

The Stanford Education Experiment

Two university professors let the public take their artificial intelligence course online, for free. Then 160,000 students signed up. Now the plan is to change higher learning forever.



BY STEVEN LECKART

Sebastian Thrun and Peter Norvig in the basement of Thrun's guesthouse, where they record class videos.

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TANFORD DOESN'T WANT ME. I can say that because it's a documented fact: I was once denied admission in writing. I took my last math class back in high school. Which probably explains why this quiz on how to get a computer to calculate an ideal itinerary is making my brain hurt. I'm staring at a crude map of Romania on my MacBook. Twenty cities are connected in a network of straight black lines. My goal is to determine the best route from Arad to Bucharest. A handful of search algorithms with names like breadth-first, depth-first, uniform-cost, and A* can be used. Each employs a different strategy for scanning the map and considering various paths. I've never heard of these algorithms or considered how a

PHOTOGRAPH BY SAM COMEN

computer determines a route. But I'll learn, because despite the utter lack of qualifications I just mentioned, I'm enrolled in CS221: Introduction to Artificial Intelligence, a graduate-level course taught by Stanford professors Sebastian Thrun and Peter Norvig.

Last fall, the university in the heart of Silicon Valley did something it had never done before: It opened up three classes, including CS221, to anyone with a web connection. Lectures and assignments—the same ones administered in the regular on-campus class—would be posted and auto-graded online each week. Midterms and finals would have strict deadlines. Stanford wouldn't issue course credit to the non-matriculated stu-

dents. But at the end of the term, students who completed a course would be awarded an official Statement of Accomplishment.

People around the world have gone crazy for this opportunity. Fully two-thirds of my 160,000 classmates live outside the US. There are students in 190 countries—from India and South Korea to New Zealand and the Republic of Azerbaijan. More than 100 volunteers have signed up to translate the lectures into 44 languages, including Bengali. In Iran, where YouTube is blocked, one student cloned the CS221 class website and—with the professors' permission—began reposting the video files for 1,000 students.

Aside from computer-programming AI-heads, my classmates range from junior-high school students and humanities majors to middle-aged middle school science teachers and seventysomething retirees. One student described CS221 as the "online Woodstock of the digital era." Personally, I signed up to have the experience of taking a Stanford course. Learning about artificial intelligence would be a nice bonus. After all, if I'm ever going to let a self-driving car speed me down a highway at 65 mph, it'll be comforting to have a basic understanding of what's behind the wheel.

It's not until the second week of class that I notice a small disclaimer on the AI course website: *Prerequisites: A solid understanding of probability and linear*

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

Labels: POSTERIOR, LIKELIHOOD, PRIOR

Labels for P(B): MARGINAL LIKELIHOOD, TOTAL PROBABILITY

$$P(B) = \sum P(B|A_i) \cdot P(A_i)$$

$$P(+|+) = \frac{P(+|C) \cdot P(C)}{P(+)} = \frac{0.5 \cdot 0.01}{0.005 + 0.198} \approx 0.0434$$

Online videos for CS221 feature Thrun deconstructing key concepts and formulas.

algebra will be required.

Solid understanding? I majored in English. This makes me a "fuzzy" (what Stanford techies call liberal arts majors behind their backs). And now I'm trying to wrap my head around Bayesian probability, a branch of statistics that in the past 25 years has revolutionized a dozen fields from genomics and robotics to neuroscience. I'm told it all boils down to this formula:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

Apply this rule to a computational problem and you can make efficient predictions based on otherwise unreliable data. Practical applications, aside from programming autonomous cars, include calculating a woman's risk of breast cancer, analyzing DNA, and building a better spam filter.

That stuff's all easier said than done. But the basics are actually fairly basic. I manage to score 58 percent on this homework assignment. I may not comprehend every which way to Bucharest. But in five weeks maybe I'll be ready to tackle a spam filter.

SEBASTIAN THRUN STEPPED onstage at the March 2011 TED conference in Long Beach, California. In a ballroom filled with 1,000 heavyweight thinkers, the roboticist and AI guru offered a peek at his latest proj-

ect at Google: a charcoal-gray Toyota Prius outfitted with a laser range finder, radar, and cameras. He showed video of the sedan navigating through highway traffic, dodging deer on a pitch-dark road, and even zig-zagging down San Francisco's Lombard Street—all without a human so much as touching the wheel, the gas, or the brake. The applause roared.

You'd think that would have been Thrun's favorite moment at TED. But it wasn't. Salman Khan also made a presentation that week. The founder of Khan Academy, which WIRED profiled last August, told the story of his nearly six-year-old website, which provides more than 2,800 tutorial videos in subjects like science, math, and economics. Khan capped off his talk by emphasizing how he's growing a "global one-world classroom." Joining him onstage. Bill Gates called Khan Academy "the future of education." For Thrun, it was a full-on epiphany. "I was flabbergasted," he says. "I teach a lot of great students at Stanford. But the entire world is out there."

