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More on STEM ...

**FIXING THE STEM PIPELINE** Page 7

**FLYING COLORS** Page 9  
International students flocking to Ninth District

**AN INTERNATIONAL QUILT** Page 12



**INTERVIEW: ADNAN AKYUZ** Page 13  
Climate change and Ninth District ag

**DATA MAP** Page 16

## Getting to the root of STEM

*Colleges and universities in the district are producing more science and technology graduates. But job opportunity for those workers varies by occupation and geography, and demand for STEM skills is likely to grow*



**Career**



**Education**



# STEM

**SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS**



By PHIL DAVIES  
Senior Writer

**“STEM careers are in high demand and are an important part of our economy. ... I encourage students to consider getting a degree in a STEM field.”**

—South Dakota First Lady Linda Daugaard

Like fresh vegetables and retirement savings, STEM education is something we can't seem to get enough of. Nation-

wide and in the Ninth District, there's a general concern that not enough college students are earning degrees in STEM (science, technology, engineering and mathematics) fields. Educators and state officials urge more students to enroll in STEM programs so they can earn high wages and contribute to innovation and increased productivity.

Employers also want more young people to earn STEM degrees, and some report difficulties hiring STEM

graduates to fill entry-level positions and worry that the overall supply of STEM-educated workers is inadequate. “One of the major constraints of our business is getting enough talent,” said Todd Hauschildt, CEO of Swat Solutions, a Twin Cities software firm.

Worries about a STEM shortfall have prompted widespread efforts to boost the output of science and technology degree programs at U.S. universities and colleges. For example, Al Franken, a

Continued on page 2

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## STEM from page 1

U.S. senator from Minnesota, has sponsored legislation that would establish a national corps of top STEM teachers to improve science and technology instruction in K-12 schools, with the idea of encouraging more college students to major in STEM fields.

In the district, South Dakota First Lady Linda Daugaard has actively promoted STEM secondary education in her state. And a number of district universities have established statewide STEM networks of educators, state officials, employers and other stakeholders to prime the STEM pump and increase the number of science and technology majors. (For more on public and private efforts to foster STEM education, see “Fixing the STEM pipeline,” page 7.)

Like those in many other parts of the country, employers in the district rely heavily upon graduates of universities and colleges in their home states to staff their operations. Homegrown graduates are more likely to take jobs in Minneapolis, Bismarck, N.D., and Mitchell, S.D.—and stay in those positions—than graduates from outside the region.

It’s impossible to say with certainty whether the district suffers from a deficiency of STEM graduates, as many STEM advocates fear. The supply of and demand for STEM graduates varies geographically and over time, and the STEM rubric covers many occupations, each with its own labor market dynamics. Also, some components of demand, such as replacements for workers who retire or quit their jobs, are difficult to measure.

Moreover, as with any good or service, market forces tend to work to equalize supply and demand. There’s evidence that demand for STEM workers has increased in an expanding regional economy, but the output of STEM graduates from higher education institutions in the district has also increased. In addition, wage trends suggest that overall demand for STEM graduates is being met.

## The Quick Take

Educators, employers and others worry that the higher education system is producing too few science, technology, engineering and mathematics (STEM) graduates, workers prized for their skills and contribution to innovation and economic growth. A *fedgazette* analysis of STEM education and employment in the Ninth District finds that numbers of STEM graduates and job openings are both rising. But the availability of these graduates and other workers to fill STEM vacancies varies markedly across STEM fields.

However, the supply of STEM graduates relative to job opportunities in STEM occupations varies markedly across STEM fields. And there are signs of rising demand for STEM workers in some parts of the district and in certain STEM occupations. In Minnesota, for example, STEM job vacancies jumped last year, particularly in computer science and engineering.

Some employers have had to try harder to attract talented STEM graduates—raising wages, for instance, or offering internships to snag promising students while they’re still in school.

In coming years, demand for STEM graduates is likely to grow, and not just in traditional tech fields such as information technology, computers and scientific research. The pervasiveness of technology in today’s economy has led employers in an array of industries to value the aptitudes and skills that come with a STEM education.

## The root of prosperity

For all the attention paid to STEM, a surprisingly small slice of jobs can be categorized as STEM—positions requiring scientific or technical expertise. (See box for a discussion of how STEM occupations and degrees are defined.) Nationwide, only about 6 percent of

workers are in science, technology, engineering and mathematics occupations. In district states, STEM as a proportion of the nonfarm workforce ranges from 4 percent in South Dakota to 7 percent in Minnesota.

But STEM’s minor presence in the workforce belies its outsize impact on

cities that generated fewer patents. The high-tech hubs of Minneapolis-St. Paul and Rochester, Minn., made Brookings’ top-20 list of high-patenting metros.

Innovation doesn’t happen without workers trained in STEM fields, observes University of Minnesota President Eric Kaler, a STEM graduate (Ph.D. in chemical engineering) himself. “These are people employed in high-tech companies; they’re people creating the inventions and products that are going to drive the Minnesota economy in the future,” he said. “The leverage you get from somebody who’s innovative and who applies science and technology is very important.”

Kaler noted that alumni of the university’s College of Science and Engineering have founded 2,600 Minnesota companies that generate about \$46 billion in annual revenue and employ more than 175,000 people. Notable examples in the district include Medtronic, Ceridian and Pentair.

## STEM (ill) defined

STEM—science, technology, engineering and math—is a familiar acronym, widely used in government, academia and business to describe a set of fields of study in higher education, as well as a set of occupations that require STEM skills. But there’s no standard definition of a STEM degree or job. While fields such as computer programming, mechanical engineering and environmental science are generally considered STEM, there’s less consensus about fields such as medicine, architecture and science education.

The U.S. Department of Labor, for example, includes social scientists and health care workers in its definition of STEM occupations, while the U.S. Department of Commerce and the Minnesota Office of Higher Education exclude them.

For the purposes of this article, STEM degrees are those in engineering, math and the physical and life sciences (chemistry, biology, computer sciences, and so on) awarded at the two-year (associate) level and above.

STEM occupations are those typically requiring degrees in a STEM field, including agriculture-related disciplines such as soil, plant and animal sciences. The definition of STEM jobs used here encompasses managerial positions in STEM and workers such as laboratory technicians who support the work of STEM professionals.

Left out of the discussion and charts are health care workers, social scientists (such as psychologists and economists), and science and technology teachers.

—Phil Davies

the U.S. economy and the economies of states and local communities. New products and services born of technological advances (think the iPhone and cloud computing) increase the productivity of firms and workers, raising incomes and improving standards of living.

A 2013 study by the Brookings Institution found that U.S. metro areas with high patenting activity—a proxy for innovation—in fields such as computers, biotechnology and energy had higher productivity and lower unemployment than

STEM’s share of total employment may be small, but workers in STEM occupations enjoy higher pay and better employment prospects than non-STEM workers. STEM workers in occupations requiring a bachelor’s or advanced degree earned 4 percent to 24 percent more than similarly educated non-STEM workers in district states, according to federal labor statistics (see Chart 1). Minnesota had the highest STEM pay among district states; in 2012, the median wage for STEM workers in the

fedgazette

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One of the Minneapolis Fed’s congressionally mandated responsibilities is to gather information on the Ninth District economy. The *fedgazette* is published quarterly to share that information with the district, which includes Montana, North and South Dakota, Minnesota, northwestern Wisconsin and the Upper Peninsula of Michigan.

The opinions expressed in the *fedgazette* are expressly those of the authors or of attributed sources and are not intended to represent a formal position of this bank or the Federal Reserve System.

