

Degrees, designed by the numbers

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Which courses should a student take? How should professors proceed in class? Let the new data-mining software decide.

Campuses are places of intuition and serendipity: A professor senses confusion on a student's face and repeats his point; a student majors in psychology after a roommate takes a course; two freshmen meet on the quad and eventually become husband and wife.

Now imagine hard data substituting for happenstance.

As Katie Allisone, a freshman at Arizona State University, hunkers down in a computer lab for an 8:35 a.m. math class, the Web-based course watches her back. Answers, scores, pace, click paths--it hoovers up information, like Google. But rather than personalizing search results, data shape Ms. Allisone's class according to her understanding of the material.

With 72,000 students, Arizona State is both the country's largest public university and a hotbed of data-driven experiments. One core effort is a degree-monitoring system that keeps tabs on how students are doing in their majors. Stray off-course and you may have to switch fields.

And while not exactly matchmaking, Arizona State takes an interest in students' social lives, too. Its Facebook app mines profiles to suggest friends. One classmate has eight things in common with Ms. Allisone, who "likes" education, photography, and tattoos. Researchers are even trying to figure out social ties based on anonymized data culled from swipes of ID cards around the Tempe campus.

This is college life, quantified.

Data mining hinges on one reality about life on the Web: What you do there leaves behind a trail of digital bread crumbs. Companies scoop them up to tailor services, like the matchmaking of eHarmony or the book recommendations of Amazon. Now colleges, eager to get students out the door more efficiently, are awakening to the opportunities of so-called Big Data.

The new breed of software can predict how well students will do before they even set foot in the classroom. It recommends courses, Netflix-style, based on students' academic records. Data diggers hope to improve an education system in which professors often fly blind. That's a particular problem in introductory-level courses, says Carol A. Twigg, president of the National Center for Academic Transformation. "The typical class, the professor rattles on in front of the class," she says. "They give a midterm exam. Half the kids fail. Half the kids drop out. And they have no idea what's going on with their students."

As more of this technology comes online, it raises new tensions. What role does a professor play when an algorithm recommends the next lesson? If colleges can predict failure, should they steer students away from challenges? When paths are so tailored, do campuses cease to be places of exploration?

"We don't want to turn into just eHarmony," says Michael Zimmer, an assistant professor in the School of Information Studies at the University of Wisconsin at Milwaukee, where he studies the ethical dimensions of new technology. "I'm worried that we're taking both the richness and the serendipitous aspect of courses and professors and majors--and all the things that are supposed to be university life--and instead translating it into 18 variables that spit out, 'This is your best fit. So go over here.'"

ALERT! YOU ARE OFF-TRACK

Ever since childhood, Rikki Eriven has felt certain of the career that would fit her best: working with animals. Specifically, large animals. The soft-spoken freshman smiles as she recalls the episode of Animal Planet that kindled this interest, the one about zoo specialists who treat rhinos, hippos, and giraffes. So when Ms. Eriven arrived at Arizona State last fall, she put her plan in motion by picking biological sciences as her major.

But things didn't go according to plan. She felt overwhelmed. She dropped a class. She did poorly in biology (after experiencing problems, she says, with the clicker device used to answer multiple-choice questions in class). Ms. Eriven began seeing ominous alerts in her e-mail inbox and online student portal. "Off-track," they warned. "It told me that I had to seek eAdvising," she says. "And I was, like, eAdvising?"

Yes, eAdvising. Universities see such technology as one answer to a big challenge. On average, only 31 percent of students at public colleges earn their bachelor's degrees within four years, and 56 percent graduate within six years. Such statistics have come under greater scrutiny as parents and politicians demand accountability from colleges. Tennessee, for example, doles out higher-education dollars in part by measuring how effective an institution is at graduating students.

Yet some students show up with ambitions that bear no relation to their skills. Or parents push them into majors that don't interest them. Or they feel like shoppers in a cereal aisle, confounded by the choices.

At Arizona State, which has more than 250 majors, the old system let students explore without much structure. A student could major in engineering to please his parents, only to pack his schedule with "Chinese Thought" and music, says Elizabeth D. Capaldi, the provost. No longer. Technology has redrawn the road map.

Under Arizona State's eAdvisor system--in use since 2008-9 and based on a similar effort at the University of Florida--students must pick a major in their freshman year and follow a plan that lays out when to take key courses. (Students can still study broadly, by choosing from five "exploratory" majors, like "arts and humanities" or "science and engineering," and staying in them for 45 credits.) If they fail to sign up for a key course or do well enough, the computer cracks a whip, marking them "off-track." A student who wanders off-track for two semesters in a row may have to change majors.