Even on a campus with 17 Nobel laureates, four Pulitzer Prize winners, and 18 recipients of the National Medal of Science, Thrun has managed to distinguish himself. In 2004,

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six months after arriving at Palo Alto as an associate professor, he was named director of the Stanford Artificial Intelligence Laboratory. The next year his team won the Darpa Grand Challenge, a competition to build an autonomous car that can drive itself across the Nevada desert, (WIRED wrote about the 132-mile robo-race in 2006.) For Thrun's achievement, Stanford was awarded a \$2 million prize. Today "Stanley," Thrun's self-driving Volkswagen Touareg, lives at the Smithsonian. In April 2011, Thrun gave up his tenure at Stanford to head Google X, a lab created to incubate the company's most ambitious and secretive projects. He was also free to pursue outside ventures.

After seeing Khan at TED, Thrun dusted off a PowerPoint presentation he'd put

sity of Bonn in Germany in the late 1980s, he found his AI professors to be clueless. He spent a lot of time filling in the gaps at the library, but he longed for a more direct connection to experts. Thrun created his PowerPoint presentation because he understood that university education was a system in need of disruption. But it wasn't until he heard Khan's talk that he appreciated he could do something about it. He spoke with Peter Norvig, Google's director of research and his CS221 coprofessor, and they agreed to open up their next class to the entire world. Yes, it was an educational experiment, but Thrun realized that it could also be the first step in turning that old PowerPoint into an actual business.

In June he took the next step: cofounding KnowLabs, which he funded with \$300,000 of his own money. He pulled in David Stavens, one of Stanley's cocreators, as CEO; he tapped Stanford robotics researcher Mike Sokolsky to be CTO. They converted Thrun's guesthouse into a temporary office. Thus ensconced on a scenic hillside on Page Mill Road near Stanford's campus, the team began planning. They had eight weeks before the fall term started—not unreasonable given the modest scope of the project. Stavens thought they'd

get 500 students. Sokolsky hoped for 1,000. Norvig figured they might hit 2,000.

In late July, Thrun emailed 1,000 members of the Association for the Advancement of Artificial Intelligence, a group that had weathered the AI winter of the 1980s and '90s only to see the field later revitalized by the likes of Stanley. By the next morning 5,000 students had signed up. A few days later the class had 10,000. That's when the Stanford administration called. Thrun had neglected to tell them about his plan—he'd had a hunch it might not go over well. The university's chief complaint: You cannot issue an official certificate of any kind. Over the next few weeks, 15 meetings were held on the matter. Thrun talked to the dean's office, the registrar, and the university's legal department. Meanwhile, enrollment in CS221 was ballooning: 14,000, 18,000, and—just two weeks later—58,000.

In all those meetings, not one person objected to Thrun's offering his class online for free. They admired his vision. The administration simply wanted Thrun to drop the assignments and certificate. He refused. Those two components, he argued, were responsible for driving the signups. Someone proposed removing Stanford's name from the course website altogether. Eventually they reached a compromise: (1) Offer a Statement of Accomplishment, not a certificate, and (2) include a disclaimer stating that the class wouldn't count toward Stanford credit, a grade, or a degree.

Thrun didn't have time to celebrate. By mid-August, word of his AI class went viral after a write-up in *The New York Times*. Enrollment skyrocketed past 100,000. KnowLabs' website had been built to handle 10,000 students. Class was starting in a matter of weeks. "That," Sokolsky says, "is when I stopped sleeping."

EDUCATION, MARK TWAIN once said, is the path from cocky ignorance to miserable uncertainty. By that standard, it seems I'm making progress. After a month of CS221, I've come to dread the homework, especially when I check back on my performance: 60 percent, 33 percent, 44 percent. Technically, I guess you could say I'm failing. Few of the concepts in CS221 click easily for me.

The videos, which are sometimes weirdly entertaining, do help. A unit usually begins with a close-up of Thrun or Norvig in a makeshift studio speaking directly to the camera. Then you see a tight shot of a drawing pad and watch their hands write out variables, diagrams, and calculations as they provide voice-over elucidation. It's all recorded with a DSLR camera mounted on a tripod. The videos are broken up with questions, prompting students to engage, so the team overlays HTML form boxes onto each video. This allows answers to be submitted directly into the browser. The videos aren't flashy or polished; they take their inspiration from Khan Academy, which pioneered this technique of intimate, direct instruction. It's a stark contrast to MIT's OpenCourseWare videos, which mostly depict professors from afar, scribbling on blackboards. Still, some of my classmates are underwhelmed. "In a world of slick presentations and animated diagrams," one student blogs, "this looks a little homespun."

