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Integrating Philosophy, Cognitive Science, and Computational Methods at a Polytechnic Institution: Experiences of Interdisciplinary Course Designs for Critical Thinking

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Introduction

The pilot run for the interdisciplinary course, HUM 207: Informed Decision Making for Technical and Medical Professionals (IDM), debuted in the summer of 2013 at Oregon Institute of Technology (also known as Oregon Tech). The purpose of the course was to introduce students with engineering, medical technology, computing technology, and management backgrounds to the concepts, techniques, knowledge, and perspectives that diverse fields of study (such as classical literature, mathematics, and cognitive psychology) can contribute to their technical careers and to their lives as informed citizens.[1]

The design of the course drew on the instructor's prior teaching experiences of a number of general-education courses at a sister institution in the Oregon state system, principally drawing from a standard critical-thinking course described below in the section "Course Design and History."

The pilot course has led to a very closely related new course, HUM 207h: Science, Medicine, and Reason (SMR), designed by the author with the help of a faculty member in the humanities. The new course, to be taught spring quarter, 2014, is also the first course at Oregon Institute of Technology to be scheduled specifically for the institution's new Honors Program.

The Honors course features a stronger focus on philosophy of science in lieu of the attempt to incorporate the classics into the coursework. The reasons for this and the avenues considered for re-integrating the classics in future courses are discussed below.

For convenience, henceforth the two courses will be referred to as "the pilot course" and "the Honors course" referring to HUM 207: Informed Decision Making (IDM) and HUM 207h: Science, Medicine and Reason (SMR), respectively.

This is an exploratory paper about the two courses (and plans for additional future courses), detailing the experiences of students and the instructor in the pilot (IDM) as well as the design and the plan of assessment of the resulting new course (SMR). In the process, we examine the need for and some challenges in integrating liberal education into engineering, technology, IT, and management curricula, along with the role of the humanities, social sciences, and communication in engineering education as the means for deepening students' undergraduate experiences.

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1 Although the course has a Humanities prefix, it involves almost equal parts psychology, philosophy, and mathematics.

Literature Review

Introduction

There has been much thought given to the role, the importance, and the state of the Humanities and the Social Sciences within education in general, and even engineering education in particular, as evidenced by the variety of books, journal articles, blog posts, and conference papers on the topic. A review of the literature, then, will help place the present paper in its historical, intellectual, and international context. This review will address first the need for the Humanities and the Social Sciences (to be abbreviated "HSS" below), and then the implementation and integration of HSS[2] within engineering curricula.

The Need for Humanities and Social Sciences in Engineering

The need for meaningful and coherent HSS integration within engineering education[3] falls into two categories: The professional value of HSS to engineers, and the societal value of HSS to all citizens, of whom engineers, or at least many engineering-trained individuals, constitute an influential portion.

The direct value of HSS education and exposure to careers in engineering has been articulated by the National Research Council in 1985 [1], Johnston, Jr., Shaman, and Zemsky in their book *Unfinished Design: The Humanities and Social Sciences in Undergraduate Engineering Education* in 1988 [2], Blewett in 1993 [3], Arms in 1994 [4], Rugarcia, Felder, Woods, and Stice in 2000 [5], Lee in 2002 [6], Splitt in 2003 [7], Felder and Brent indirectly in 2003 [8], Rojter in 2004 [9], Yang, Gao, and Chen in 2009 [10], Albert in 2011 [11], by Mitra, Raj and Agrawal in 2013 [12], and, most recently, again in 2013 in the TUEE Pre-Workshop Summary [13].

In its 1985 report called "Engineering Education and Practice in the United States: Foundations of our Techno-Economic Future Committee on the Education and Utilization of the Engineer" (as summarized in the appendix to [1]), The National Research Council states that "[i]f US engineers are to be adequately prepared to meet future technological and competitive challenges, … the curriculum must be expanded to include greater exposure to a variety of non-technical subjects (humanities, economics, sociology) …" [1, p. 145]

With a more specific reasoning, Johnston, Jr., Shaman, and Zemsky argue that "[a] strong liberal education … promotes qualities—a breadth of curiosity, reference, and understanding; flexibility; critical thinking; an ability to learn—that serve one well in any career" [2, pp. 7–8]

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2 Some of the literature refers to "liberal education," "liberal arts," or "general education" in the context of engineering education to imply the same content as the Humanities and Social Sciences. Hence, all three of these expressions are here considered equivalent for the purpose of the present discussion.

3 Since various forms of the expression "HSS within engineering education" also will be used many times in this paper, those will be abbreviated to HSSEE when convenient.

and that specifically, “liberal learning helps develop decision making and other skills needed for good engineering design” [2, p. 8]. Further relevance of HSS to engineering careers and education are explored with regards to “intuition and creativity,” “how specifications are to be written,” “clear, persuasive communication,” “professional growth,” and the confronting of the ethical, political, and social dimensions of engineering problems [2, p. 8].

Blewett discusses the need for HSS pragmatically in that it is a requirement of engineering curricula both due to ABET and due to “sound educational theory” [3, p. 175] while Arms [4] affirms the role of HSS in the making of a good engineering career through the words of “Ernest Boyer, president of the Carnegie Foundation for the Advancement of Teaching” [4, p. 142], emphasizing how engineering education can enable students “to weigh alternatives and reflect upon meanings,” a skill he argues engineers need in the corporate environment, and again on p. 145 in the critical role of the Humanities in team work.

In a thorough and well-argued discussion presenting the benefits of HSS [5], Rugarcia et al. present engineering skills as falling into seven categories that map onto the ABET (a)–(k) outcomes. Among these is the skill set comprising “[p]roblem solving, critical thinking and creativity (EC 2000 Criteria a–c, e, and k)” the possession of which skills is evidenced when students can “draw upon a wide range of analytical, synthetic, and evaluative thinking tools, problem-solving heuristics, and decision-making approaches” [5, p. 17] as well as “identify main ideas, underlying assumptions, and logical fallacies, and evaluate the credibility of the identified sources; … draw sound inferences [and] develop cogent arguments …” (Ibid.) which together constitute the definition of critical thinking as addressed in the courses that are the subject of the present paper. These authors also present greater than typical depth in their justification of the teamwork aspect of the ABET criteria: “The skills associated with successful teamwork—listening, understanding others’ viewpoints, leading without dominating, delegating and accepting responsibility, and dealing with the interpersonal conflicts that inevitably arise—may be more vital to the success of a project than technical expertise” [5, p. 18]. Whether these are *more* important than technical expertise may be debated—the best approach to teamwork may not solve the problem if no one on the team has the requisite knowledge and experience—but perhaps the two can be seen on an equal footing as necessary-but-not-sufficient conditions for successful engineering design.

Lee, in a paper presented at the ASEE Southeast Section Conference in 2002 [6], pulls no punches when it comes to stating the role of an understanding of philosophy of science in battling junk science, or fraud, as part of engineers’ responsibility to society. He also places this understanding in the context of ABET criterion (b), “an ability to design and conduct experiments, analyze and interpret data” [6, p. 2], in that such ability is part of the scientific method, which has its foundations in the philosophy of science, and which together also constitute one of the primary components of the course design for IDM and SMR.

Splitt [7] interprets the demand on engineers as the “solution of problems involving human values, attitudes, and behavior, as well as the interrelationships and dynamics of social, political, environmental, and economic systems on a global basis” [7, p. 182], restated in the conclusion in terms of “problems involving … world cultures, religions, ethics, and economics” and “unforeseen questions” [7, p. 185].

Felder and Brent, address the role of HSSEE indirectly in the connection between critical thinking and problem solving [8, p. 15, Section V, Part B, items 3 & 4] through a discussion of problem-based learning (PBL).