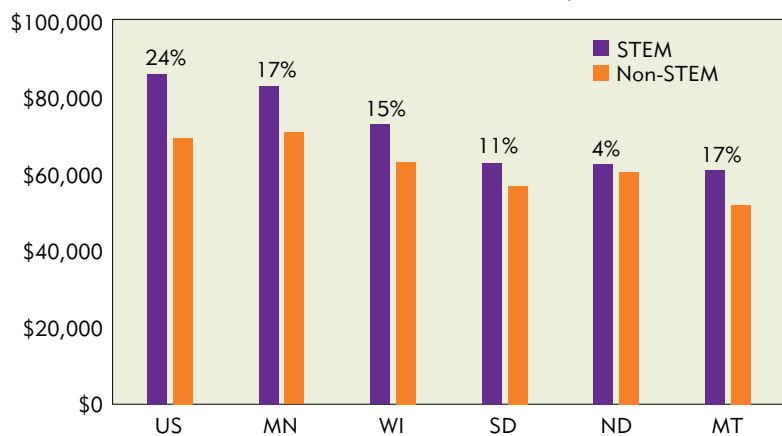
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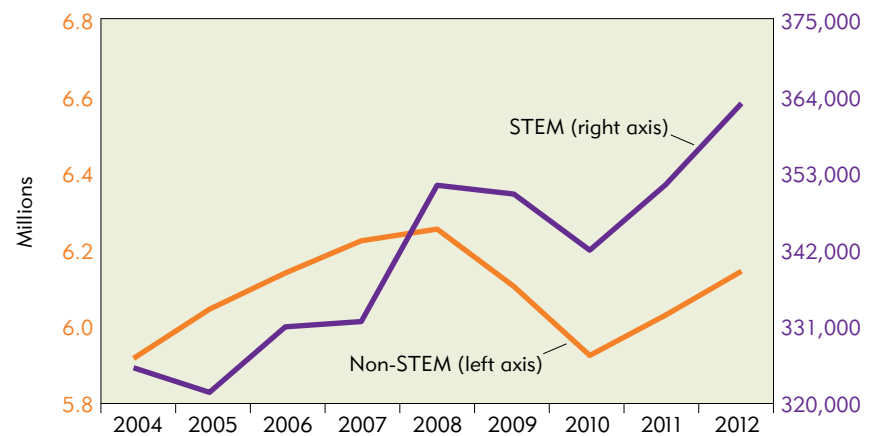
Worries about a STEM shortfall have prompted widespread efforts to increase the number of college graduates in science and technology. Employers want more young people to earn STEM degrees, and some report difficulties hiring STEM graduates to fill entry-level positions.

Chart 1  
**The STEM premium**  
Average weighted median wages and percent difference between STEM and non-STEM occupations,\* 2012



\*Includes occupations with typical entry-level education of at least a bachelor's degree  
Source: U.S. Bureau of Labor Statistics, occupational wage estimates

Chart 2  
**Tech leads in job growth**  
Ninth District STEM employment



Source: U.S. Bureau of Labor Statistics, occupational employment estimates

state topped \$82,000, though that still trailed the national average.

Earnings of engineers, computer programmers and other STEM workers are on par with professional and managerial salaries in sectors such as health care, business and finance.

STEM jobs are also growing faster than the rest of the labor market. Like

everybody else, STEM workers took their lumps during the recession; nationwide, a quarter-million STEM jobs disappeared from 2008 to 2010. Despite this pullback, STEM jobs grew at three times the rate of non-STEM employment from 2004 to 2012 (see Chart 2). Three years after the recession, the district had regained all

of the STEM jobs it lost and more, while non-STEM employment still languished below 2008 levels.

In Minnesota—the district state with the most STEM workers due to well-established construction, computer software and medical technology industries—STEM employment grew 6 percent from 2010 to 2012, to about

180,000 workers. North Dakota's STEM workforce is only one-tenth as large, but STEM employment grew 29 percent over the same period.

In most district states, engineering, and computer science and math, account for the bulk of STEM jobs, and those occupations have led post-recession growth in STEM employment (see

STEM from page 3

Chart 3). In North Dakota, computer science and math employment has surged, driven by demand from computer software and health care firms in Fargo, Grand Forks and other cities in the Red River Valley.

Engineering employment has also increased sharply in North Dakota since the recession. “There’s a healthy demand for engineers right now” to work in the state’s oil and gas industry, said

STEM jobs. Firms value new graduates for their energy and the fresh ideas and skills they bring to the workplace, such as novel analytical techniques or the latest web development tools. The Brookings study found that metro areas with high patenting levels also had high shares of college graduates in STEM fields.

Roughly 200 institutions of higher learning confer STEM degrees in the district, and national education statis-

per thousand people than the nation as a whole (see back page map).

However, production of STEM graduates varies considerably by field of study. In the nation, and in most district states (see Chart 5), higher education institutions produce more graduates with degrees in natural science—majors such as physics, chemistry and soil science—than degree holders in either engineering or math-related fields such as statistics and computer science. And every district state has seen larger increases of graduates in natural science and engineering than in computer science and math. Growth in computer science and math has lagged particularly at the bachelor’s degree level (see Chart 6).

In Montana, awards of four-year STEM degrees fell across the board from 2002 to 2012, but fell by over 30 percent in computer science and math. Enrollment in computer science programs fell nationwide in the early 2000s, after the high-tech stock bubble burst and Internet firms started laying off workers.

“It’s not just a Montana thing,” said John Paxton, head of the computer science department at Montana State University (MSU). “Those two things in conjunction produced an environment where you lost half of the people studying computer sciences from 2001 to about 2009.”

At MSU, which produces most of the state’s computer science graduates, bachelor’s degrees fell from 47 in 2004 to just 20 in 2013. At other district schools, computer science enrollments and graduations have bounced back since the recession, but not enough to make up lost ground.

STEM anxiety

The nationwide falloff in computer science graduates has fed a persistent concern among educators and employers—often echoed by politicians—that the overall supply of new STEM graduates in the district is inadequate to meet current and future demand from employers.

Studies by organizations such as the National Academy of Sciences, the Council on Competitiveness and the Association of American Universities have argued that a shortage of science and engineering graduates threatens the country’s capacity to innovate and compete in the global economy. An oft-cited statistic: In 2009, the United States ranked 27th among developed nations in the proportion of college students receiving undergraduate degrees in science or engineering.

