and among students [14]. Our room is set up for lectures, so room arrangement is a problem. Fortunately, with the instructor placed on a side wall a small rearrangement of chairs gives universal eye contact with minimal contortion.

The instructor is a facilitator, seeding the discussion with an item from the week's news that bears on the topic. The instructor also occasionally intervenes to point out an alternative interpretation or to steer the discussion towards points of view that would otherwise be missed.

Maintaining eye contact with the speaker is incompatible with giving accurate participation marks. Consequently, a TA records participation marks sitting beside the instructor, so that students observe the evidence of marking. Marking discriminated the quality of contributions, based on new material, a new viewpoint or a new association. Outside class several students told the TA that they noticed the extra writing that accompanied a good comment. It did not surprise us that reticent students often provided quality comments in their infrequent participation.

That some students participate in discussion because marks are offered is unattractive, yet mark-motivated participation is better than no participation. Some students are speaking in class for the first time. For encouragement we remind them that logarithmic curving gives more marks for the first few contributions. We also set aside five minutes toward the end of most classes for students who have not yet participated. (This period is less needed as the term goes on.) Many students who started by discussing for marks later developed real enthusiasm, which vindicates our approach.

Students speaking in class inevitably seek the instructor's approval, unconsciously assessing the instructor's bias [13]. The instructor thus discussed bias explicitly, explaining that an SI course may seem negative because it assesses technology critically. This explanation helped students to move comfortably between arguments for and against technical novelty.

Given the variable social skills of students entering the course, equal participation is an unrealistic expectation. Universal participation is, however, possible to achieve: in the 2017 offering only one student failed to participate at all; that student missed many

Table 2: Raw discussion marks by rank in participation.

ACTIVITY & PARTICIPATION RANK	2015	2017
Small group: top third	52%	58%
Small group: middle third	29%	33%
Small group: bottom third	18%	9%
RPE: top third	56%	74%
RPE: middle third	33%	25%
RPE: bottom third	10%	1%

classes, and was unique in doing so. For judging equality of participation the raw participation marks are a rough proxy for the number and quality of contributions. The top half of Table 2 shows the participation marks for the small group discussions. The two offerings are very similar, more than half the participation from the top third of the class, one third from the middle third and less than one sixth from the bottom third. Participation is more uniform than in lecture-dominated courses, and less uniform than anonymous response using clickers. Digital mediation and anonymity are, however, contrary to our goal of encouraging students to associate themselves with their opinions.

Small group discussions occupied two-thirds of our classroom time. The remainder was occupied by modified role-playing exercises (RPEs). In business training, where they originated, an RPE has a few participants who play well-defined roles. A coach detects mistakes and gives advice, like the director of a play. In academia, they are common in small group learning, but generalize poorly to normal class sizes. Howes and Cruz [9], for example, describe an RPE where all but five of a class of 25 are passive onlookers. Our goal is general participation in a class of 50.

In our course the purpose of an RPE is two-fold. CS programs offer few opportunities for students to read novels or otherwise analyse the perspective of others. Playing a role forces them to do so. Second, leading discussions is as important a practical skill as participating in them. The following procedure obtains these ends.

(1) For each RPE the instructor provides a situation related to the topic of the week along with two or more complementary roles that might occur in the situation. (These descriptions are available on the course website [2].)
(2) Each role is assigned to a team of two or three students which does research to fill it out.
(3) In class, each team in the week's RPE explains its point of view to the other students.
(4) The teams together then lead a general discussion of the situation.

Simple in theory, this procedure easily misfires. For example, in our first two offerings some teams debated with each other ignoring the class, and others had a question and answer session with the class.

Preparing for the 2017 offering we wondered how to involve all 50 students. We thus reframed the RPE away from presentation to the class and towards participation of the entire class. We suggested that the teams do joint planning, and encouraged a playful atmosphere by giving bonus marks for groups that came in costume. We gave few suggestions as to how these goals might be achieved,
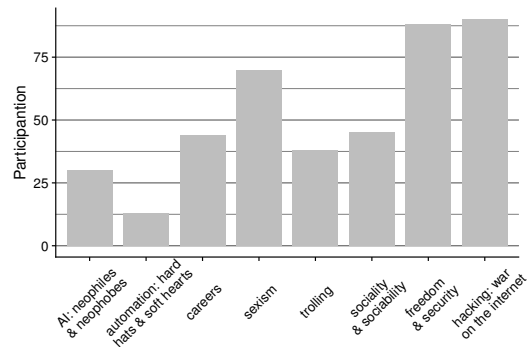
Figure 3: Raw role-playing discussion mark by topic. There were no RPEs for the first and last topics, growth & politics.

hoping to observe creative solutions. As a practical reminder of the emphasis on general participation, a TA at the front of the class recorded participation.