On the practice of engineering and of engineering education, and the role of HSS in both in Australia, Rojter states that "engineering graduates lacked cultural awareness and diversity needed for an effective engineering practice" [9, p. 2], that the social aspect of engineering is the reality of engineering workplaces, and that an increased role for HSS in engineering curricula has been recognized as the requisite step. He echoes the widely argued position that HSS as part of the curriculum "provides professional engineers with means of … critical thinking and inquiry" [9, p. 2] and that Humanities graduates typically had highly developed divergent thinking skills lacking in most engineering graduates. In particular, Rojter highlights History as being "relevant to workplace discourses" because "History expands cultural references and enhances the understanding of human condition (sic) in the context of development of ideas" which may "[e]nsure that engineering graduates will not go through a process of 're-inventing the wheel'" [9, p. 3].

Yang, Gao, and Chen argue [10], albeit in only a partially substantiated manner[4], that exposure to the Humanities add to an engineering graduate's perceived value in the workplace: "Those students who received humanities education tend to have better performance" in the workplace, based on pre-and-post surveys given to employers of graduates.

In a recent blog post for *Science* [11] on the reasons to include the Humanities in career preparation, and even though writing about science careers, not engineering, Albert brings forth ten enumerated reasons, many of which are relevant to engineering practice as well. Reason 2 is that "[s]tudying the humanities allows you to become familiar with and use the creative ideas from great minds outside of science. As a poignant example in support of this argument, consider the application of art-inspired mathematics to the applied chemistry of an oil-spill clean-up, presented at the *Bridges 2012: Mathematics, Music, Art, Architecture, Culture* conference: "Crystallizing Topology in Molecular Visualizations [14].

Similarly applicable to engineering careers, Albert's reason 3 is that "the preparation for a scientific career one receives in graduate school leaves the individual competitive for a [brief] period only" and that "[t]he study of humanities … rewards the student with the skills needed for self-critical reflection, adaptability, and self-teaching … needed to be an independent learner" [11]. Reason 4 is teamwork and communication. Reasons 8 and 10 link science and technology, along with another component of the SMR course that has not received much attention in the present paper thus far: Medicine. Albert points out that "Humanities study helps you understand the impact that science, technology, and medicine has had on society" and that "[s]cience,

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[4] The surveys were given in 2003 and 2004 to the employers of graduates of one engineering school. No analysis of statistical power or significance was reported in the paper. Still, this paper is included in this literature review because it shows that the issue of HSS integration is on the table in Chinese engineering education.

technology and medicine—far from being value-neutral—are the embodiment of values in theories, things and therapies, in facts and artifacts, in procedures and programs." [11]

Mitra, Raj and Agrawal, from the Department of Computer Science and the Department of Electrical and Electronics Engineering at the Birla Institute of Technology and Science in India, approach the role of HSS in technological education from a refreshingly different point of view [12]. They indicate that the "soft" disciplines are not soft in the sense of "easy," but in the sense of greater complexity. Having "as many sound [interpretations] as there are serious readers" is the complexity of so-called softness in the Humanities, and this complexity is what helps encourage critical and creative thinking [12, p. 392]. The authors go further to caution that HSS in technical education ought not be "considered as disciplines of relaxation" (Ibid.—an oddly oxymoronic turn of phrase that makes a good point), or as a form of entertainment, as many music courses, for example, may be viewed as by students and by engineering faculty. On the contrary, HSS must be "integrated in the curriculum as branches with all the weight that other subjects have" (Ibid.). The justification for this claim is that although it is "possible to profit from technology without understanding anything about it [just as] it is quite possible to live a life without any real understanding" (Ibid.), and while we can survive as human beings in either case, the former is not a characteristic acceptable in an engineer, just as the latter is not a characteristic of an educated human being. The key point here, stated more explicitly in a number of other articles quoted in this paper, is that engineers are human beings, and that the study of the Humanities reminds us of this fact, the practical consequence of which is that we do not "confound" (Ibid.) our disciplinary activities, our contributions to technology, with the whole of what matters to human society (and beyond).

Most recently, the TUEE: Transforming Undergraduate Education in Engineering Phase 1 Workshop Report indirectly states the need for HSSEE in terms of the industry's perspective on what is lacking in today's engineering graduates: "an international and global perspective," along with "decision-making [and] communication" (among other skills). [13, p. 4] This observation ties in strongly with Mitra et al.'s interpretation that engineering graduates need a broader perspective of the role they and their activities play in the world at large.

In addition to the practical purpose of strengthening our graduates' engineering careers, the literature also has much to say about the role of engineers in society, and the societal value of HSS in preparing engineering graduates (who may function as engineers, managers, entrepreneurs, lawmakers, etc.) for that role. "The liberal arts help equip us for citizenship," states *Unfinished Design* [2, p. 7]. "They can sharpen our critical powers and help us examine our preconceptions." (Ibid.) Arms writes about "the development of the student as a person" [4, p. 141], and emphasizes Drexel's E^4 program's selection of "[m]eritorious texts … to highlight humanistic concerns about the impact of technology so that students recognize the engineers' obligation to the world we all share." [4, p. 144].

Lee's discussion of the role of HSS in equipping engineering graduates with the mental tools to protect society against junk science is at the heart of the course design for IDM and SMR, as it formed the core of the course cluster that inspired it. Engineers, Lee states, "must be able to make decisions related to a wide variety of issues that involve qualitative areas such as politics [as well as] health care, environmental issues, and technology" [6, p. 1]. Some examples of the types of decisions related to health care, environmental issues, and technology, in which junk science and pseudoscience have a strong foothold, are homeopathy, anthropogenic-climate-change denial, and cell-phone cancer, respectively. (In this list, I included both junk science and pseudoscience.) Lee quotes various authors in explaining what junk science is and what is wrong with it: It is a form of "fraud … used to advance a special interest" [6, p. 2]; it can be deadly (Ibid.); and engineers, as valued participants in debates related to science and pseudoscience, "must protect or at least warn society against adverse developments" [6, p. 2] such as the types of pseudoscience promoted by the anti-vaccination movement, quantum healing, and the like.

There are further parallels between Lee's research and the IDM and SMR courses. The familiarity section of Lee's survey has almost all elements in common with the course content, including "inductive method, deductive method, empiricism, David Hume, … Karl Popper, … Thomas Kuhn, … [and] confidence interval" [6, p. 3]. Similarly, the opinion section of the survey involves the concepts of reality, truth, and fact (corresponding to week one of the course syllabi) as well as "logical reasoning, scientific method, theories of knowledge acquisition, … [and] statistical analysis" [6, p. 3]. Lee's findings show statistically significantly lower self-reported familiarity among engineering students with almost all of these concepts as compared to Honors Program students (a very small portion of which were also engineering students) [6, pp. 4–6]. Furthermore, Lee reports that no significant differences in the mean scores were found with respect to gender and other potentially confounding factors [6, p. 7]. The conclusion is that "most engineering students are unfamiliar with the philosophical underpinnings of scientific method and related issues because such issues have not been addressed … in a required course" [6, p. 7]. Furthermore, this is a societal problem because "we are assaulted by all kinds of claims regarding health[-]care issues, … environmental issues, social issues, etc. that may or may not be grounded within a rational framework" [6, p. 8], and it is the duty of the educated, especially the technologically educated, to bring an awareness and understanding of these issues, and critical-thinking skills for evaluating evidence. In addition, Lee observes that engineering students who reported such lack of familiarity with these concepts also categorized them as important, suggesting that if only philosophy-of-science education were available to them, they would recognize its relevance to their education as future engineers.

A similar thrust can be found in [7], echoing the call to engineers to take active roles in shaping public policy and working to "change the world [to] make it a better place" [7, p. 182], which Splitt ties to the new paradigm of incorporating HSS as a key component in engineering education. The same idea is found in Albert's reasons numbered 1 and 8, in particular that the "humanities prepare you to fulfill your civic and cultural responsibilities" (reason 1) and "understand the future scientific needs of society" (reason 8) [11].