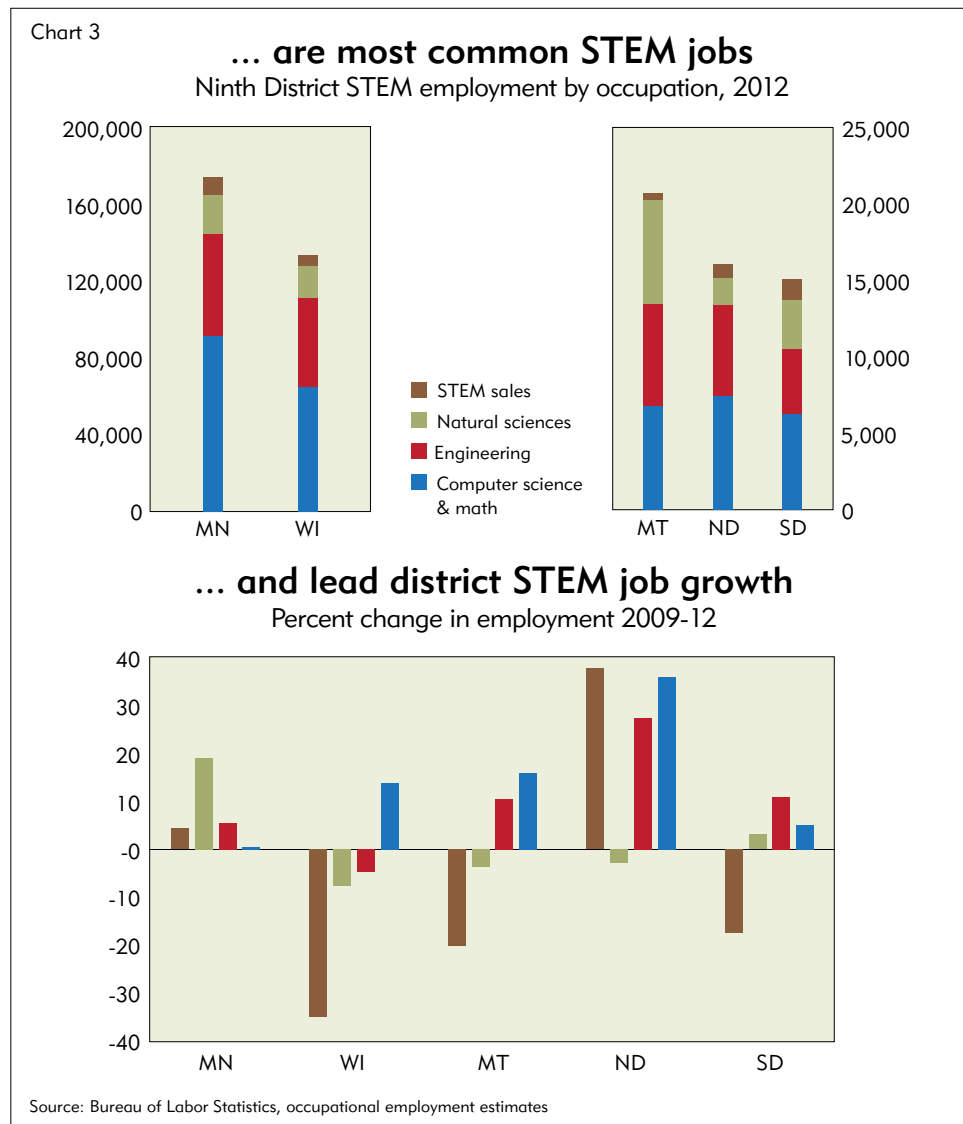
Such statistics stir anxiety about the state of STEM in the district. A March presentation by North Dakota university and economic development officials at a small business innovations summit in Fargo talked about “The STEM Dilemma,” asserting that “the demand for STEM professionals in the U.S. outpaces supply,” and “too few university students are graduating in STEM fields.”

In the state, “there’s a general sense that there’s a shortfall, that there aren’t enough STEM graduates” from state institutions entering the workforce, said Wayne Kutzer, director of the state Department of Career and Technical Education, the lead agency for STEM education in North Dakota.

By many measures, demand is high for homegrown STEM graduates. Many employers, especially smaller firms or those based outside metro areas, say they concentrate their recruiting efforts in their own backyards. College graduates from the same state or adjacent states are seen as not only more likely to join the firm, but also more predisposed to stay.

“We’ve found out as a small company that it’s really hard to recruit somebody from another geography,” said Hauschildt of Swat Solutions. “It’s hard to get people to see Minnesota as a destination unless they have some sort of family tie to Minnesota.” Roughly 60 percent of the firm’s employees are graduates of the University of Minnesota, the University of Wisconsin and other schools in the Upper Midwest.

Engineering, and computer science & math jobs ...



Wayne Biberdorf, a former energy industry engineer who sits on the advisory board of the petroleum engineering program at the University of North Dakota (UND).

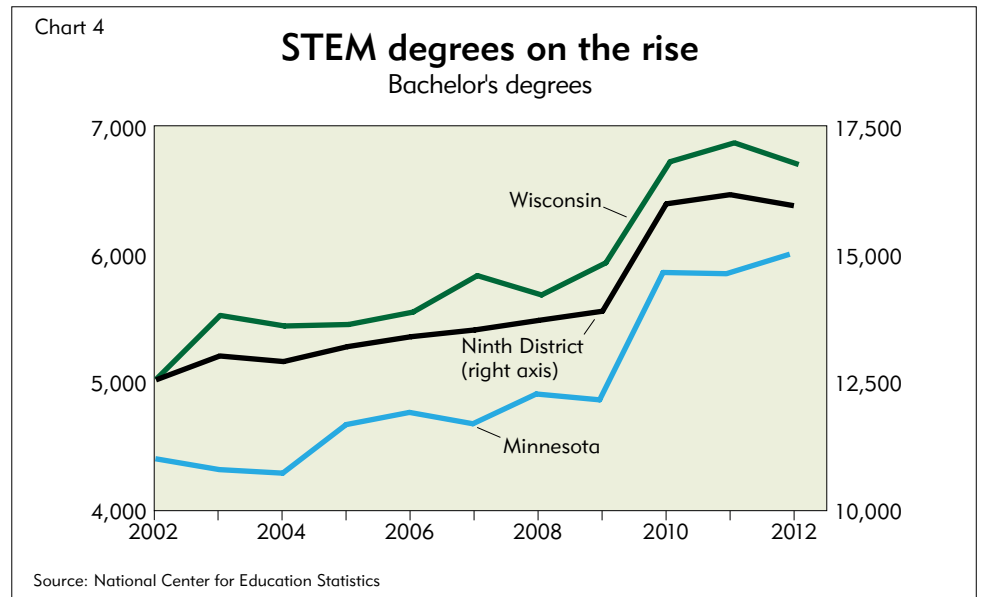
Minnesota and South Dakota saw relatively small increases in computer science and math jobs from 2009 to 2012 because employment losses in the computer industry continued into 2010 before firms resumed hiring large numbers of workers.

Here come the graduates

A multitude of college science and technology programs across the Ninth District supply much of the labor for these

tics show that their output has increased since the early 2000s. About one in five sheepskins awarded in the district is in a STEM field, and baccalaureate degrees account for about three-quarters of STEM degrees.

In Minnesota and Wisconsin, the district states with by far the largest number of STEM graduates, STEM bachelor’s degrees awarded rose after 2004, then surged after the recession (see Chart 4). In the Dakotas, awards of four-year STEM degrees also rose markedly after the recession. Only in Montana have degree awards declined over the past decade. On a per capita basis, the district beats the U.S. average in STEM degree production; in 2012, every district state awarded more STEM bachelor’s degrees



At Bartlett & West, an engineering firm that does general construction and pipeline projects in the North Dakota oilfields, 90 percent of the engineers in the Bismarck office are graduates of engineering schools in either the state or neighboring Montana. “We haven’t had a lot of people from out of [the region] come to Bismarck,” said Jame Todd, a principal with the firm. “The winters are pretty harsh here.”

Despite concerns about a shortfall of STEM graduates, there’s little evidence that STEM jobs in the district are going begging for lack of science and technology graduates to fill them. But demand for STEM graduates is higher in some district states than in others. And at least in Minnesota and North Dakota, STEM fields differ greatly in the ratio of graduates to job vacancies. The types of STEM degrees students pursue have a strong bearing on the level of job competition they face upon graduation.

### Why pay more?

Gauging demand for STEM graduates in the district is tricky because homegrown college graduates aren’t the only fish in the labor pool. In most STEM occupations, older workers, including those who lost their jobs during the recession, are available to fill job openings. To some extent, employers can hire STEM graduates from other parts of the country to fill entry-level positions. And not all STEM positions require a bachelor’s degree or even a two-year degree in a STEM field.

One way to look at demand for STEM graduates in the district is to examine wage trends. Basic economics dictates that a tighter labor supply puts upward pressure on wages as employers compete for scarce workers.