If that sounds harsh, there's a rationale: One way to ensure that students will reach the finish line is to quickly figure out if they've selected a suitable track. So the Arizona State system front-loads key courses. For example, to succeed in psychology, a student must perform well in statistics.

"Kids who major in psych put that off, because they don't want to take statistics," Ms. Capaldi says. "They want to know, Does their boyfriend love them? Are they nuts? They take all those courses, then they hit statistics and they say, 'Oh, God, I can't do this. I can't do experimental design.' And so they're in the wrong major. By putting those courses first, you can see if a student is going to succeed in that major early."

Arizona State's retention rate rose to 84 percent from 77 percent in recent years, a change that the provost credits largely to eAdvisor.

For students who run off-track, the outcome can sting. Ms. Eriven was shocked to learn that she would have to change her major after the system flagged her. She cried, called her mother, and recalibrated her plans. In a meeting with an adviser, she described her interests. She likes science. She is family-oriented, interested in music, and good at writing. The adviser suggested a few possible majors, including psychology, family and human development, and creative writing.

Writing. It would involve only a couple of classes each semester. She could still take science and, she hoped, switch back to biology. So that's what she chose. "I didn't really have, like, a backup plan," Ms. Eriven says.

But what if you could rewind that story and shape a student's path before she reached such a crossroads?

YOU WILL PASS (OR NOT)

When Adam Lange began working full time at Rio Salado College, in 2008, he was still an undergraduate at nearby Arizona State, a 22-year-old computer-science major with a budding obsession with data. Over time, that obsession would shape the learning experience for thousands of students--and drive his fianc?(c)e bonkers.

Mr. Lange's idea of fun is converting his home into a surveillance lab. He outfitted his cat, Sammy, who has an eating disorder, with a device that is read by a scanner every time the cat cranes his neck over the bowl. Mr. Lange monitors the logs and feeds Sammy a treat if he hasn't eaten. He also rigged a Webcam next to the fish tank, logging the coordinates of his Betta fish several times a second to find out what paths it commonly takes and how far it travels (90 feet in one hour!).

At Rio Salado, a community college with about 70,000 students, 43,000 of them online, Mr. Lange got excited about the behavioral data they leave behind: the vast wake of clicks captured by software that runs Web courses. Records of when they logged in, opened a syllabus, turned in homework--all just sitting there. Could you mine the data to model patterns of students who succeeded in the past? Use the analysis to identify current ones likely to fail? And then help them? Many educators are now asking similar questions.

Mr. Lange and his colleagues had found that by the eighth day of class, they could predict, with 70-percent accuracy, whether a student would score a C or better. Mr. Lange built a system, rolled out in 2009, that sent professors frequently updated alerts about how well each student was predicted to do, based on course performance and online behavior.

To Mr. Lange, the underlying math doesn't differ much from what he might deploy in his fish espionage. Say the Betta makes two consecutive movements side to side and then 85 percent of the time swims upward. In the future, if the fish moves left and then right, Mr. Lange can say with confidence that it will then swim up. Similarly, Rio Salado knows from its database that students who hand in late assignments and don't log in frequently often fail or withdraw from a course. So the software is more likely to throw up a red flag for current students with those characteristics.

"There's a predictability about the fish," says Mr. Lange, now 26 and working for Ellucian, a higher-education-software company. "The same concept applies to students."

The software can help a professor identify students who may need extra assistance. But Rio Salado's experiments with more-formal intervention strategies have yielded mixed results. And in a cautionary tale about technical glitches, the college began sharing grade predictions with students last summer, hoping to encourage those lagging behind to step up, but had to shut the alerts down in the spring. Course revisions had skewed the calculations, and some predictions were found to be inaccurate. An internal analysis found no increase in the number of students dropping classes. An improved system is promised for the fall.

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Austin Peay State University, a midsize institution about 45 minutes northwest of Nashville, takes the algorithmic approach to higher education one step further. Before students register for classes, a robot adviser assesses their profiles and nudges them to pick courses in which they're likely to succeed.

The project is the work of Tristan Denley, a programmer turned math professor turned provost. His software borrows a page from Netflix. It melds each student's transcript with thousands of past students' grades and standardized-test scores to make suggestions. When students log into the online portal, they see 10 "Course Suggestions for You," ranked on a five-star scale. For, say, a health-and-human-performance major, kinesiology might get five stars, as the next class needed for her major. Physics might also top the list, to satisfy a science requirement in the core curriculum.

