EXPLAINER

Digital-Twin Technology and Higher Ed

What is a "digital twin"?

A digital twin is a virtual replica of an object, system, or environment in the physical world — a human heart, an automobile, or a crowded college campus. Often it can be updated with real-time data from sensors, evolving whenever — and however — its physical counterpart evolves. This lets observers monitor its transformation immediately and in detail.

Digital-twin technology also allows for running simulations that anticipate how an object or system will change at various points in the future — the moment when the heart might fail, or the car might crash, or the campus infrastructure might fall apart — and predict what kinds of interventions could alter its course.

"We can replicate the physical world in the virtual world and make predictions about what's going to happen," says the information-technology scientist Michael Grieves, who introduced the digital-twin concept at a conference more than two decades ago and is now founder and executive director of the Digital Twin Institute, a research and consulting company, as well as a professor at the University of Central Florida. (Grieves notes that his colleague John Vickers, principal technologist for advanced materials and manufacturing at NASA, gave the concept its name.)

Over the years, industries like engineering, manufacturing, and health care have begun to use digital twins to allow their products to be tested and refined before they're manufactured. (This is an example of the kind of twins that don't yet have counterparts in the physical world.) Once manufacturing starts, twin technology can also help make sure the process is going according to plan.

"There's huge efficiency and effectiveness in being able to have information" and "not to waste resources," Grieves says. He believes that twinning increasingly will help to track objects' locations and thus help to solve mysteries like the widely publicized Malaysian airliner disappearance in 2014: "We'll know exactly where airplanes are, because

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they'll have digital twins." In fact, digital twins may be used in a number of industries — and recent advances in virtual reality and artificial intelligence mean this future will arrive faster than it otherwise might have.

For higher education specifically, these pairings represent a pair of opportunities: First, Grieves and other experts say, the technology can substantially improve college operations — campus planning and tours, facilities management, and energy efficiency, just to name a few. Second, it can transform academics and scholarly research in dramatic ways, as students and faculty gain new methods of exploration and experimentation with virtual objects and in virtual settings.

Dan Munnerley, co-founder and executive director of Next Lab (formerly Learning Futures) at ASU Enterprise Technology, has helped to make Arizona State University a digital-twinning pioneer. Students at Next Lab created ASUniverse, a digital twin of the Tempe campus. This involved gathering data from the interiors and exteriors of university buildings, and then uploading the information to a game-development engine. (While many metaverses aren't digital twins, because they're fantasy worlds, a number of colleges are creating digital twins of their campuses, known as "metaversities.")

ASU community members can enter the ASUniverse by visiting Next Lab, a kind of production studio for technology innovation on campus, which employs roughly 50 students for 20 hours a week to learn, create, and then teach about twinning. Munnerley says their metaverse includes lecture theaters, sports facilities, and the Memorial Union community center. "We've actually built the whole campus — 250 buildings and 650 acres of virtual real estate," he says. "We can run virtual tours, have teaching and co-curricular activities, and sporting events."

ASU's digital-twinning work is also developing new means of improving life for residents of the university's region. "We've built twins of Maricopa County — the whole of the county — and the watershed that comes from the Colorado River to help tell stories about how dropping water levels will impact Arizona residents," Munnerley explains. "We've also built twins of manufacturing plants, including a microelectronics plant, letting students learn how to use those plants."

Munnerley says Next Lab is focused on where technology fields are heading and what skills and mind-sets students will need to thrive in these fields — and it's not just engineering students at ASU who are curious to learn more about digital twins.

Many students and faculty members are visiting Next Lab. "Every discipline at the university is interested," Munnerley says, "because there's some way each of them can use simulations and twinning." As he sees it, twinning is fundamentally about world building — it's a field that can open up a world of new possibilities for colleges, if they're prepared to take advantage of it.

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How can digital twins help colleges with their campus operations?

By creating digital twins of their campuses — or even just parts of their campuses — colleges can assess everything, including their traffic flow, how much solar power they're generating and using, and what the construction of new buildings would look like.

"If you want to make sure a class is sitting in comfort, you can use sensors to

measure the temperature or humidity of a particular room and gain insights about what's happening now and what's going to happen over the next two hours," explains Soheil Sabri, who directs the University of Central Florida's Urban Digital Twin Lab. "You can even use historical data to plan for classes and their occupancies in the future." As climate change brings about more extreme weather, questions about heat and shade on campuses may become more salient.