The success of our intervention became evident in the fourth week. The topic was sexism. The situation was a CS camp for secondary school girls organized by professors and TAs: parents had complained that the camp was misleading their daughters by ignoring sexism in the programming workplace. The two roles were organizers who thought the complaint was justified, and others who did not. On their own the role-players found a role for the audience, parents at a meeting called to discuss the matter. They came to class with a description of a daughter for each table. After giving reasons for and against the complaint, the groups distributed the descriptions and asked the students at each table to confer for a few minutes, thinking about what they would want for their daughter. The discussion was lively and general. The remaining groups imitated this innovation, with the class incarnated as users of social media, users of trolled chat-rooms, citizens choosing between safety and freedom, and representatives of G-20 countries meeting to limit collateral damage from cyberwar.

Our measure of participation (Figure 3) roughly doubles at the fourth week and stays relatively high to the end of the term (The average of weeks 1-3 is 29; the average of weeks 4-8 is 66). Comparing these numbers to average small group participation (~90 per topic from Figure 2) we see that the best we obtain from 50 students is comparable to the average we obtain from 25. Taking the overhead of an RPE into account this result is impressive. However, drilling down in Table 2, we see that RPE participation in 2017 is anomalously dominated by high participation students. Most likely this result is an artefact: our marking did not capture intra-table discussion, after which stronger discussants spoke on behalf of whole tables.

Gender balance is always important when the classroom is dominated by a single sex, as ours is by men. We broke down the raw participation score by gender for 2017, when the class was 21% female. Per capita, women outcontributed men by 30 to 24 during small group discussion, and by 12.1 to 8.3 during RPE discussion. Thus, although females are usually underrepresented in CS classrooms, their level of engagement in our course indicates that we succeeded in creating an inclusive and unthreatening environment.
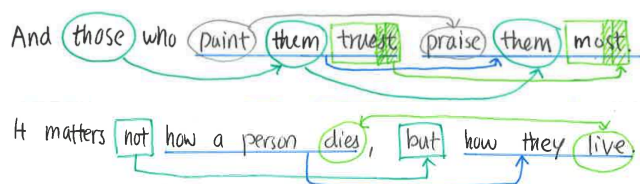
Figure 4: Two diagrammed tweets from a time machine.

Let us close with two philosophical remarks. First, this innovation highlights a dilemma: should one add the innovation to the course, imposing it on the students in following terms? Or should future students have the opportunity to innovate on their own? Second, in a discussion class, students observe other students succeeding and failing. Doing so they see object lessons of what to do and not do, and learn by modeling. By the amount that a big class lowers practice time it increases the time for learning by modeling.

Working on improving participation in discussion we discovered two important techniques. Evidence of grading improves the participation level of less socially-gifted students. In addition, students innovated in their RPEs, finding a role for the audience that greatly lifted the level of discussion.

6 WRITING

The assignments we inherited required students to write many thousand words spread across four essays. To maximize discussion we did not teach writing in class, but supplied web pages on various aspects of writing well, hoping to see a result when grading, which consisted of copy-editing, a lot of work but worthwhile if the student attends to it. The results disappointed us: few students read the feedback conscientiously. We concluded that copy-editing essays was not a good use of our time and that we needed to rethink the writing assignments from scratch.

In 2017 we reconsidered the day-to-day writing of students. Two facts stood out. First, in industry and business, concise writing is expected; students, for example, are taught to write one page resumes. Second, their non-curricular writing is short and informal, following the global trend toward shorter and more frequent writing, with Snapchat superseding e-mail and twitter superseding blogging.

We also rethought our strategy for providing advice about writing. Too much of our advice was negative, pointing out what to avoid. But avoiding bad habits is harder than practising good ones [15]. Thus, advice on writing should be positive. It should show students how to do things and to give them practice doing them. Finally we wanted to emphasize the importance of rereading and revising.

In the end we kept two essay assignments and created two new assignments. As in 2015, the first essay had been diagnostic, writing a 300-word summary of a longer essay about luxuries becoming necessities. As an object lesson in reading we discussed the essay in class. Still we received some ungrammatical and/or incoherent essays. In 2015, we let poor marks speak for themselves; in 2017 we told students to contact the TA, who sent them to the university writing centre. The result was a success; more students stayed in the course doing the following assignments at a higher level. Early, unequivocal diagnosis worked.

For the two new assignments we picked two features of stylish writing: the narrative arc, and parallel structure. Each assignment had two parts. In the narrative arc assignment students read several short passages and detected the narrative arc in each; they then wrote a story in the form of twenty TEXTs exchanged among two or more messagers. The story's subject was to be taken from course content and each TEXT plus the story as a whole was to have a well-defined narrative arc. We stressed that getting a good narrative arc requires careful attention to every word and that they should expect to spend much more time editing their work than writing it.