Behind those recommendations is a complex algorithm, but the basics are simple enough. Degree requirements figure in the calculations. So do classes that can be used in many programs, like freshman writing. And the software bumps up courses for which a student might have a talent, by mining their records--grades, high-school grade-point average, ACT scores--and those of others who walked this path before.

"We're steering students toward the classes where they are predicted to make better grades," Mr. Denley says. The predictions, he adds, turn out accurate within about half a letter grade, on average.

The prediction process is more subtle than getting a suggestion to watch *Goodfellas* because you liked *The Godfather*. Take the hypothetical health major encouraged to take physics. The software sifts through a database of hundreds of thousands of grades other students have received. It analyzes the historical data to figure out how much weight to assign each piece of the health major's own academic record in forecasting how she will do in a particular course. Success in math is strongly predictive of success in physics, for example. So if her transcript and ACT score indicate a history of doing well in math, physics would probably be recommended over biology, though both satisfy the same core science requirement.

Mr. Denley points to a spate of recent books by behavioral economists, all with a common theme: When presented with many options and little information, people find it difficult to make wise choices. The same goes for college students trying to construct a schedule, he says. They know they must take a social-science class, but they don't know the implications of taking political science versus psychology versus economics. They choose on the basis of course descriptions or to avoid having to wake up for an 8 a.m. class on Monday. Every year, students in Tennessee lose their state scholarships because they fall a hair short of the GPA cutoff, Mr. Denley says, a financial swing that "massively changes their likelihood of graduating."

"When students do indeed take the courses that are recommended to them, they actually do substantially better," he says. And take them they do. Last fall 45 percent of classes on students' schedules were from the top-10 recommendations, and 57 percent from the top 15. Though these systems are in their infancy, the concept is taking hold. Three other Tennessee colleges have adopted Mr. Denley's software, and some institutions outside the state are developing their own spins on the idea.

Some people express concerns about deferring such important decisions to algorithms, which have already come to dictate--and limit--so much of what we see and do online. Mr. Zimmer, the Milwaukee information-studies professor, sees the value in preventing students from going down paths that may frustrate them or even cause them to quit college. But as higher education gets more efficient, he fears the loss of the unanticipated discovery.

"It's the same as if you're worried about whether or not Google or Amazon are going to present you with alternative topics, or only the topics that fit your history," he says. "We hope the role of a university is to make sure people are exposed to diverse things and challenged."

DIRECTION THROUGH DATA

At Arizona State, algorithms figure in course content, too. Thousands of students there now take math courses through a system that mines data on performance and behavior, building a profile of each user and delivering recommendations about what learning activity should be

next. The system, created by the start-up company Knewton, has given the university a fresh way of addressing the continuous problem of students' being unprepared for college math. It also offers a glimpse into what many more students will experience as teaching increasingly shifts from textbooks and lectures that feed the same structure of information to a class of 300, regardless of individual expertise, to machines that study users' learning patterns and adapt to them.

That excites some educators. George Siemens, a data-mining expert at the Canadian distance-learning university Athabasca, calls the traditional approach an inefficient model "that generates a fair degree of dropouts."

Knewton dismantles that model. Ms. Allison's 8:35 a.m. class is not a lecture. Although students are supposed to show up at a fixed time, and an instructor is there to work with them, the action is on screen. Knewton allows Ms. Allison to skip past some concepts she gets, like factors and multiples. When she struggles with inverting linear functions, the software provides more online tutoring. Two students who complete the same lesson might see different recommendations as to what to do next, based on their proficiency.

As the company develops and works with more data and content--major institutions like University of Nevada at Las Vegas are adopting its technology, as is the publishing giant Pearson--it will tailor instruction more finely. What time of day does a student best learn math? What materials and delivery styles most engage the student? Say you have the same concept explained in a video, in a textbook-like format, and in interactive Socratic steps. Knewton will associate a student's "engagement metrics" with those styles and use that to help determine the next step.

But what sounds flashy may be based, at least in part, on flawed assumptions, warns Richard E. Clark, a professor of educational psychology and technology at the University of Southern California. There is no evidence, he says, that there are "visual" learners who benefit from video over text, as Knewton's technique implies. Studies, he says, have shown that learning styles are not effective for shaping instruction.

The broader problem with data mining, as Mr. Clark sees it, is that it is seldom done right. Data analysts often make "questionable assumptions" about the meaning of keystrokes, he says. They assume, for example, that students who are spending the most time on some learning material are most interested in that content. "That assumption may be true when people choose to watch Netflix movies but is not at all the case in many university courses where few choices are available," he says.