Another significant component of the integration of HSS into engineering education arises from the interplay of technology, the sciences (social and natural), and the arts: Systems Philosophy and Systems Science. Splitt [7], for example, lists "systems thinking" as one of the six attributes of the crucial new paradigm for engineering education. The Executive Summary of the TUEE report goes further, proposing a slightly diminished role for mathematics in the engineer's foundation, and newly surfaced components that include "systems thinking" [13, p. 4]. What is perhaps somewhat unusual about the IDM and SMR courses in terms of Humanities subject matter is that the instructor's graduate work in systems science has enabled the integration of systems thinking into these courses. Some of this influence, which permeates the instructor's approach to the material, is directly reflected in the choice of Dr. Melanie Mitchell's *Complexity: A Guided Tour* as one of the textbooks. *Complexity* is an award-winning book from a leading scientist that brings cutting-edge findings in dynamic systems, complexity, and emergence to the level of the layperson while still offering much food for thought to an engineer-in-training.

Systems philosophy is relatively new to the international debate on engineering education, but the implementation and integration of HSSEE has evidently been in effect even longer than the debate itself. Splitt lists MIT, Harvey Mudd College, Colorado School of Mines, Worcester Polytechnic Institute, Drexel University, Texas A&M University, Rose-Hulman Institute of Technology, Columbia University, the University of Colorado, Georgia Tech, Mississippi State University, Northwestern University, Stanford University, the University of Illinois, the University of Notre Dame, the University of South Carolina, the University of Tennessee, and Virginia Tech [7, p. 184] as institutions that have made various efforts to incorporate HSS into engineering curricula.[5] Some of these implementations, and several not listed by Splitt, are described in detail in *Unfinished Design: The Humanities and Social Sciences in Undergraduate Engineering Education*, Chapter Three. Highly innovative and ambitious programs of various types and differing philosophies have been instituted at Auburn University, the University of Virginia, Worcester Polytechnic Institute, Colorado School of Mines, Dartmouth College, Stanford University, the University of Florida, Harvey Mudd College, California State Polytechnic, the University of Illinois, the University of Rochester, MIT, and Calvin College. Several of the institutions on this list have implemented especially relevant programs or policies to the topic of the present paper.

The Auburn University Technology and Civilization program incorporates History and Sociology with broad coverage in a fashion that is similar to some of the options considered for a possible multiple-term version of the IDM/SMR course, in terms of its treatment of the development of tools, engineering, and science in ancient cultures (thus presenting history in a way that is of interest to more engineering students) and the interactions throughout history of 'technology and other aspects of human development, art, religion, literature, politics, economic life, military institutions, social and cultural values, environmental issues, and so on" [2, p. 35, where some excellent examples are listed in detail].

The University of Virginia's two-school system has an extensive HSS requirement wherein students take courses at both the regular College of Arts and Sciences and in a Division of Humanities housed within the School of Engineering and Applied Sciences. The educational objectives of the two centers reflect the two needs identified for HSS in engineering education above: the direct, practical value for engineering careers, and the societal value, respectively. [2, pp. 36–37].

Colorado School of Mines has also opted for a unique approach, designing an interdisciplinary honors program specifically in public affairs, taking a direct approach to one particular aspect of the societal need for HSSEE.

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[5] We can add Oregon Institute of Technology and Portland State University to that list.

The Worcester Polytechnic Institute (WPI) favors a method that emphasizes depth over breadth. The Humanities content is more of a minor specialty than broad general education, including a substantial junior-year project that has "a significant technical component and an important humanistic and/or social dimension [2, p. 44], and which is in addition to the more common senior-year technical design project.

Dartmouth College, home of "the nation's first engineering school" [2, p. 56], offers a bachelor's degree in engineering sciences at the end of the regular four-year undergraduate curriculum, having all the same liberal-arts requirements as any other major on campus, and only after that can engineering students complete a fifth year in which they earn their bachelor's degree in engineering [2, p. 57]. Thus, the role of HSS is paramount, and engineering is seen as additional coursework and experience, rather than the more common (reverse) perspective in engineering education.

Last to be discussed here, Stanford University has an extensive sequence of courses in Western culture (and its relationships to technology), the description of which reads like the ultimate general-education program, with the caveat that it strictly deals with Western culture, except for a foreign-language requirement.

We have seen that there are many ways of implementing HSSEE, and some of these are closely integrated within engineering curricula while others stand apart. The efforts described in the rest of this paper constitute small steps, not an entire program or even a programmatic change (except for helping launch the Honors Program). Since the Oregon Tech Honors Program is new, with only one previously offered course, and the SMR as the first course to be specifically scheduled to fit the schedules of a small Honors cohort, this course has a significant role to play in the shaping of the Honors Program. Furthermore, since the more populous majors at Oregon Tech by far are in engineering, engineering technology, and various health technologies, the Honors cohorts are drawn primarily from these majors, allowing the courses and the program to have an impact on engineering and technology education.

Pilot Run

Course Description

The syllabus of the pilot course was centered on standard critical-thinking material. These typically include cognitive science and psychology[6], logic, epistemology, and philosophy of science. In addition, key concepts in Statistics[7], experiment design, history of medicine, and computational techniques from machine learning and decision making were incorporated to forge connections to the students' technical majors. These were, in turn, linked to the humanities content through several means, including prompted written and oral inquiry into connections and parallels between contemporary and historical issues and their representation, the use of a

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6 Such as content from [19–25].

7 "Statistics" is capitalized here in order to differentiate the field from the plural of a statistic.

graphic novel on the quest for logical completeness in mathematics, and ongoing discussions and recurring exposition to heuristics, biases, illusions, and fallacies as applicable to each seemingly distinct topic.

Exposure to the classics and different philosophical streams were provided in the form of varied reading sources, including required books with differing perspectives. As a result, students were exposed to a variety of viewpoints as they learned to use cognitive tools for recognizing common pitfalls of thinking. The goal was to help them develop rigorous, scientific habits of mind while cultivating an appreciation of commonalities among philosophical, scientific, artistic, and mathematical modes of thought.

The pilot course was taught under an adjunct (summer) contract, so there is no direct-assessment data for that term, only self-report student-evaluation data. However, the Honors version of the course (SMR) will be taught during the spring quarter (starting in April 2014), and direct assessment will be conducted, with the pre-test of incoming-student critical thinking administered during the first week of April, the post-test during the first week of June, and the writing assessment (using the rubric provided in the appendices) during finals week, the second week of June. (Our spring term ends June 12, 2014.)

Course Design and History

The course was based on a general-education requirement at a sister institution (Portland State University) where the present author co-taught for several years with three faculty members from the Philosophy Department. The title of the original course was "Knowledge, Rationality and Understanding." It was initially designed by a faculty member from the Psychology Department, and had a strong emphasis on decision-making.

The present author was hired in 2005 as a "quantitative person" at the graduate-assistant level to handle the Statistics content as well as the three hour-long weekly discussion sessions. During the next three years, the primary instructors either retired or passed away, with the present author (graduate assistant) as the main constant and an increasingly central role in the implementation of the course, having co-taught the course six times and designed several versions of sets of ten lesson plans.

The following textbooks were adopted over the years (in addition to two course packs).

- *How We Know What Isn't So: The Fallibility of Human Reason in Everyday Life* (Gilovich),
- *Inevitable Illusions: How Mistakes of Reason Rule Our Minds* (Piattelli-Palmarini),
- *Don't Believe Everything You Think: The 6 Basic Mistakes We Make in Thinking* (Kida), and
- *An Intelligent Person's Guide to Philosophy* (Scruton).

Source books used by the various instructors to develop lecture and discussion material included

- *Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building* (Box, Hunter, and Hunter), and

- *How to Think about Weird Things: Critical Thinking for a New Age* (Schick, Jr., and Vaughn),
- *The Complete Thinker: A Handbook of Techniques for Creative and Critical Problem Solving* (Anderson),
- *How to Lie with Statistics* (Huff and Geis),
- *Beyond Feelings: A Guide to Critical Thinking* (Ruggiero),
- *Essentials of Psychology* (Baron and Kalsher),
- *Mirage of Health* (Dubos),
- *The Elements of Statistical Learning: Data Mining, Inference, and Prediction (Springer Series in Statistics)* (Hastie, Tibshirani, and Friedman), and
- *Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers* (Yates and Goodman).