In fact, STEM wages nationwide haven’t risen much since the recession—leading some analysts to conclude that the country has more than a sufficient supply of STEM workers. Wages have also barely budged in the

### STEM wages nationwide haven’t risen much since the recession—leading some analysts to conclude that the country has more than a sufficient supply of STEM workers. Wages have also barely budged in the district.

district. Adjusted for inflation, the average STEM wage in the district actually fell slightly from 2008 to 2012, while wages for non-STEM workers rose about 1 percent (see Chart 7 on page 6). Even in fast-growing STEM occupations such as computer science, real wages stayed flat or declined in a recovering regional economy.

Similar wage patterns are evident in individual district states, including North Dakota, which has experienced torrid economic growth, partly due to the oil boom in western counties. Stagnant STEM wages suggest that employer demand is being met by new STEM graduates of district institutions, together with other STEM workers.

Thousands of STEM workers in the district were laid off during the recession. From 2008 to 2010, Wisconsin lost almost 4,000 engineering jobs, and in Minnesota, computer and math employment shrank by 1,100 jobs over the same period. Today, job openings continue to be filled by these experienced workers and other job seekers, including recent college graduates who have moved to the region from elsewhere in the country.

North Dakota’s labor vacuum—the state unemployment rate was less than 3 percent in January—has drawn workers from across the country. From 2010 to 2012, the state added on average about 1,900 STEM jobs annually, more than twice the number of STEM degrees awarded in the state each year. Thus, the state is almost certainly a net importer of STEM graduates.

“North Dakota needs workers everywhere, not just in STEM,” said Beth Zander, director of Workforce Development at the state Department of Commerce. “If

we educated and retained all of our youth, we still wouldn’t have enough workers for the jobs that we have and will see. So we also look to talent outside the state.”

In computer hardware and information technology, many district firms have hired foreign computer science graduates who enter the U.S. workforce on H-1Bs or other types of visas (see “Does foreign labor hurt U.S.-born workers?” in the October 2013 *fedgazette*).

However, wage trends for STEM graduates aren’t uniformly flat. Some STEM occupations have seen substantial wage gains, indicating increased pressure on supply; for example, the U.S. average annual wage for petroleum engineers rose 9 percent in constant dollars from 2010 to 2012—five times the increase for all occupations.

### STEM help wanted

Job openings provide another perspective on supply and demand for STEM graduates. Job vacancies capture total demand for workers in a particular occupation, including replacement workers and jobs that are waiting to be filled. And while job openings offer just a snapshot of labor market conditions at one point in time, they’re usually more up to date than aggregate job statistics and so often can capture recent labor market trends.

The Minnesota Department of Employment and Economic Development (DEED) conducts a semiannual survey of employers to determine job vacancy levels in over 20 occupational groups. In the most recent survey, in the spring of 2013, employers reported over 5,300 openings in computer science and math, engineering and natural sciences

occupations. In comparison, about 7,500 STEM graduates with bachelor’s and advanced degrees entered the job market in 2012 (statewide graduation data were unavailable for 2013). The inference—assuming that many of those graduates sought jobs close to home—is that employers could take their pick of Minnesota STEM graduates last year.

However, a more nuanced picture emerges when the balance of STEM vacancies versus graduates is viewed in terms of different STEM fields.

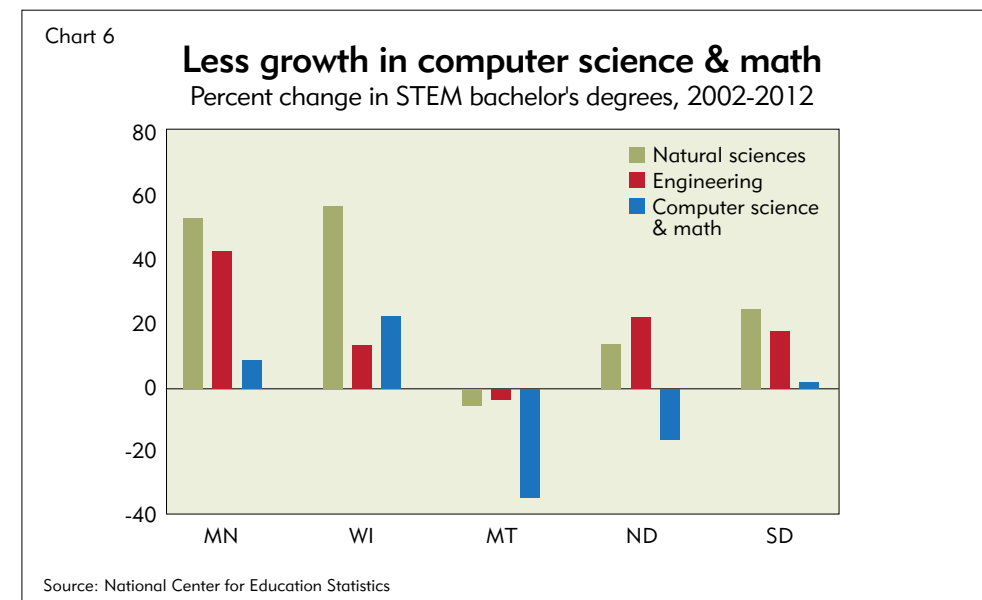
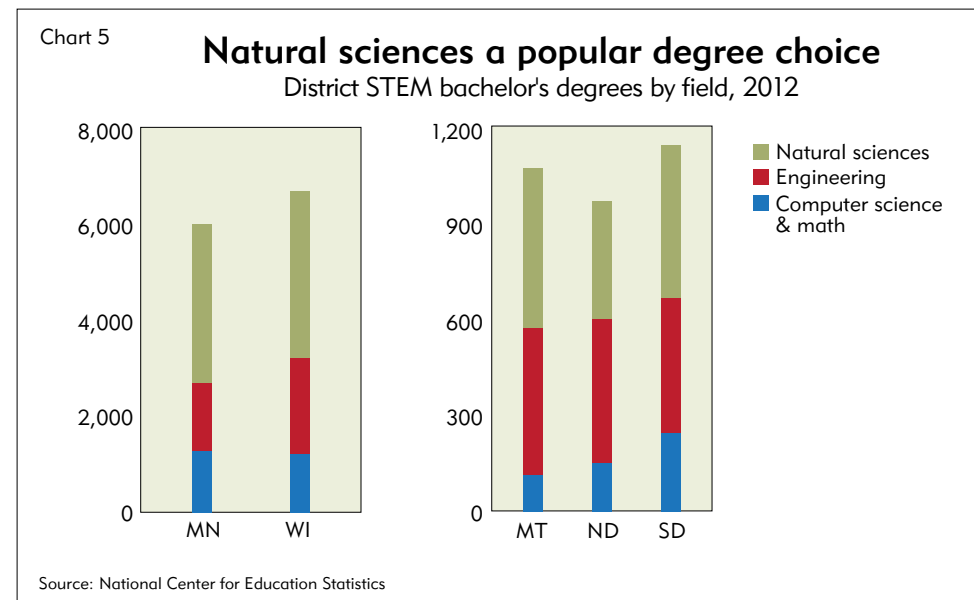
The survey showed higher demand for engineers, and computer science and math professionals, than for natural science workers. The job vacancy rate—openings as a percentage of all jobs in a given occupation—was over 4 percent for computer science and math workers, and over 5 percent for engineers. The rates for physical and life scientists were less than 3 percent, lower than the rate for all occupations.

The survey also indicated tighter supplies of computer science and math workers than in previous years. Computer science and math employers had over 3,400 openings statewide—four times the number of such openings in 2009, although still short of a prerecession peak of over 4,000. Vacancies in that occupational group were double the number of Minnesota college graduates with bachelor’s or advanced degrees in computer science or math who entered the job market in 2012 (statewide graduation data were unavailable for 2013).