Then there's the potential twinning holds for allowing students to participate as avatars in a virtual realm — attending classes, concerts, or sporting events virtually. This could be especially beneficial for remote students or those who, for whatever reason, can't be present on campus at any given time.

How can digital twins enhance academics and research?

Adopting operational uses of twinning technology may prove the easiest sell for colleges. (There's an obvious business benefit to the efficiencies and cost savings they promise.) Yet it's also easy to imagine the ways twins could make learning more personal and experiential inside and outside the classroom: History students could put on virtual-reality headsets and explore a twin of a historical site. Business students could work not just with twins of products, but also twins of manufacturing facilities or supply chains. ("You can actually simulate a production line," Munnerley says. "You can simulate every single robot on that line, throwing in disasters to stress test and see the effects on the bottom line of the business.")

Performing-arts students could benefit from twins of theaters, where lighting, sound, and set design could be tested. Doctors and nurses in training could use twins of the human body to test whether treatments would work — or use twins of particular organs to learn, for example, how to perform heart surgery. "When you're teaching medical students which ablation techniques work best and you're doing that in a simulation, that's a heck of a lot better than turning them loose on a patient for the first time," Grieves says. Another possible use, he says, is in archaeology: "You could put on immersive goggles and walk through an old temple in Greece in 400 BC."

Grieves notes that there are countless projects students could do virtually with twins that they'd never be able to complete otherwise, sometimes because they'd be cost-prohibitive: "You want to build a rocket ship? You can't afford to do it physically, but you can do it digitally — and send it to Mars."

Grieves and Munnerley both say there's evidence that many students learn better when they use simulations and 3-D visualizations, arguing that digital twins could be very advantageous in this respect. "Simulation is probably the most powerful way to learn," Munnerley says, "but in the past it's been something we've done in our brains — we've had to imagine the simulation. A digital twin gives you an actual working model." Especially when you're learning anatomy, he emphasizes, "if you see it three-dimensionally, you'll learn it better than if you see it on paper."

Toby Vaughn Kidd, Next Lab's co-founder and studio director, says digital twinning also can be "a tool for social good," including by furthering academic research into issues like water scarcity and lack of broadband access. A digital twin of a city or county can provide a detailed picture of where there are broadband shortages and then, by running various models and experiments, can help provide a better idea of where and how to improve the situation.

What are some of the concerns about digital twins?

Like all emerging technologies, twins raise new ethical questions, including how their detailed data can be used. There is a risk of personal data being exposed without permission. "We should be aware, if we're automating a system to make a decision, there's a responsibility to iden-

tify the extent to which we can rely on the results," Sabri says. "Culturally, we have to consider digital literacy and make sure this innovation is being used by all different age cohorts and people with different cultural backgrounds" and not assume everyone will have the same level of access to this technology or knowledge about how it works.

What are colleges doing to embrace this technology?

Vaughn Kidd believes twinning technology is ultimately going to become ubiquitous in higher education. We're in a moment "now when it's experimental," he says. "We're coming up with new ideas. But we'll reach a point where a twin won't be something you have to go to a special facility — or talk to a special team — to see. It'll be regular business at the university to pull up a twin to look at the health of systems and data across campus." He adds that twins will become easier to create and interact with.

For now, though, this field isn't a focus on most campuses.

"I talk to student after student, from great schools, who've never heard of digital twins," Grieves says. While most colleges may have programs in architecture or allow students to study topics like the built environment, gaming, design, animation, and visual communication, Munnerley says, "I have not seen any that specialize in digital twins or spatial computing as a subject."

Grieves worries academe is missing out on an enormous opportunity to draw digital natives into a burgeoning field. "There ought to be an introductory course about digital twins and their capabilities

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right as" engineering students "come in as freshmen," he says, "and I don't know of anybody who's doing that, to be perfectly honest."

Grieves and Sabri are working on drafting a curriculum that could be shared with colleges to help fill the gaps, particularly introductory coursework on digital twins. They are both part of the Digital Twin Consortium, which aims to create "digital-twin coursework for universities," including "showcasing early-stage use cases and how digital twins are applied in a variety of settings," and "develop an entire curriculum on how digital twins work, the value of digital twins, and the evolution of the technology."

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