Direct involvement in the evolution and teaching of this course for a number of years had a profound effect on the present author's outlook on life, education, and dissertation work. Subsequently, upon entering a tenure-track position in Electrical Engineering and Renewable Energy at Portland State University, teaching a similar critical-thinking course that combined the humanities, social sciences, mathematics, and engineering has been at the forefront of the author's professional goals. When then Honors Program was initially discussed, it seemed like an appropriate venue for a highly interdisciplinary and challenging course (especially in terms of challenging students' worldviews). Discussions began in 2012 for the design of the Honors Program. In the summer of 2013, the pilot course was run (outside the Honors Program), and then incorporated into the Honors Program with small changes, starting Spring 2014.

The content addressed in the pilot course was very ambitious, and comments to this effect formed one of the two main themes in the student evaluations. The selection, coverage and measurement of achievement for so much content require some discussion.

The material was selected based on three criteria: appeal to students, perceived importance, and the instructor's experience with it. The introductory materials on visual illusions [26–36] were chosen in order to demonstrate to students the immediacy of perceptual errors, to tie this concept to conceptual and cognitive errors, and to "hook" the students—to get them deeply and personally interested in the course. This was successfully achieved—every student in the class consistently showed a level of attentiveness that is quite rare. All other material, from the readings to the lecture topics and discussion topics, were selected so as to allow for broad coverage of essential information regarding cognition and perception, and also to tie in with students' majors. Probability, Statistics, and Bayesian decision-making are relevant to computer engineers, business/IT majors, and the health-care industry. Issues of memory, eyewitness testimony, and the ideomotor effect have the potential to be relevant to everyone's life at some point or another. Causal and quantitative reasoning, along with practical philosophical concerns regarding the nature(s) of science, mathematics, and technology are pertinent topics for all college graduates, and especially for those in the STEM fields. And finally, controversies about funding, publication, and the decline, placebo, nocebo and Hawthorne effects are all critical to understanding the complex systems of public health, individual health, health care, and medical practice.

Coverage of this much material was quite a challenge, but the experience of the "Knowledge, Rationality and Understanding" course provided a secure foundation. The topics are numerous, so the depth of coverage in each could not be at the level of a senior or graduate course—the goal was to spark interest and achieve a baseline of understanding. Nonetheless, online learning tools allowed supporting material to be made available on an optional basis to students interested in delving deeper into any particular topic. Subsequent in-class discussions allowed those students to share their perspectives on the supplemental material with other students, leading to productive exchanges of ideas.

In the IDM course, the primary measurement of achievement came in the form of graded work: a midterm exam, a final paper (with stages of revisions), and some short quizzes. In addition to these, the Honors course (SMR) will feature pre-/post-tests, a final exam, and rubric-based evaluation of writing.

<u>Course Experiences, Successes and Challenges</u>

The pilot course started out with the presentation of personal sensory experience as evidence of the significance of (subjective) perception. On the first day, students were shown optical illusions in the form of videos, drawings, and photographs. Some, like the "invisible gorilla," demonstrate the filtering effect of attention on our sensory inputs. Others like the upward-rolling balls of Professor Kokichi Sugihara [15] demonstrate how sensory information and intuition can disagree, as well as how visual tricks can make us believe what turns out to be false or fake. These and other illusions are used as the basis of the idea that if our eyes (the most trusted organ of perception for most people) can be so thoroughly deceived, then the rest of our perceptive and cognitive faculties may also be deceived in ways we may not be aware of.

As a result of this exposition of optical illusions, the cool detachment of the first day when students come into a new class outside their major was dispelled within half an hour. Starting with the next class meeting, several students began sitting at or near the front of the class, and were noted to be taking extensive notes. The engagement level remained high throughout the term. One of those students who moved up front went on to make various comments and exclamations of amazement at numerous concepts during almost every class session.

The primary challenge also became apparent early on. Small-group discussions were consistently more effective than all-class discussions because there was a great deal of student-driven "scope creep" (the desire to add more to the discussion than the topic at hand calls for). This turned out to be more easily controlled—even by students—in small-group discussions. During class-wide discussions, one or two students regularly—though with good intentions—derailed discussion away from the instructor's intended focus (a particular point that would become clear when the exercise is completed) due to an apparent discomfort with or unwillingness to consider hypothetical cases. It is, of course, standard scientific practice to model a system or situation with a germane subset of the most relevant considerations. In science, as in engineering, models are recognized are false but useful. As part of a greater discussion of the philosophy of science, Sober points out the incompleteness (yet usefulness) of models [16, bold emphases added, italics in the original]:

> **Every model involves simplifications**. Many evolutionary forces impinge simultaneously on a population. The evolutionist selects some of these to include in a mathematical representation. Others are ignored. The model allows one to predict what will happen or to assign probabilities to different possible outcomes. All such models implicitly have a *ceteris paribus*[8] clause appended to them. This clause does not mean that all factors not treated in the model have *equal* importance but that they have *zero* importance. The Latin expression would be more apt if it were *ceteris absentibus* (Joseph 1980). **Models can be useful even when they are incomplete if the factors they ignore have small effects**. This means that an evolutionary model is not defective just because it leaves out something. Rather, the relevant question is whether a factor that was ignored in the model would *substantially* change the predictions of the model if it were taken into account.

Or, to put it more succinctly, "Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful. … Essentially, all models are wrong, but some are useful." [17] Hence, as in any model, some less-poignant aspects were left out of some of the discussions of decision-making under uncertainty. Whenever these problems involved practical matters of a personal or financial nature, however, one student in particular could not accept the consideration of a subset of factors, and insisted that any other factor that could possibly arise must be taken into account for the discussion to have value.

An obvious way to address this challenge may be to clearly specify the parameters of each discussion topic, but this turns out to be undesirable because it can overly narrow down and limit the ensuing student discussion. Yet, with a highly mixed group of students from different academic backgrounds and standings, it was found that at least a general description of assumptions and scope was needed as a preface to each discussion to avoid spending valuable class time on technicalities of little import. In small-group discussions that followed a prompt or introduction by the instructor, students reported that they were comfortable addressing conceptual difficulties within the group. They were, however, not comfortable doing so in class-wide discussions, and the need for the instructor's repeated reassurance of an objecting student took away from the allotted discussion time. In small groups, however, even a group that spent time on these technicalities could later benefit from another group's presentation.

Specifically, this situation arose in the discussion of various techniques of Bayesian decision-making. In order to make the mathematics manageable—to demonstrate the techniques without undue complication—decisions involving at most three factors are preferable to more realistic cases with many more factors. The equations have the same form (and already look cumbersome) even when they are conceptually simple. It was expected that students could extrapolate to higher-dimensional spaces after understanding simpler cases. While familiar to some students, this technique of trying out the math with fewer terms and extrapolating to the practical case was unexpectedly foreign to some, and is a prime example of the challenges of working with students from different disciplinary backgrounds and different levels (sophomore

[8] "if all other relevant things, factors, or elements remain unaltered," or "all other things being equal" (http://www.merriam-webster.com/dictionary/ceteris%20paribus)

through senior). The two-fold solution was first to recognize students' difficulties with this way of thinking and find a setting in which their concerns can be addressed without holding back the others in the class, and secondly to delineate in advance the scope of each concept or discussion topic.

In summary, as a result of this recurring roadblock in the first three class meetings, such clear delineation of scope by the instructor became a crucial preface to each discussion. This may be particularly important when a class consists of students from different academic standings and backgrounds. (For instance, seniors or physics majors may be more at ease with models, abstract reasoning, or hypothetical cases than sophomores or engineering-technology majors.)