Computer software firms in the state are feeling the pinch, said Margaret Anderson Kelliher, president of the Minnesota High Tech Association. “Distinctly in the computer science world, there is a numbers deficit. It’s a situation right now where there’s almost a negative unemployment rate for computer science, especially in the Twin Cities metropolitan area.”

Hauschildt of Swat Solutions can attest to a computer sciences hiring crunch in the metro area. The St. Louis

Continued on page 6



## STEM from page 5

Park firm, which helps software manufacturers ensure quality, has grown rapidly to about 75 employees since the recession but has struggled to fill new positions, including entry-level jobs suitable for recent graduates with bachelor's degrees. "It's hard to find software engineers," he said. "These graduates are fielding multiple offers and taking their pick of them."

In contrast, the DEED job vacancy survey suggests that employers of engineers had less trouble filling job vacancies than computer science and math firms. Demand for engineers in Minnesota has also increased in recent years; in 2013, engineering job openings increased 42 percent from the year before, to over 1,600—the highest number of vacancies in this sector in the past decade. But that was less than the 2,050 engineering degrees at the bachelor's level and above awarded by Minnesota institutions in 2012.

Employers of natural science graduates appeared to be in the best position

**More computer science, math and engineering graduates will be needed to work in growing industries such as mobile communications, data analytics and medical devices.**

**Demand is also likely to rise for STEM graduates in non-STEM fields.**

engineering, there were slightly more STEM grads than openings, while in physical and life sciences, graduates outnumbered vacancies by more than three to one.

### From the lab to Wall Street

Yet another way to measure demand for STEM graduates is to view the labor market through a wider lens. Some analysts have suggested that employer demand for STEM grads is greater than that indicated by a straightforward STEM-job accounting because many STEM graduates are getting hired for

Nationally, it does appear that STEM graduates are being pulled into non-STEM fields. In 2009, almost two-thirds of 9.3 million U.S. workers with a STEM bachelor's degree or higher worked in a non-STEM job, according to a study by the U.S. Department of Commerce.

Degree holders in the life and physical sciences are most likely to have non-STEM jobs. A 2011 study by the Center on Education and the Workforce at Georgetown University found that only 35 percent of physical scientists with bachelor's degrees were working in a STEM field immediately after graduation. Many natural science baccalaureates land managerial jobs or continue their education to become doctors or college professors.

Determining the extent to which STEM graduates from district institutions divert into non-STEM careers is beyond the scope of this article. Comprehensive, state-level employment statistics track workers only by occupation and industry, not by the type of degree they hold. Another unknown, both in the district and across the country, is the proportion of science and technology graduates who are working in non-STEM fields involuntarily—that is, because they can't get a job related to their field of study.

### Creative recruiting

Imbalances or apparent misalignments of supply and demand for some types of STEM graduates don't necessarily mean that employers can't find the workers they need. Even in occupations or areas of the district with seemingly tight supplies of STEM graduates, there are those alternative sources of labor—new college graduates from outside the district and the unemployed from near and far.

But the uneven distribution of STEM graduates relative to job opportunities in the district does mean that some employers have to go to greater lengths to garner their share of the annual harvest of homegrown college graduates.

Since the recession, Swat Solutions has raised wages about 20 percent for entry-level software engineers and programmers and sweetened its benefits package. And the firm pulls out all the recruiting stops to compete with the likes of Thomson Reuters, 3M and Google, attending job fairs at the University of Minnesota, offering summer internships and encouraging employees

to visit Twin Cities colleges to talk about the quality assurance industry and career opportunities at the firm.

"We're a small organization, competing for the same limited pool of graduates," Hauschildt said. "So we have to be a little more creative ... to start establishing our name as a good place to be for STEM graduates."

Bartlett & West also hires interns; last summer, about a dozen engineering students, mostly from North Dakota State University, worked in the Bismarck office, assisting with field surveys, contractor paperwork, engineering reports and other everyday tasks. Todd said that, because of the intense competition for engineering talent in western North Dakota, the quality of engineering students applying to the firm has dropped over the past couple of years. Internships are a way to home in on the best students before they graduate and get snapped up by other employers.

"You can kind of get an idea of who's the cream of the crop," Todd said. "We're able to train these people early on and find out more about them, so by the time they graduate, then we've got a much higher quality candidate."

Innovative Systems, a Mitchell, S.D., provider of software and hardware for the telecommunications industry, goes one step further in its internship program. For several years, the firm has paid an instructor at the South Dakota School of Mines and Technology in Rapid City to supervise interns who work in a satellite office on campus, writing software for Innovative. Each year the firm hires several of these programming apprentices. The arrangement allows the instructor to spend part of the day teaching classes in leading-edge communications software at the School of Mines.

### STEM for all

In coming years, demand for STEM graduates from district higher education institutions likely will increase. More computer science, math and engineering graduates will be needed to work in growing industries such as mobile communications, data analytics, medical devices, and oil and gas extraction. And technological advances have created STEM occupations that didn't exist a few years ago—like drone imagery analyst.

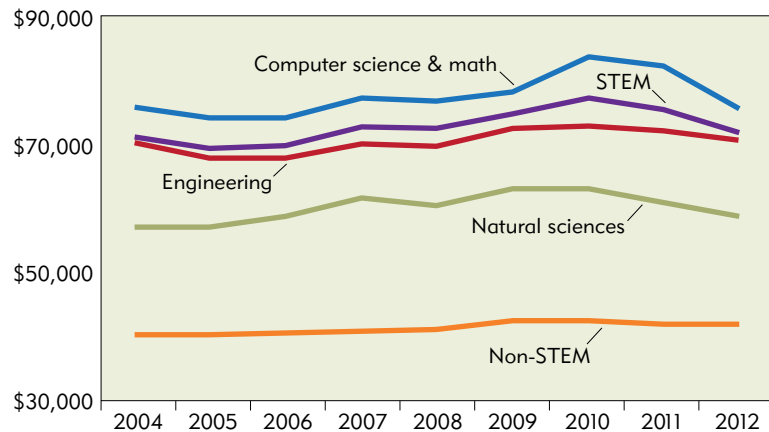
Last fall, Northland Community and Technical College in Thief River Falls, Minn., began offering a one-year certificate in imagery analysis for unmanned aircraft systems. Graduates of the program may get jobs analyzing aerial video just to the west in North Dakota, which has been designated a test site for new commercial uses of drones by the Federal Aviation Administration.

A number of national studies have projected STEM jobs as a share of total employment increasing over the next de-

Chart 7

### Stagnant wages in STEM

District average wages, 2012 dollars



Source: Bureau of Labor Statistics, occupational employment estimates

of all in the survey; there were 313 openings in the physical and life sciences—a fraction of the almost 3,800 natural sciences graduates from state institutions the year before. In Minnesota, as in other district states, these fields are popular degree choices. But since the recession, state employment in the natural sciences has grown less than STEM jobs overall. Job openings in the natural sciences increased only about 20 percent from 2012 to 2013.

North Dakota Job Service also tracks job openings, although its data are limited to online job postings. The monthly average of STEM openings in the second quarter of 2013 actually fell year over year, but the ratio of openings to college graduates in different occupational groups was similar to those in the Minnesota survey. Computer science and math openings exceeded the number of bachelor's-and-above graduates from North Dakota colleges and universities in 2012. In

non-STEM positions.

Employers in a range of industry sectors—finance, health care, manufacturing—value STEM knowledge and skills in their workforces. And some holders of science and technology degrees are attracted to non-STEM occupations because they pay higher salaries or are more personally satisfying than traditional STEM jobs.