For parallel structures, seeking current content we asked students to study a selection of recent tweets from a prominent tweeter. Seeing the assignment female students asked us to change the assignment, saying that they were uncomfortable with the endemic sexism on Twitter. What a blunder! Rethinking the assignment we noticed that many widely shared tweets resemble aphorisms, pithy sayings with strong parallel structure and a narrative twist. In the writing of aphorists like Addison, Johnson, Swift and their contemporaries we found many excellent tweets, calling them 'Tweets from a time machine'. Each student diagrammed ten historic tweets, marking parallel features of grammar, vocabulary, rhythm and sound, as shown in Figure 4. They then wrote five tweets expressing course content and using parallel structures.

Students diagrammed with evident enthusiasm, often diagramming their own tweets as well as the supplied ones. Their work shows that they understand how parallel structures work in short passages, assuring us that they will recognize parallel structures when reading, which is the first step to using them while writing. The tweets, twelve of which are reproduced below, often reached the level of aphorism, commenting with wit on course topics. Their attention to sound and rhythm shows that students edited carefully, thinking of every word.
(Tweets marked * are by students who finished in the bottom half of the class, demonstrating that the lesson reached weaker students.)

*"There is no difference between trolling as a joke
and trolling as a jerk."*

*"He says that he can imagine being in her shoes,
but he can't understand why she has more than one pair."*

*"Progress for its own sake benefits few;
progress for the greater good benefits everyone."*

"Finding wisdom on twitter is like finding a gem in glitter."

*"Our profiles show more character than our actions do."**

*"Social media provides us with a tool to connect, and audience to
engage, and a profile to impersonate."*

*"I'd like to make a Facebook account. All I need to give is my name,
email, birthday, privacy and sense of self-worth."*

*"Ten years ago I was told don't use your real name,
don't share personal pictures, don't chat with strangers.
And we have Facebook, Instagram, Tinder."**

*"A diverse workforce creates diverse ideas."**

*"Status updated, pictures posted, messages messaged, snaps sent.
Does this mean we are more social or less?"*

"The desire to be entertained brings forth news that does not inform and social media that does not socialize."

"I feel scared if there is an AI who can pass the Turing Test, I feel more scared if there is an AI that chooses not to pass the Turing Test."*

With respect to writing, we innovated by asking students to write short pieces of prose where every word counts and received carefully-edited writing showing attention to word choice, rhythm and sound. Whether we like it or not, short writing is the future, and we are happy to see student work that is sensitive to its nuances. Not surprisingly, the average assignment mark was higher in 2017 than it was in 2015, rising from 70% to 76%.

7 LESSONS LEARNED

Sections 4, 5 and 6 above dealt separately with the three primary aspects of the class: reading, discussing and writing, describing individually the methodology, results and discussion of each. This section summarizes those observations. While they were learned teaching an SI course to upper-year students at a research university they may well be applicable to other courses in other types of university or college.

(1) CS students are interested in the content suggested for SP courses in the ACM model curriculum [10], but want to see it in the context of current topics relevant to themselves. Successful topics are today's technical news.
(2) CS students are creative, showing it when a task describes goals without specifying methods.
(3) CS students want to join discussions, but many need help overcoming shyness. Overt assessment of participation is a powerful stimulus for them.
(4) CS students get better practice writing when they write short [4]. Doing so they can economically master elements of style that are otherwise hard to teach.

Student response to our offerings was unusually good. All three offerings received spontaneous general applause from the class at the end of the final in-class session, which is unusual in the authors' experience. The RPEs with small group interaction produced similar applause.

8 FUTURE EVOLUTION

An unimprovable course is rare: most courses evolve, with each instructor modifying the course to suit their own teaching style, a process punctuated by course re-designs. Whether or not innovations persist depends on the vagaries of teaching assignments and on the tastes of future instructors.

Teaching this course in the future we would continue to keep the news readings current. Students' memories are short: none remember MySpace (although some have read about it), and Facebook is increasingly seen as old hat. From term to term we retain only a two or three background/analysis articles, replacing almost all the rest. Keeping readings current is time consuming: many articles are read and discarded for each that is used. We would weight more heavily participation mentioning reading material, and record it to improve our understanding of students' reading preferences. We desire to extend the distributed discussion techniques used by students in the 2017 RPEs, trying to capture small group participation. We are pleased with the writing assignments in 2017 and might try shorter writing in place of the second essay assignment.

In addition to improving the course we would like to quantify our measurements of student response more precisely. Taking a pre-survey of student expectations and comparing it to a post-survey of student attitudes is one way of doing so. We could also ask the TA to make free-form notes about class atmosphere. Even that, however, risks damaging the informal relaxed atmosphere that encourages timid students to contribute to the class.

Over three offerings we have made progress in finding content that is challenging, educational and read by the students, in managing discussion that is as equitable as possible, and in teaching writing so that students at a variety of entry levels improve in style and expressive power. Our primary message is that students know themselves, what their interests are, what they will and will not do, and even how teaching can be improved. To be sure, instructors know better what is out there to learn and how it might be taught but students know what engages students. We can force students to sit in a classroom, but we cannot force them to learn. (Note the parallel structure.)

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