Another significant challenge was directing students to make connections among ancient, modern, scientific, and literary works without giving too much away or leading the student discussion in a particular direction. The present author (the instructor of the courses under discussion) has taught music and engineering since 1994, but this does not necessarily imply sufficient cultivation of the skills required in fostering thought and debate about Homer and Aeschylus, or finding parallels between various author's critiques of behaviorism and Homerian morality. The direct approach of pointing to various pieces of assigned reading and asking students to draw connections was not successful, resulting in superficial responses of the type "Yes, the author's take on Homer was surprising" without elaboration.

The need for collaborative teaching became apparent because the tricks of the trade in teaching literature were not part of the instructor's skill set. As a result, the Honors course will be collaboratively taught with philosophy faculty, and a two-term course design is being considered so as to involve a collaboration with literature faculty (not to mention, a more appropriate course load, since the amount of reading assigned in the pilot course was disproportionately high for a three-credit eight-week summer course, although necessary for sufficient coverage of the course objectives).

Even with these birthing pains, the indirect assessment conducted at the end of the course revealed across-the-board support for the course material and instruction. The results of the student evaluations (in which there was 100% participation) fall into the following categories.

- The material was very interesting and important.
- The course was very ambitious. (There was more reading than students expected.)
- It related to and illuminated other classes students have taken.
- It was enjoyable, except for the occasional student commentary deemed excessive by other students.
- The students left wanting more.

Some comments from anonymous written student feedback follow. This set includes at least one comment from every student. Not all students answered every evaluation prompt, and some had essentially the same thing to say. This selection summarizes the themes found in the student evaluations, but does not include every comment made.

- “Open discussion, the materials and subjects covered are very interesting. Variety in learning methods.
- “Occasionally allowed one or two individuals to control or dominate discussion time”
- “Highly recommended subject and well taught. Should be required in any education.”
- “It is very interesting and quite informative. I enjoyed every minute.”
- “Eight weeks meeting one time a week is not enough!!”
- “Too much reading”
- “… cool statistics and Beysian (sic) theories”
- “While the reading was interesting, I feel it is a little much.”
- “very thought provoking”
- “quite circular (good & bad)”
- “Actually this class was a good physical application of concepts learned in the statistics class im (sic) taking concurrently”
- “Subject matter: it was interesting and relevant.”
- “I enjoyed the discussions in the class, learning the information.”
- “I liked that it was a culmenation (sic) of several subjects that help you in your everyday life with decision making.”
- “”I wish we had more time.”

By the end of the eight-week summer term, students and the instructor had navigated a dense set of material and delivered on an ambitious list of course objectives including persuasive writing, information literacy, interpreting classic and modern works of fiction, deductive, inductive, and multi-valued logic, Bayesian decision making, applications to justice and health care, and the role of science in society. The instructor, specifically, learned about the importance of framing discussions with a precise focus, the importance of multiple teaching techniques, the role of prerequisites even in non-quantitative courses, and about the effectiveness of small discussion groups.

Choice of Texts

The selection of textbooks for both the pilot course and the Honors course were, naturally, based on the “Knowledge, Rationality and Understanding” course in the University Studies program at the sister institution (Portland State University), and also influenced by a talk and subsequent discussion at the *Bridges 2012: Mathematics, Music, Art, Architecture, Culture* conference, as described below. Upon strong recommendation from the Knowledge, Rationality, and Understanding faculty at Portland State University, we adopted *The Undercover Philosopher* by Philips as the primary text for the pilot course.

The Undercover Philosopher features all the standard critical-thinking coverage one would expect, but in a more accessible narrative form than many of the books previously used in “Knowledge, Rationality and Understanding.” (Only Kida’s *Don’t Believe Everything You Think* comes close in general appeal and readability, but it does not quite have the narrative flow of *The Undercover Philosopher*.) Furthermore, Philips leaves more of the practical questions open-ended than the textbooks previously used, and thus leaves more room for student discussion and inquiry.

The secondary (and unconventional) text was chosen for its succinct coverage and distinctive interpretation of several key classics such as Homer's *Iliad*, Aeschylus' *Oresteia*, and Melville's *Moby-Dick*, as well as for being an intentionally imperfect choice with a mix of well-supported and unsupported claims, arguments, and analyses. (The book is *All Things Shining: Reading the Western Classics to Find Meaning in a Secular Age* by Dreyfus and Kelly.) This book was selected as somewhat of a counterpoint to the well-documented main text. It was also more manageable for engineering, technology, and business students taking a three-credit summer course than a large-volume survey of classic works. Since one of the objectives of the course is to make students more comfortable with opposing perspectives and the idea that not everything printed can be trusted implicitly (information literacy as part of critical thinking), this controversial yet valuable text with its highly subjective, debate-worthy content was selected as the secondary text.

With the philosophy, psychology, critical-thinking, and classics angles addressed via these two texts, the third book (on mathematics and logic) had the greatest appeal to students because it came in the form of a graphic novel. *Logicomix: An Epic Search for Truth* by Doxiadis and Papadimitriou was introduced to the author at the *Bridges 2012: Mathematics, Music, Art, Architecture, Culture* conference during the presentation of the paper "The Creative Process: Risk-taking in an Interdisciplinary Honors Course" [18].

Logicomix traces the evolution of Bernard Russell's development as a logician, his work on set theory, his personal demons and intellectual trajectory, Kurt Gödel's later contribution to the philosophy of mathematics, and the events unfolding in the world at large. Mathematics and logic are presented through their importance and beauty, and with both their strengths and their shortcomings. Students are, by their own admission, more drawn to read a graphic novel than any other text, and this book makes mathematics attractive and human to those who may not readily perceive its beauty and humanity.

Design of the Official Honors Course

Based on the experiences and results of the pilot course, the present author contacted the faculty and chair of the Department of Humanities and Social Sciences at Oregon Tech during the fall term of 2013 to help design either a slightly less ambitious course to fit into one quarter, or a series of courses that would address all objectives in a longer time period. An additional objective was to find a co-instructor to better address (and learn more about) the variety of approaches and teaching techniques necessary for a multidisciplinary course that serves students from a variety of disciplines.

A new faculty member with a Ph.D. in philosophy of science volunteered to take part in the redesign and also to serve as a guest lecturer. He also helped construct the first option: A course with greater emphasis on philosophy of science and systems thinking, and no explicit literature component. The multi-term design with the classics component is also on the table, to be considered by the Humanities faculty as part of their regular curriculum-development activities. In the meantime, the new one-term course, Science, Medicine, and Reason (SMR), is being offered this coming spring as part of both Humanities and Honors.

The design of the new course is reflected in the selections from the syllabus listed in Appendix E below. The choice of textbooks is slightly different than in IDM, with two of the same required texts as before (*The Undercover Philosopher* and *Logicomix*), but with the third selection being dependent on students' majors. In addition, two medical-decision-making texts that are available freely online are included as recommended readings. These are *Know Your Chances: How to See through the Hype in Medical News, Ads, and Public Service Announcements [Understanding Health Statistics]* (Woloshin, S., MD, MS, Schwartz, L. M., MD, MS, and Welch, H. G., MS, MPH, Berkeley, University of California Press, 2008) and *Testing Treatments: Better Research for Better Healthcare* (Evans, I., Thornton, H., and Chalmers, I., London, The British Library, 2006).

Students majoring in engineering, engineering technology, IT, geomatics, and business are required to read *Complexity: A Guided Tour* by computer and complex-systems scientist Melanie Mitchell. Students majoring in medical technologies, clinical psychology, or the natural sciences are required to read *Trick or Treatment: The Undeniable Facts about Alternative Medicine*, written, in collaboration, by popular-science author Simon Singh and medical doctor and former alternative-medicine practitioner Edzard Ernst (M.D.). These sources add the system-level perspective to the phenomena and techniques discussed throughout either course, and serve to link medical and high-tech disciplinary content to the general-education material that forms the core of the course.