But because CS221 seems like a work in

FIFTY YEARS FROM NOW, ACCORDING TO THRUN, THERE WILL BE ONLY 10 INSTITUTIONS IN THE WHOLE WORLD THAT DELIVER HIGHER EDUCATION.

together in 2007. Back then he had begun envisioning a YouTube for education, a for-profit startup that would allow students to discover and take courses from top professors. In a few slides, he'd spelled out the nine essential components of a university education: admissions, lectures, peer interaction, professor interaction, problem-solving, assignments, exams, deadlines, and certification. While Thrun admired MIT's OpenCourseWare—the university's decade-old initiative to publish online all of its lectures, syllabi, and homework from 2,100 courses—he thought it relied too heavily on videos of actual classroom lectures. That was tapping just one-ninth of the equation, with a bit of course material thrown in as a bonus.

Thrun knew firsthand what it was like to crave superior instruction. When he was a master's-degree student at the Univer-

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progress, students are also eager to help improve it. Early in the term, for example, Thrun and Norvig decided to nix the programming exercises (a bummer to techies but a relief to us fuzzies). The team at KnowLabs had enough on its plate. But Vitalik Buterin, an 18-year-old high school senior in Toronto, stepped in to help. He spent a few days creating an "AI playground" where students could practice coding all those basic AI algorithms we'd been hearing so much about. The site presents puzzles, such as asking for the most efficient path from point A to B. Students can write a function in JavaScript—testing out A* search, breadth-first, and naive Bayesian analysis—and check their performance. "Find your way through a world with deadly obstacles and uncertain senses and actions and make your way to the goal," Buterin's site prompts students. Just like an autonomous Prius.

THRUN IS THRILLED. His experiment is working. More than 20,000 students have taken the midterm and are turning in weekly assignments. The website's stability is improving. CS221's YouTube videos have been viewed 5 million times. The team at KnowLabs has automated and ramped up the workflow: film, edit, double-check the lessons, post, and monitor the message boards to put out fires.

The course is hitting eight of Thrun's nine educational components. Sure there's room for improvement. But what they're building is starting to look less like a whimsical one-off and more like a legitimate venture. They've hired a second engineer, who also serves as a teaching assistant to oversee the discussion forums. By November they're staffing up again, with a new video editor and a web designer to rethink the interface for future courses.

Stavens is thinking about potential business models. Though Thrun cringes at the notion of charging students, people might eventually pay for add-ons—say, TA services, study aids, or offline materials. He also considers other revenue streams. Near the end of the term, he emails his top 1,000 students, the ones with perfect or near-perfect scores on homework and tests. The subject: Job Placement Program. Thrun solicits resumes and promises to get the best ones into the right hands at tech companies, including Google. A recruiter who places a hire typically earns 10 to 30 percent of an

engineer's first-year salary, which might be \$100,000. Stavens figures he could charge much less. After all, KnowLabs discovers talent in the course of doing business.

In December the company secures a sizable chunk of money from Charles River Ventures, a VC firm specializing in early-stage investments. First order of business: another hiring spree, which more than doubles the staff, bringing it to 14. KnowLabs revamps its software from scratch and starts to work on a full site redesign.

KnowLabs already has competition: At the same time as CS221, two other computer science courses are being taught at Stanford using another digital platform. (Neither has attracted near the number of enrollees as CS221, but some students taking all three say the materials and website for CS221 are less polished.) Two Stanford professors then develop that platform into Coursera, an independent venture for serving online courses. (They're beginning with Stanford but plan to expand to other institutions.) The plan is to offer 14 classes in 2012, including cryptography, anatomy, and game theory. For now, these are all free. Then MIT announces it is racing to catch up with Stanford by creating a program called MITx, which will serve up a handful of online courses in the fall of 2012. Enrollment and participation will be free, but to earn a certificate of completion students will have to pay a "fairly modest" but yet-to-be-determined fee.

Thrun isn't worried that these respected universities or faculty will crush his startup. He's envisioning his own digital university, with a less conventional curriculum, one based on solving problems, not simply lectures on abstract topics. It would offer a viable alternative for students of the global one-world classroom—particularly those who lack the resources to move to the US and attend college.