Meanwhile, dismantling old models leaves both professors and students adjusting to new roles. Suzanne Galayda, an Arizona State math instructor, finds that it takes longer to penetrate the wall of computer screens and build rapport with students. In her remedial class, they start off feeling uncomfortable asking questions. But even as the software elbows her off center stage, it also helps her play her part with far more information--so much data about what students do, and when, that it sometimes surprises them.

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"Students don't realize that we're watching them in these classes," she says.

Ms. Galayda can monitor their progress. In her cubicle on a recent Monday, she sees the intimacies of students' study routines, or lack of them, from the last activity they worked on to how many tries they made at each end-of-lesson quiz. For one crammer, the system registers 57 attempts on multiple quizzes in seven days. Pulling back to the big picture, a chart shows 15 students falling behind (in red) and 17 on schedule (in green).

On Wednesday, Ms. Galayda rubs her hands with satisfaction. The chart is mostly green. Mostly. When the class meets, she taps her nails on the hard drive of Carolina Beltran's computer. "You were working on it at 4 a.m.," the instructor tells the student.

"Yeah, I mean, like, I sleep. My sleeping schedule is weird," Ms. Beltran stammers.

Arizona State's initial results look promising. Of the more than 2,000 students who took the Knewton-based remedial course this past year, 75 percent completed it, up from an average of 64 percent in recent years.

In Ms. Galayda's experience, students "either love it or hate it."

Ms. Allison raves: "I learned more in this semester than I have in a year in high school." She praises the clarity and concision of the system's instructional videos, contrasting them with the many teachers who "have issues communicating correctly."

But another freshman, a health-sciences major who requested anonymity because she did poorly for two semesters, recalls a downward slide that began when she started falling a couple of lessons behind. That scared her at first, until she talked with her peers. Some were six lessons behind. Twelve, even. How bad could two be? She didn't sweat it. As she juggled social life, work, and other classes, math fell through the cracks. She ended up having to retake the course, a case study in the danger of giving self-paced classes to freshmen.

"I like lecture better," she says. "I'm not used to teaching myself. So it was a huge adjustment."

THE SOCIAL NETWORK

These experiments are only the beginning. Colleges will very likely dig deeper into the data at their disposal, touching more and more aspects of student life. Already, some researchers are eyeing the next frontier: social life.

Research shows that social ties can influence academic success. If students are more integrated into campus life, they're more likely to stay in school. If a friend drops out, they're more likely to as well.

"If the university could model, at a high level, the social network of the college, that would be a very useful data layer," says Matthew S. Pittinsky, who co-founded Blackboard, a company that provides platforms for online classes, and later became an assistant research professor in the sociology program at Arizona State. A college might reach out to a student "who is not showing evidence of social integration," pointing out extracurricular activities and communities that might tie them more deeply to the institution, he says.

Working with computer scientists, Mr. Pittinsky started an academic research project that tiptoes toward a better understanding of social connections. The research team's raw material: anonymous logs from swipes made with Arizona State ID cards. When students use the cards, be it to buy food on campus or enter the fitness center, the transaction is recorded. The question that struck Mr. Pittinsky was whether social ties could be inferred from those trails.

Say two students swipe within 10 seconds of each other at different times of day in different contexts. Are they more likely to be friends? And can you predict attrition by pinpointing changes in how a student uses a campus? Say someone goes to Starbucks at 2 p.m. every day before a 2:15 p.m. class. Then stops. "If that happens three weeks in a row," Mr. Pittinsky says, "and we're not seeing log-ins into Blackboard, and maybe you've made a request at the registrar to have your transcript sent somewhere, there ought to be an adviser with a really big red flashing light saying, Reach out to this student."

The prospect of card-swipe surveillance discomfits Mr. Zimmer, the Milwaukee information-studies professor. He worries that authorities might misuse location data to do things like track foreign students or organizers of a protest demonstration.

But the broader issue of privacy hangs over less Orwellian efforts to collect and monitor personal data. In his own syllabi, Mr. Zimmer includes a disclaimer disclosing what he can see via the university's online-learning platform, including "the dates and times individual students access the system, what pages a student has viewed, the duration of visits, and the IP address of the computer used to access the course Web site."

For his part, Mr. Pittinsky emphasizes that the card-swipe research is "very focused on the ability to protect anonymity."

As for students, they've never been fond of adults meddling on Facebook, let alone getting all Big Brother with card swipes. "Creeping on us" is how Ms. Allisone, the freshman, describes the card-swipe project. She has managed to keep one aspect of her life--she hopes to transfer from Arizona State--from any "creeping." But that, too, may change.

Arizona State monitors requests for transcripts to be sent elsewhere, notes Ms. Capaldi, the provost. "Which," she says, "is kind of sneaky."

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