Assessment of the Official Honors Course

There are three assessments planned for the Honors course, two direct and one indirect. One form of direct assessment is a writing rubric focusing on argumentation, organization, usage, syntax, grammar, and information literacy to be applied to the term paper. Another will be a pair of pre/post tests using standard types of logic, reasoning, and critical-thinking questions. The pre-test is expected to help gauge students' strengths, weaknesses, and needs at the beginning of the term. The post-test will provide an estimation of the extent to which students have begun to cultivate (or improve) superior thinking habits by the end of the course. Finally, there will be the usual indirect assessment of student perceptions and experiences through the self-report measure of anonymous evaluations.

Results of these assessment activities will be included in the author's presentation at the ASEE Annual Conference and Exposition in Indianapolis in June, 2014.

Plans for a Future Sequence or New Curriculum

The institution, Oregon Tech, is currently undertaking a large-scale investigation into general education, including what it means, what its goals are, how it is done throughout the US, how we do it, and how we ought to do it. The author is involved with these investigations through several committees and subcommittees.

Likewise, the HSS department that houses both these courses is designing a new curriculum that both expands the humanities experiences (specifically, arts, languages, and philosophy) of our students, and injects a technology-relevant arts component into their traditional STEM curricula (an approach sometimes known as "STEAM").

The HSS faculty is considering the SMR course as a potential part of this arts, languages, and philosophy curriculum (ALPs). Conversations include the development of a multi-term sequence that expands the SMR course with the classics component taught by a better-qualified humanities instructor, as well as courses combining technology with artistic expression and the social sciences. Possibilities include the analysis and development of high-tech empathy games and the use of modern audio and music technology in artistic self-expression. The precise role (if any) of the SMR course in this new curriculum is to be determined. Nonetheless, we are addressing the need for integrated (and, to the students, interesting) humanities and social sciences in engineering and technology curricula through both departmental and institution-wide initiatives.

Conclusion

The efforts at integrating the humanities, social sciences, engineering, mathematics, medicine, and technology constitute an ongoing endeavor throughout the world in engineering education, throughout the United States in particular, and specifically here at Oregon Tech.

The courses described in this paper represent one such effort that specifically and explicitly targets critical thinking as the key component, with HSS as the primary strategy for achieving the development of demonstrable critical-thinking skills in engineering, business, and technology graduates.

The upcoming implementation of the course (spring quarter, 2014) will be the first of these at Oregon Tech to be incorporated into the Honors Program, and to be assessed using direct measures. Preliminary indirect findings show that students' attitudes toward philosophy, literature, and critical thinking have been positively influenced by the pilot course (IDM). Data from direct assessment is expected to help efforts to integrate the new course (SMR) as a component in the majors, as inspired by the positive examples of various integration strategies both in the author's experience and in the literature.

Appendix A: Assessment Instrument: Writing Rubric for the Term Paper

	Weak	Developing	Satisfactory	Excellent
Organization	The paper lacks organization. Sections are in nonsensical order, or material is found in sections where it does not belong.	The paper is organized, but one or more requisite sections or arguments are missing.	The paper is organized, but at most one requisite section is missing or imperfect; e.g., a new idea is introduced in the conclusion, or the abstract is overly detailed.	The paper is well organized. The content of the abstract and the conclusion are appropriate.
Quality of Sources	Either no external sources are referenced, or the sources are unreliable and of questionable origin, such as ordinary books, websites, and magazines.	Some sources are peer-reviewed, but a significant portion is non-peer-reviewed Internet sources or nonfiction books.	There is adequate external source material of good quality. The majority of sources are either peer-reviewed or from well-established university presses or academic publishers.	There is adequate external source material of good quality. All sources are peer-reviewed or from well-established university presses or academic publishers. They are dated recent (if this is relevant).
Number of Sources	One source, or none	Two or three, or if more, cross-referential or by the same authors	More than three non-redundant sources	More than three non-redundant sources from multiple perspectives or multiple fields.
Accuracy of Information	The information content is inaccurate or unverifiable.	The information content is mostly accurate or verifiable.	The information is fully accurate or verifiable.	All crucial information is included, is fully accurate, and is verifiable.
Explanation of Relevance	The relevance of the topic is neither clearly explained nor obvious.	The relevance of the topic is stated without adequate support for its importance.	The relevance of the topic is supported with substantial evidence or argumentation.	The relevance of the topic is eloquently supported with substantial evidence or rigorous argumentation.

Writing Quality	The writing features multiple spelling, syntax, punctuation, or formatting errors. Some words are colloquial or not appropriate.	The writing features no spelling, no grammar, and few punctuation errors. Word use is appropriate for the intended audience. The style is consistent.	The writing features no spelling, grammar or punctuation errors. Word use is appropriate for the intended audience. The style is consistent.	The writing features no errors. Word use is appropriate, both in terms of nuances of meaning and intended audience. The style is consistent.
Presentation	Typeface, justification, captions, or margins are inconsistent, unprofessional, or illegible.	Some of the following are inconsistent, unprofessional, or illegible: Typeface, justification, captions, and margins.	The report features consistent, professional, and legible typefaces, justification, captions, and margins.	The report features consistent, professional, and legible typefaces, justification, captions, and margins that match a professional editing standard such as IEEE, APA, or Chicago.

Appendix B: Assessment Instrument: Pre-Test of Critical Thinking [20, 38–43, and the author]

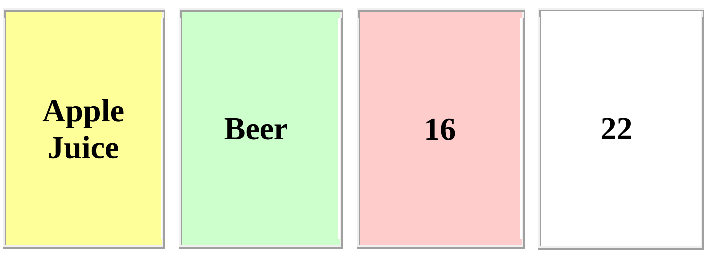
Please answer the following questions to the best of your ability.

1. Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in antinuclear demonstrations. Choose the option that is more likely to be true.

a) Linda is a bank teller.
b) Linda is a bank teller and active in the feminist movement.

2. You are shown four cards[9]. Each card has the name of a drink on one side and an age (in years) on the other side. Given the cards below, what cards, exactly, must one turn over to check whether the following statement is false (according to the cards)?

"*If a person is drinking beer, then the person is over 20 years old*"



3. Suppose I am tested for a terrible disease by means of a very reliable test—it is 99% accurate. To be specific, it has only a 1% rate of false positives (says you're sick when you're not) and a 1% rate of false negatives (misses the disease when you actually have it).

My test result comes out positive.

I ask for more information, and find out that this disease only occurs at a rate of 1 in 10,000 people in my population

Which of the following is closest to the probability that I have the disease?

a) 99%
b) 98%
c) 90%
d) 50%
e) 9.8%

---

[9] From left to right, the cards are yellow, green, pink, and white.

4. Label each of the following statements as rational or fallacious (which means irrational, or involving mistakes of reasoning).

- The Ford F-150 is the best-selling consumer truck in the US. Therefore, it is the highest-quality consumer-grade truck available for sale in the US.
- Since no conclusive evidence has been collected of alien spacecraft, they must not exist.
- Scientists don't know everything about human physiology, so science-based medicine is useless.
- Both atmospheric CO_2 levels and illegal drug use have increased monotonically since the '50s. We can see from this that CO_2 in the atmosphere leads to increased illegal drug use.

5. If in a two-child family, one child is a boy, what is the probability that the other child is a girl?

6. In which case below is this person more concerned about education than about financial aid?

a) I shouldn't drop out of school because I don't have money.
b) I shouldn't drop out of school, because I don't have money.

7. Which is <u>*by definition*</u> a natural thing to do?

a) natural resource consumption
b) natural-resource consumption

8. According to which sentence should you be sure that "somatic" and "bodily" mean the same thing?

a) Radioactive materials that cause somatic, or bodily, damage are to be limited in their use.
b) Radioactive materials that cause somatic or bodily damage are to be limited in their use.