"A STEM education is a very good preparation for a productive career in any number of fields," observed Kaler of the University of Minnesota. "There are a lot of mathematicians and physicists who wind up on Wall Street, doing quantitative economics. They may even wind up at the Federal Reserve."

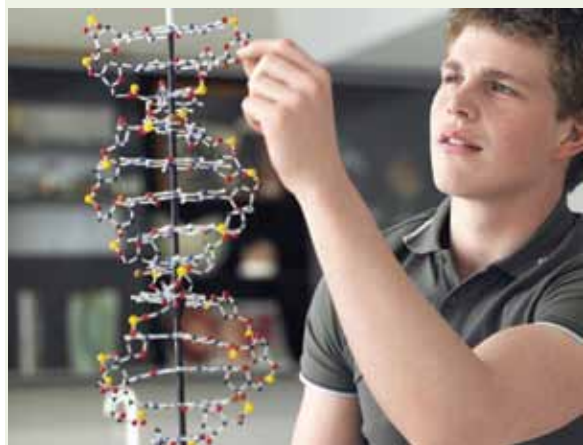
If significant numbers of STEM graduates are finding jobs in non-STEM occupations, the supply of graduates to fill engineering, R&D and other types of STEM jobs is less than the annual sum of STEM degrees awarded by colleges and universities.

# Fixing the STEM pipeline



STEM high schools

STEM scholarships



Workshops for STEM teachers

State STEM networks

Mentoring opportunities



By PHIL DAVIES  
Senior Writer

As any good engineer can tell you, a pipeline is only as sound as its component parts. If it has bottlenecks or leaky joints, it can't perform at anything close to top capacity. So it is with STEM. Whether or not there is a STEM crunch—too few science and technology students graduating from Ninth District colleges and universities to meet employer demand—educators, state officials and many employers say that not enough science or technology students are making it all the way through the pipeline from elementary school to the workplace.

The K-12 learning environment is widely seen as a major contributor to the problem. Many middle and high school students do poorly in science and advanced math, or avoid those sub-

jects because they're considered boring or too difficult. (In Minnesota, 2015's graduating high school class will be the first required to complete a chemistry or physics course.)

There's evidence to support the idea that potential STEM workers are falling by the wayside in the education system. Nationally, less than 40 percent of college freshmen who declare their intention to major in a STEM field end up getting a STEM degree, according to the President's Council of Advisors on Science and Technology.

And U.S. high school students post

lower math and science scores on international tests than peers in many other developed countries. It may not be a coincidence that students from high-scoring countries such as Canada, Korea and China account for a rising share of the graduating classes of STEM degree programs in the district. (For more about international college students in the district, see "Flying colors," page 9.)

But earnest efforts are afoot across the Ninth District to increase the flow of homegrown STEM graduates into the workforce.

## Get your geek on

The past five years have seen a groundswell of initiatives in the district intended to encourage more students to pursue STEM degrees and to improve science and technology teaching at all levels of education.

Several district states have developed STEM networks, broad-based programs designed to engage a wide variety of stakeholders in the STEM effort. The Twin Cities-based Minnesota STEM Network describes itself as "a community of practice" for STEM education and workforce development that includes schools, government agencies, businesses and community groups. An outgrowth of SciMathMn, a nonprofit focused on STEM education from prekindergarten through college, the organization seeks to raise public awareness of STEM,

Continued on page 8

**Fixing STEM** from page 7

promote effective STEM teaching and boost the number of students pursuing STEM careers.

A \$300,000 appropriation by the 2013 North Dakota Legislature established that state's STEM Network. Executive Director David DeMuth Jr., a physics professor at Valley City State University, says the nascent network will foster a teaching and learning philosophy—based on the engineering design process—in which students work cooperatively in teams to solve problems. Five regional STEM networks are planned in the state, including one representing Indian tribes.

STEM schools represent another broad approach to getting students involved in science and technology. Public schools in every district state—among them Richfield STEM School in Minnesota and Fond du Lac STEM Institute in Wisconsin—have embraced the STEM designation, although STEM schools are not certified as such by any official body. Some simply beef up offerings and requirements in science, math and related subjects, while others emphasize novel approaches such as interdisciplinary and project-based learning.

A variation on STEM schools—and the latest buzzword in K-12 education—is the STEAM school. Since 2010, a number of middle and high schools in district states have adopted curricula that blend math, science and the arts.

Other STEM initiatives in the district focus on discrete student populations or fields of study within STEM. A program

**The past five years have seen a groundswell of initiatives in the district intended to encourage more students to pursue STEM degrees and to improve science and technology teaching at all levels of education.**

developed last year at South Dakota State University (SDSU) aims to improve STEM education in the state, emphasizing rural areas where one instructor may be called upon to teach several science and technology subjects. The Institute for STEM Education Enhancement supports workshops for science and math teachers, and administers federal grants for college juniors and seniors pursuing secondary school teaching certificates in math and science.

“The goal is to ... encourage more students to go into STEM education,” said Institute Director Sharon Vestal, who teaches math education at SDSU. “We all know that’s a necessary part of the big STEM picture, because we can’t recruit students if we don’t have awesome teachers out there.”

Racial minorities earn science and engineering degrees at less than half the rate of whites, according to the National Science Foundation. In Minnesota, the goal of the NorthStar STEM Alliance is to double every five years the number of minority students at 14 higher education institutions in the state receiving STEM bachelor’s de-

grees. NorthStar, funded by the National Science Foundation, tutors college students and provides mentoring, internship and undergraduate research opportunities. Alliance members include the University of Minnesota, Carleton College, the Science Museum of Minnesota and the Minnesota High Tech Association (MHTA).

### The future of industry

Efforts to promote STEM education include direct intervention in the career-building process by employers, who have a vested interest. The more young people who study science and technology in secondary school and go on to earn STEM degrees, the larger the pool of potential STEM recruits.

In Montana, over 1,000 high school students take part in a privately funded program that awards \$10,000 in prizes for learning computer programming online. Computer science is not part of the core curriculum in Montana public schools (or in most school districts across the country). “Introducing computer science in K through 12 allows stu-

dents to apply math in a way that makes their core studies more interesting,” said Greg Gianforte, a Bozeman tech entrepreneur who co-founded CodeMontana last fall and has covered most of its startup costs.

Gianforte said that one of the program’s goals is “to raise awareness that there are careers for people who work with computers in Montana,” so that high school students will be motivated to study computer science in college—and stick around to take jobs in burgeoning technology hubs such as Bozeman.

Scholarships are another example of private sector efforts to increase the number of STEM graduates entering the workforce. For the past several years, the MHTA Foundation has awarded more than \$70,000 annually in scholarships to Minnesota undergraduates pursuing degrees in STEM or STEM teaching. Awards can include internships at MHTA member companies.

And Land O’Lakes, the giant dairy cooperative, offers \$5,000 annual scholarships to juniors and seniors studying food, agriculture and natural resource sciences at the University of Minnesota. “Our goal with the scholarship program is to support students who want a career in agriculture, and STEM fits right into that,” said Lydia Botham, director of the Land O’Lakes Foundation. “Science and technology are key components to the work we do at Land O’Lakes, and these students are the future of our industry.” **f**

**STEM** from page 6

cade. A caveat applies to job projections: Labor markets are dynamic, with constant shifts in supply and demand due to wage changes, industry slowdowns and other factors. But a 2010 analysis by the Georgetown University researchers estimated that, from a base year of 2008, total U.S. employment would increase 10 percent through 2018. But the number of STEM jobs was projected to grow by 17 percent during that time.