Thrun decides that KnowLabs will build something called Udacity. The name, a mashup of *audacity* and *university*, is intended to convey the boldness of both Thrun's and his students' ambitions. His goal is for Udacity to offer free eight-week online courses. For the next six months or more, the curriculum will focus on computer science. Eventually it will expand into other quantitative disciplines including engineering, physics, and chemistry. The idea is to create a menu of

high-quality courses that can be rerun and improved with minimal involvement from the original instructor. KnowLabs will work only with top professors who are willing to put in the effort to create dynamic, interactive videos. Just as Hollywood cinematography revolutionized the way we tell stories, Thrun sees a new grammar of instruction and learning starting to emerge as he and his team create the videos and other class materials. Behind every Udacity class will be a production team, not unlike a film crew. The professor will become an actor-producer. Which makes Thrun the studio head.

He's thinking big now. He imagines that in 10 years, job applicants will tout their Udacity degrees. In 50 years, he says, there will be only 10 institutions in the world delivering higher education and Udacity has a shot at being one of them. Thrun just has to plot the right course.

IT'S A CRISP AND SUNNY December morning at Stanford—the last day of class—and Thrun steps up to a podium to deliver the in-class lecture. I'd pictured crashing a

hall packed with techies, but only 41 students out of 200 show up. Four stroll in late. Two fall asleep. Five leave early. That's not uncommon. There's little incentive to come to class. During the fall term, the Stanford students taking CS221 preferred watching the KnowLabs videos. Thrun says this improved their performance. In previous years his students averaged 60 percent on the midterm; this time around they did much better. Thrun swears the exam was tougher than any other he's given at Stanford. My online classmates averaged 83 percent overall. (I did not help the average.)

He doesn't congratulate himself for long. Along with the technical hurdles, including scaling up the website and staving off at least three denial-of-service attacks, Thrun acknowledges some harsh feedback from his students. "We made a lot of mistakes," he says. "In the beginning I made each problem available only once. I got a flaming email from a student saying, 'Look, you're behaving like one of these arrogant Stanford professors looking to weed out students.' I realized we should set up the student for success, not for failure." Know-

Labs tweaked the software to allow students to keep trying problems.

My initial approach to the class was wrong too. At the beginning of the term, I joined an offline study group in San Francisco and met with six of my classmates at a pub. As I expected, discussing problems was very helpful. Unfortunately, the group fizzled well before the midterm. Agreeing on a time and location proved too difficult.

Online, of course, that wasn't an issue. A dozen or more discussion groups formed on Facebook, and students organized virtual study sessions via Google+ and private IRC channels. I posed questions on the Q&A site Aiquis and on Reddit discussion boards at all hours of the day and night and received explanations and tips from around the world in near real time. On Aiquis alone, more than 4,000 questions were posted, and they received more than 13,000 answers. All that information was scattered, though. I had to filter through a dozen comment threads on Aiquis and open a dozen tabs in my browser just to solve one homework problem. It was difficult to focus.

Filip Wasilewski, a 30-year-old IT con-

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sultant in Lodz, Poland, experienced the same frustration. So he spent three nights coding a piece of software to fix the problem. Wasilewski's solution, a JavaScript add-on to Google's Chrome browser, fetched relevant Aiquis questions and displayed them on the AI course website, right beneath the corresponding video. I could scan discussion subject headings without clicking on another tab. More than 2,000

helmed by David Evans, a professor on sabbatical from the University of Virginia, was designed specifically for people with zero background in programming. Thrun tapped Google cofounder Sergey Brin to appear in a YouTube video promoting the class. It worked.

An hour before that last lecture, I stop by Thrun's office to say hello. "We have a recipe that works," he tells me proudly.

students installed the plug-in.

Thrun expects such student-built innovations to multiply as Udacity ramps up this year.

In February it offered its first two eight-week courses for free. These classes are not affiliated with Stanford, and as of this writing, a combined 65,000 students have registered for CS373: Programming a Robotic Car and CS101: Building a Search Engine. The robotic car course, taught by Thrun, requires some math and engineering chops. But the search engine class-

"Putting these ingredients together and working really hard to create good content and a good experience for the students, we can break through."

I have only a vague idea of how an autonomous car drives itself. I'm nearing the end of CS221 and I've never wanted a D-minus so badly in my life. Sadly, I don't quite pull it off. My total score for the term: 52.7 percent. That's 7.3 percent below passing—in other words, an F. I've never failed a class before. If I were an actual Stanford student, this would tarnish my GPA. It might wreck my chances of landing a summer internship. It would certainly disappoint my faculty adviser.

But I'm not an actual Stanford student. I'm a gate-crasher. A fuzzy one. At least I finished. That's better than the 137,000 registered students who dropped out. I decide to print out my Statement of Accomplishment. Will I frame it and hang it next to the master's degree in my office? Maybe. Will I ever build a better spam filter? Probably not. Will I take another online course? I'm no expert, but the probability seems high.