9. Rosencrantz and Guildenstern are bored waiting for their next royal assignment, so they are sitting around, tossing a fair coin. (The probability of heads is equal to the probability of tails, and we can assume the coin will never end up standing on its edge.) Identify the least likely and most likely sequence, if there are any. If there are not such sequences, explain why.

HTHHTH

TTTTTT

THHTTH

HTHTHT

Appendix C: Assessment Instrument: Post-Test of Critical Thinking [38–44, and the author]

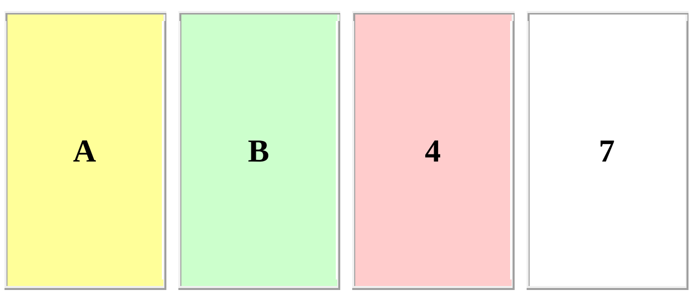
1. Bill is 34 years old. He is intelligent, but compulsive, and antisocial. In school, he was strong in mathematics, but weak in social studies and humanities.

Rank the following propositions as to how likely they are. (They may or may not be true, and they are neither mutually exclusive nor exhaustive):

A: Bill is an accountant.
B: Bill is a physician who plays poker for a hobby.
C: Bill plays jazz for a hobby.
D: Bill is an architect.
E: Bill is an accountant who plays jazz for a hobby.
F: Bill climbs mountains for a hobby.

2. You are shown four cards (below). For each card, there is a letter on one side and a number on the other side. Which card(s) must you turn over to determine whether the following statement is false?

"*If a card has a vowel on one side, then it has an even number on the other side*."



3. Label each of the following statements as rational or irrational.

- Once all gun-owners have registered their firearms, the government could confiscate them.
- “The America I know and love is not one in which my parents or my baby with Down Syndrome will have to stand in front of Obama’s ‘death panel’ so his bureaucrats can decide, based on a subjective judgment of their ‘level of productivity in society’, whether they are worthy of health care.” (Sarah Palin, Facebook, August 7, 2009, regarding Section 1233 of *America’s Affordable Health Choices Act of 2009: Advanced Care Planning Consultation*; last retrieved March 22, 2014)
- Scientists don’t know exactly what happened in the Big Bang, so it must not be true.
- It has been observed that Volkswagen and ice-cream sales (sale volumes) within a given year move up and down together. This must be mere coincidence.

4. If in a two-child family, the older child is a boy, what is the probability that the other child is a girl?

5. Which statement denies that political affiliation had anything to do with Joe's appointment?

a. Joe didn't get the appointment, because he is a Republican.

b. Joe didn't get the appointment because he is a Republican.

6. Which expression conjures an image of fake angel wings at a BBQ party instead of the more common interpretation?

a) Barbecue Style Wings

b) Barbecue-Style Wings

7. In which statement is the Argentinean president accused of being a troublemaker?

a) Whether the Argentinean communists deliberately chose to cause trouble during a period when they knew their president was going to the United States, or whether the course of events rose to a natural climax is hard to tell.
b) Whether the Argentinean communists deliberately chose a period when they knew their president was going to the United States to cause trouble, or whether the course of events rose to a natural climax is hard to tell.

8. Suppose I am tested for a terrible disease by means of a very reliable test. To be specific, it has only a 1% rate of false positives (says you're sick when you're not) and a 2% rate of false negatives (misses the disease when you actually have it).

My test result comes out positive.

I ask for more information, and find out that this disease only occurs at a rate of 1 in 1000 people in my population.

Which of the following is closest to the probability that I have the disease?

a) 99%
b) 97%
c) 25%
d) 9%
e) 1%

9. Two duelers are playing Russian roulette, in which one bullet is placed in a revolver, the duelers take turn pulling the trigger on themselves after the cylinder is vigorously spun, and the game is over as soon as one person dies.

Imagine a tradition in which the “game” is always played up to a dozen times, with the same dueler going first every time. Are the chances of death even for the two players?

Appendix D: Relevant Sections of the Syllabus for the Pilot Course (IDM)

COURSE DESCRIPTION

Starting with a survey of optical illusions and moving to cognitive illusions and common biases, this is a critical-thinking course covering misperceptions and decision-making errors like the base-rate fallacy (pertinent to medical testing), regression to the mean, ideomotor effect, confirmation bias, Hawthorne/placebo/threshold effects (applicable to health-care management), relevant concepts in math and physics, conditional probability & Bayes' theorem, and an introduction to the history and philosophy of science.

In parallel with these topics, the course touches upon various modes of thinking, from existentialism to spirituality, from scientific humanism to Kuhn and his interpreters, and to feminist and alternative-pragmatic responses to science, all through lectures, assigned readings, and class discussions.

BOOKS

Required: The Undercover Philosopher: A Guide to Detecting Shams, Lies, and Delusions (Philips, Oneworld, 978-1-85168-581-3)

Required: All Things Shining: Reading the Western Classics to Find Meaning in a Secular Age (Dreyfus & Kelly, Free Press, 978-1-4165-9616-5)

Required: Logicomix: An Epic Search for Truth (Doxiadis & Papadimitriou, Bloomsbury, 13 978-1-59691-452-0)

SUMMER-TERM OUTLINE:

1. Introduction, logic and Memory
   - Discussion: truth, fact, theory, belief, and the structure of factual statements
   - Gregory masks and other optical illusions; link to cognitive illusions
   - Elementary Logic and fallacies
   - Discussion: common sense
   - Read *Shining* through p. 26. Read *Undercover* Chapter 1.
2. Introduction to Probability
   - Pizza in the age of cell phones: A friendly introduction to Probability
   - Conditional probability and independence
   - Bayes' theorem; applications to computer engineering and medical testing
   - Discussion: truth, fact, theory, belief, and the structure of factual statements
   - Read *Shining* through p. 78. Read *Undercover* Chapter 2.

3. Everyday Probability
    - Probability trees, decision trees, and the base-rate fallacy
    - Read *Shining* through p. 126.
    - Associative memory, neuroscience, and eye-witness testimony
    - Read *Undercover* Chapter 3. First draft of paper due.
4. The Ideomotor Effect
    - Midterm Exam
    - Semmelweiss and the noble savage (optional: Simpson's paradox)
    - Facilitated Communication and the ideomotor effect (movie)
    - Read *Logicomix*, Overture and Chapters 1 & 2, or *Trick*, Chapters 1 and 2.*
5. Extraordinary claims, Regression to the Mean, and Statistics
    - Causal reasoning and extraordinary claims; regression to the mean
    - Statistical inference: Why Statistics? Why sampling?
    - Statistical significance and bootstrap methods (Box, Hunter & Hunter)
    - Read *Shining* through p. 216. Read *Undercover* Chapter 4.
    - Second draft of paper due.
6. Quantitative literacy; the history and philosophy of science
    - Quantitative literacy (How to Lie with Statistics)
    - Hume, Kuhn, Popper; the Bayesian Framework and modern science
    - Read *Undercover* Chapter 6. Read *Logicomix*, Chapters 3, 4 & 5, or *Trick*, Chapter 3.*
    - Final paper due.
7. Back to science and medicine: Public health and the limits of science and technology
    - Aristotle, Bacon, and Big Pharma: funding and publication bias
    - OPTIONAL: Read *Undercover* Chapter 5.
    - The placebo effect and the Hawthorne effect

- Plato’s cave, the problem of induction, and Gödel’s incompleteness theorems
- Pragmatism and alternative medicine; critique of science
- Read *Logicomix*, Chapter 6, Finale & Notebook, or *Trick*, Chapter 4.*
- Papers returned and discussed

Appendix E: Relevant Sections of the Syllabus for the Honors Course (SMR)

COURSE DESCRIPTION

The course synthesizes logic, probability, epistemology, neuroscience, artificial intelligence, history of medicine, principles and problems of modern science, statistical inference and methods, issues of funding and reproducibility, and criticisms of science into a coherent presentation about reasoning in the sciences, technology and everyday life.