In district states, many STEM occupations are expected to see strong growth over the next seven years, according to future growth estimates for different occupations prepared by state labor departments.

In North Dakota, for example, jobs for civil engineers were projected to increase by one-third from 2010 to 2020. In Montana, a 50 percent rise in employment for developers of system software was projected over that period. And in Minnesota, the ranks of biomedical engineers were expected to swell by 66 percent.

Demand is also likely to rise for STEM graduates in non-STEM fields

because of the increasingly technical nature of the U.S. and global economy.

Sharon Vestal, director of a program at South Dakota State University to enhance rural STEM education, sees modern farming as a burgeoning STEM occupation: “Frankly, agriculture is becoming more of a science. The equipment is run by computers, and [farmers] use GPS mapping to plant and apply fertilizer. In order for South Dakota to stay competitive in terms of agriculture, we need more people who are educated in soil science and plant science and GPS and all those things.”

If expectations for job growth within and outside core STEM occupations come to pass, district universities and colleges will likely need to prepare for more students, especially in computer science and engineering. Recent enrollment trends since the recession indicate that young people are already responding to market signals.

The University of Minnesota’s College of Science and Engineering has seen a 13 percent rise in undergraduate

enrollment since 2009 due to revived student interest in—and higher employer demand for—degrees in mathematics, civil engineering and other STEM degrees. To accommodate this growth, the university’s Twin Cities campus plans to hire 100 new STEM faculty members this year, Kaler said.

At UND’s College of Engineering & Mines, enrollment has increased over 80 percent since 2007, when the oil boom took hold in North Dakota. Biberdorf says universities in the state “grasped onto the need rather quickly” to produce more engineers in a number of subfields—civil, mechanical, petroleum—to meet demand from oil companies, construction firms and other employers in the Bakken oilfields. In 2010, UND launched the state’s first petroleum engineering degree program. Seven students enrolled the first year; this spring, 211 students are in the program, which has suffered some growing pains.

In Montana, MSU’s computer science department is poised to sharply

increase the size of its spring graduating class due to big enrollment gains over the past five years. As of last fall, the number of bachelor’s degree candidates had rebounded to 281, almost twice the number of students enrolled in 2007.

“The good news is that ... we’re about to double the number of our graduates, even compared to a year ago,” Paxton said. He added that “it’s exciting ... and it’s also scary” because of the added teaching burden being borne by computer science faculty. Despite the enrollment surge, the department still has the same number of instructors it employed in 2007. **f**

*Research assistants Bijie Ren and Dulguun Batbold contributed to this article.*



# Flying colors

*International students flock to Ninth District universities*



Go online at [minneapolisfed.org](http://minneapolisfed.org) to meet Bach Ngnyen, from Ho Chi Minh City, Vietnam, and learn why he came to study finance and French at the University of Minnesota.

By RONALD A. WIRTZ  
Editor

Life is said to be a long, winding road. Song Hoffman has certainly traveled that road, which has taken her from Beijing, China, to Brookings, S.D., by way of Australia. Today, Hoffman is both poster child for an international education trend and professional leader bringing that trend to South Dakota State University (SDSU).

A decade and a half ago, the Beijing native went to Australia in pursuit of a master's degree at Flinders University in southern Australia. "My dad taught me from an early age that there is a big world out there, and he exposed me to many different cultures, philosophies

and religions," said Hoffman. "So it is always in my heart that I want to go out there to check this world out."

While at Flinders, Hoffman worked in admissions and marketing for the international program and also met her future husband, Lee Hoffman, who grew up in Vermillion, S.D., and was working on a Ph.D. in nanotechnology. In 2011, the two came to Brookings when Lee Hoffman joined the chemistry department at SDSU, and Song accepted a position as the university's international student coordinator.

Located in the southeastern part of the state, Brookings is better known for supper clubs than dim sum. Before moving, Song said her husband "didn't describe much" about the place they were moving to. "I remember 'flat,

cornfield, cows' were a few words he used. So, it was accurate." While not a big fan of winter, Song said summer and fall are "colorful and beautiful, while in Australia summertime is always hellishly hot and brown. So I love summer and fall here."

Now Song is selling SDSU to students around the globe, and "her efforts have been fantastic," said Greg Wymer, manager of international student and scholar services at SDSU. Song brings 13 years of recruitment experience from her time spent in Australia and about five years prior to that working in this professional field in China. That international experience translates because Song "bring(s) the insight of being an international student and has the ability to encourage students to study in a cul-

ture other than their own," Wymer said.

Thanks to a variety of efforts, SDSU today is home to almost 600 foreign students, close to double the number it had six years ago, and the program hopes to attract 100 new students per year.

The university is less of an outlier than these growing numbers might suggest. Analysis of higher education institutions throughout the Ninth District shows that international students have grown by almost one-quarter since 2009 and are rising virtually across the board.

Some of this growth is the result of steadily rising demand for high-quality, postsecondary education from students whose home countries have underdeveloped or lower-quality systems. But more institutions are also actively recruiting

Continued on page 10

Flying colors from page 9

international students—to increase revenues and to diversify their student bodies—and supporting these students with more services.

Growing cultural imports

Almost any way you slice the data, foreign enrollments are growing at universities and colleges across the country and the Ninth District. That hasn't always been the case. In the early 2000s, enrollments were largely flat in district states—mostly stemming from increased national security and unease following the September 2001 terrorist attacks.

But since 2006, international enrollments have been rising steadily, interrupted only briefly in the Ninth District during the recession, according to data from the Open Doors survey conducted annually by the Institute of International Education (see Chart 1). (Unless otherwise noted, all enrollment data in this article are from the IIE.)

After a hiccup in 2008, foreign enrollments at district universities and colleges have increased by 22 percent since 2009—a sliver higher than nationwide growth of 21 percent. Almost 30,000 international students attend college in Ninth District states (see Charts 2-3).

Students have spread themselves far and wide. Montana and South Dakota institutions have witnessed the fastest growth among district states, at 33 percent since 2009. But institutions from every district state grew by at least 19 percent, save for North Dakota, where international students grew by a more modest 8 percent, according to the IIE.

But even North Dakota is seeing more international growth than IIE figures suggest. The state's numbers are skewed by a 2012 controversy at Dickinson State University—the state's third-largest destination—over major recruitment and admissions violations in its international program that affected the enrollment and degree status of some 900 students since 2003. Excluding DSU, the state's

foreign enrollment has grown by 21 percent since 2008.

Growth appears so widespread that it's hard to categorize. A breakdown of schools by international enrollment size shows that programs of all sizes saw similar (cumulative) rates of growth (see Chart 4). Growth has even come to some two-year colleges like Century College in suburban St. Paul, Minn., where international enrollment has more than doubled since 2008, to 145 students.