Starting with a survey of optical illusions, the course reveals a staggering variety of cognitive illusions, misperceptions, (sometimes useful) biases, and decision-making pitfalls. These are then discussed in the context of science, medicine, current technology, systems philosophy, and the history and philosophy of science in order to help develop critical thinking for both professional situations and social responsibility, as well as to promote enlightened discourse pertinent to medical practice, health-care management, science, engineering, policy-making, law, and business.

REQUIRED BOOKS

The Undercover Philosopher: A Guide to Detecting Shams, Lies, and Delusions (Philips), Oneworld, ISBN: 978-1-85168-581-3

Logicomix: An Epic Search for Truth (Doxiadis & Papadimitriou), Bloomsbury, ISBN: 13-978-1-59691-452-0

For students in the College of Health, Arts and Sciences: Trick or Treatment: The Undeniable Facts about Alternative Medicine (Singh & Ernst, MD), W. W. Norton & Company, ISBN: 978-0-393-33778-5

For students in the College of Engineering, Technology and Management: Complexity: A Guided Tour (Mitchell), Oxford University Press, ISBN: 9780195124415

INSTRUCTORS

Lead Instructor: Mehmet Vurkaç, Ph.D., electrical and computer engineer

Contributing Instructor: Yasha Rohwer, Ph.D., philosopher of science

GENERAL COURSE OUTLINE

WEEK & BROAD DESIGNATION	**TOPICS**	**TEXTBOOK ASSIGNMENTS & PAPER DRAFTS**	**BLACKBOARD READINGS & DISCUSSION (req.)**	If you enjoy this topic, you might like …
1: Introduction	▪ Optical illusions ▪ Truth, fact, theory, belief, common sense, and factual statements ▪ Introduction to formal deductive logic ▪ Causal reasoning and extraordinary claims	*Undercover* Chapter 1 *Chances* Introduction and Chapter 1	READ: *The Theory of Everything* by David Deutsch DISCUSS: Truth, fact, reality, belief, conjecture, hypothesis, theory, theorem, axiom, etc.	**Blindspots:** The Many Ways We Cannot See (Breitmeyer) **The Ultimate Book of Optical Illusions** (Seckel) **A Mathematician Reads the Newspaper** (Paulos)
2: Probability	▪ Pizza and cell phones: An intuitive introduction to Probability ▪ Conditional probability and independence ▪ Bayes' theorem and its applications	*Undercover* Ch. 2 *Chances* Ch. 2	READ: *A Pickpocket's Tale: The spectacular thefts of Apollo Robbins* by Adam Green DISCUSS: Ch. 1 of *Undercover*	**The Theory That Would Not Die:** How Bayes' Rule Cracked the Enigma Code … (McGrayne) **Duelling Idiots** and Other Probability Puzzlers (Nahin)
3: Memory	▪ Probability trees, decision trees, and the base-rate fallacy ▪ Memory and eye-witness testimony	*Undercover* Ch. 3 **First draft of paper** (mechanical feedback)	DISCUSS: Ch. 2 of *Undercover*	**How To Think About Weird Things** (Schick, Vaughn, Jr.)
4: Ideomotor	▪ VIDEO: Facilitated Comm. and the ideomotor effect ▪ Selected topics in the history of medicine ▪ The pillars of scientific practice	*Logicomix*, Overture and Ch. 1 and 2 **HAS:** *Trick*, Ch. 1 **ETM:** *Complexity*, Ch. 1, 2, and 3	DISCUSS: Facilitated Communication DISCUSS: Ch. 3 of *Undercover*	**Mirage of Health** (Dubos) **Cows, Pigs, Wars and Witches** (Harris)

5: Demarcation	▪ Dr. Rohwer: Demarcation ▪ Inductive logic and fallacies ▪ Placebo and Hawthorne effects	*Undercover* Ch. 6 **HAS:** *Trick*, Ch. 2 **ETM:** *Complexity*, Ch. 3 and 4	READ: *Placebos on Trial* by Dylan Evans DISCUSS: *Trick*, Ch. 1, *Complexity*, Ch. 1 and 2, and *Placebos on Trial*	**Snake Oil Science** (Bausell) **Placebo:** Mind Over Matter in Modern Medicine (Evans)
6: Opposites	▪ Probability and Statistics are opposites! ▪ Why Probability? Why Statistics? Why do we sample? ▪ Introduction to Fuzzy Logic	*Undercover* Ch. 4 **HAS:** *Trick*, Ch. 3 **ETM:** *Complexity*, Ch. 5, 6, and 7	READ: *Is the most trusted doctor in America doing more harm than good* by Michael Specter DISCUSS: *Undercover* Ch. 6, *Trick*, Ch. 2, and readings	**How to Think About Statistics** (Phillips) **Probability Theory:** The Logic of Science (Jaynes)
7: Numeracy	▪ Quantitative Literacy ▪ MIDTERM EXAM ▪ Sampling and statistical inference ▪ Statistical significance and bootstrap methods	*Logicomix*, Ch. 3 and 4 **HAS:** *Trick*, Ch. 4 **ETM:** *Complexity*, Ch. 13 and 14 **Second draft of paper**	READ: *Stupid Smart Stuff* by Don Norman READ: *Why Most Published Research Findings Are False* by John P.A. Ioannidis DISCUSS: *Undercover* Chapter 4, *Trick*, Chapter 3, and readings	**The Cult of Statistical Significance** (Ziliak and McCloskey)
8: Underdetermination	▪ Continued: Statistical methods ▪ Dr. Rohwer: Underdetermin ation	*Logicomix*, Ch. 5 & 6 **HAS:** *Trick*, Ch. 5 **ETM:** *Complexity*, Ch. 8 and 9	READ: *The Physicist and the Social Scientist* by Oz Flanagan DISCUSS: *Complexity*, *Trick*, Ch. 4, readings	**The Fabric of Reality** (Deutsch)
9: The Human Element	▪ The Bayesian framework and modern science ▪ Funding, the reproducibility crisis, and publication bias	*Logicomix*, Finale and Notebook. *Chances* Ch. 10 **HAS:** *Trick*, Ch. 6 **ETM:** *Complexity*, Ch. 10, 11 & 12	READ: *Do Clinical Trials Work* by Clifton Leaf, and *Why We Can't Trust Science Reporting* by Harriet Hall, M.D. READ: *Frequentist vs Bayesian statistics —a non-statisticians*	**On Intelligence:** How a New Understanding of the Brain will Lead to the Creation of Truly Intelligent Machines (Hawkins, Blakeslee)

		OPTIONAL: *Undercover* Ch. 5	*view* by Maarten H. P. Ambaum DISCUSS: Readings	**The Emperor's New Drugs:** Exploding the Antidepressant Myth (Kirsch)
10: Opposing Views	▪ Rebels? (Margulis, Fodor, Smolin, Mlodinov, Kosko, Ziliak & McCloskey) ▪ Pragmatism and alternative medicine ▪ Critiques of science ▪ Sokal and postmodernism	**Final version of paper**	READ: *The Nature of Light: What are "Photons"?* by Carver Mead READ: *Undiscriminating Skepticism* by Eliezer Yudkowsky READ: *The Evolution of Prejudice* by Daisy Grewal DISCUSS: Everything to date	**Power, Sex, Suicide** (Lane) **The Emperor's New Mind:** Concerning Computers, Minds, and the Laws of Physics (Penrose) **Fashionable Nonsense:** Postmodern Intellectuals' Abuse of Science (Sokal, Bricmont) **The Astonishing Hypothesis:** The Scientific Search for the Soul **The Mind's I** (compiled by Dennett and Hofstadter)
11: Final Exam	Final Exam			

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