Good lookin' freshman class

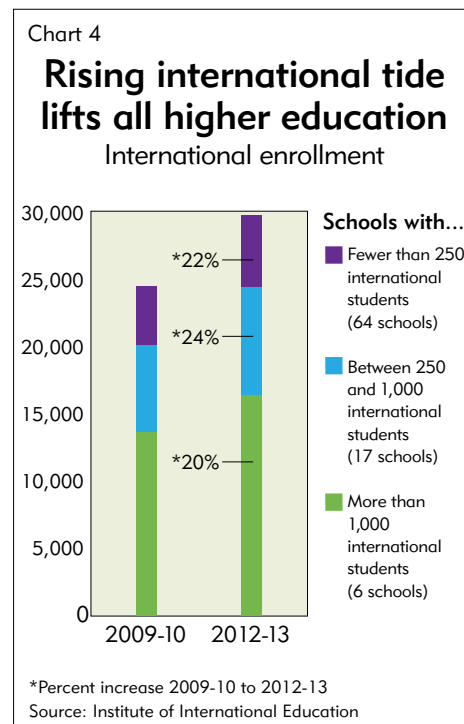
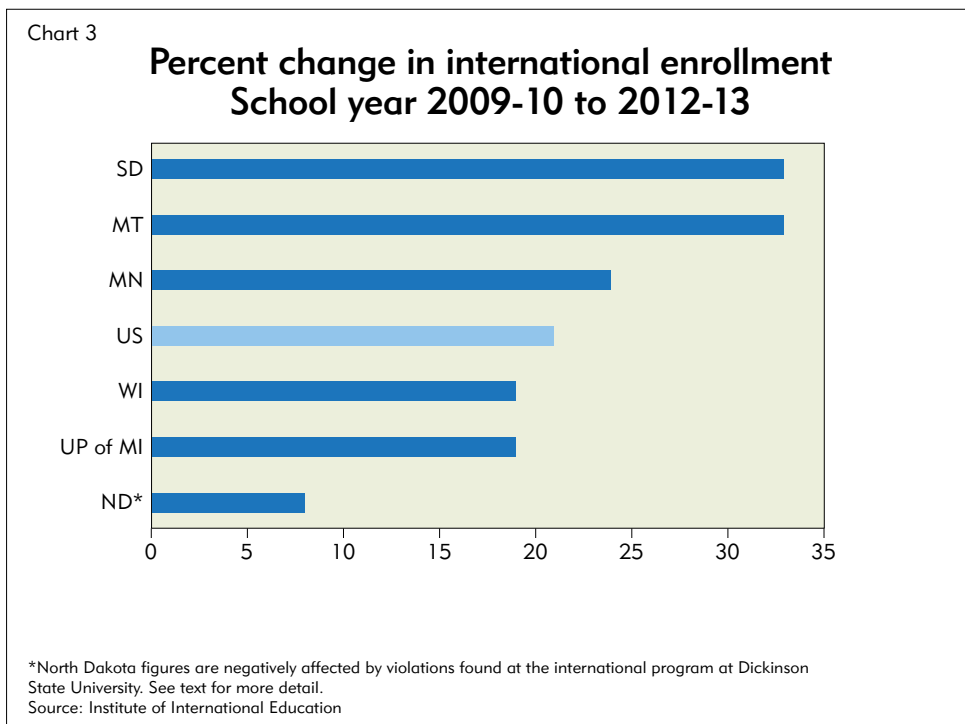
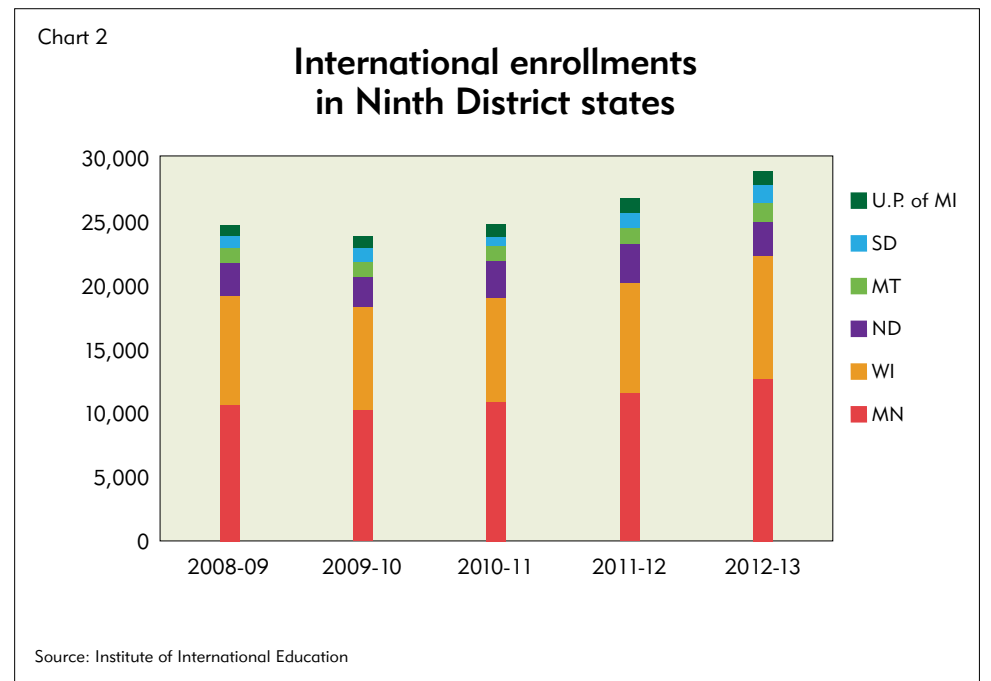
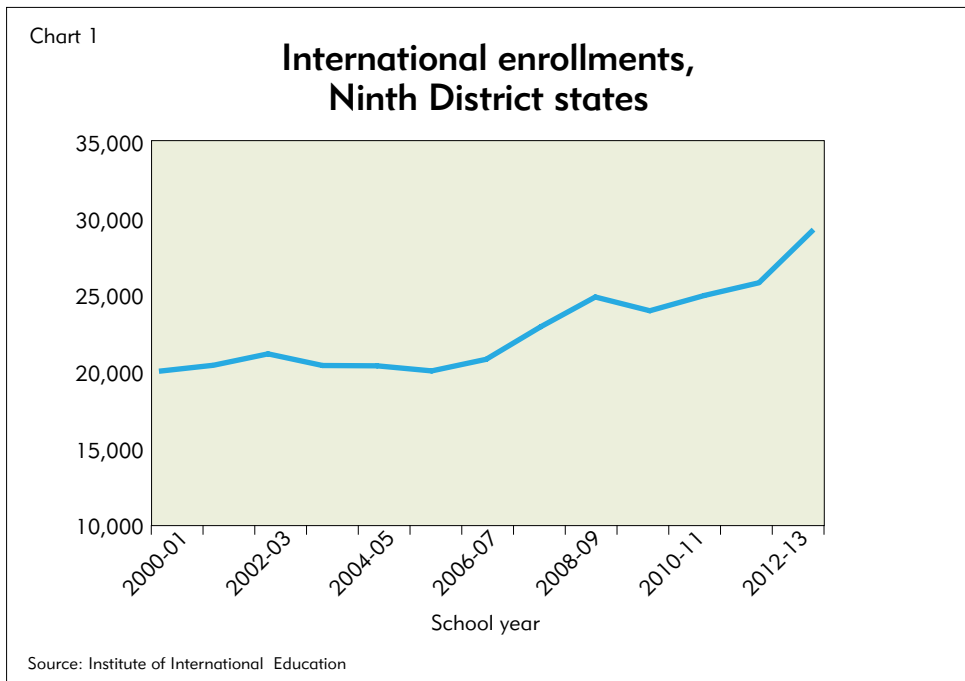
Historically, the bulk of foreign students have been graduate and Ph.D. candidates, most of them pursuing science, technology and math (so-called STEM) degrees. That's the calling card for SDSU, where about two-thirds of international enrollees are graduate students, and strong STEM programs are the study of choice for 75 percent to 80 percent of these students. "That's always going to

be the constant," according to Wymer.

Location matters little, it seems. Michigan Technological University is located in Houghton (pop. 7,700), tucked into the middle of the Keweenaw Peninsula jutting into Lake Superior. With more than 1,000 international students, it has the sixth-largest enrollment among schools in the Ninth District (including all of Wisconsin). Foreign students make up 16 percent of Michigan Tech's student body—higher than either Michigan State or the University of Michigan—and engineering is the most popular field of study.

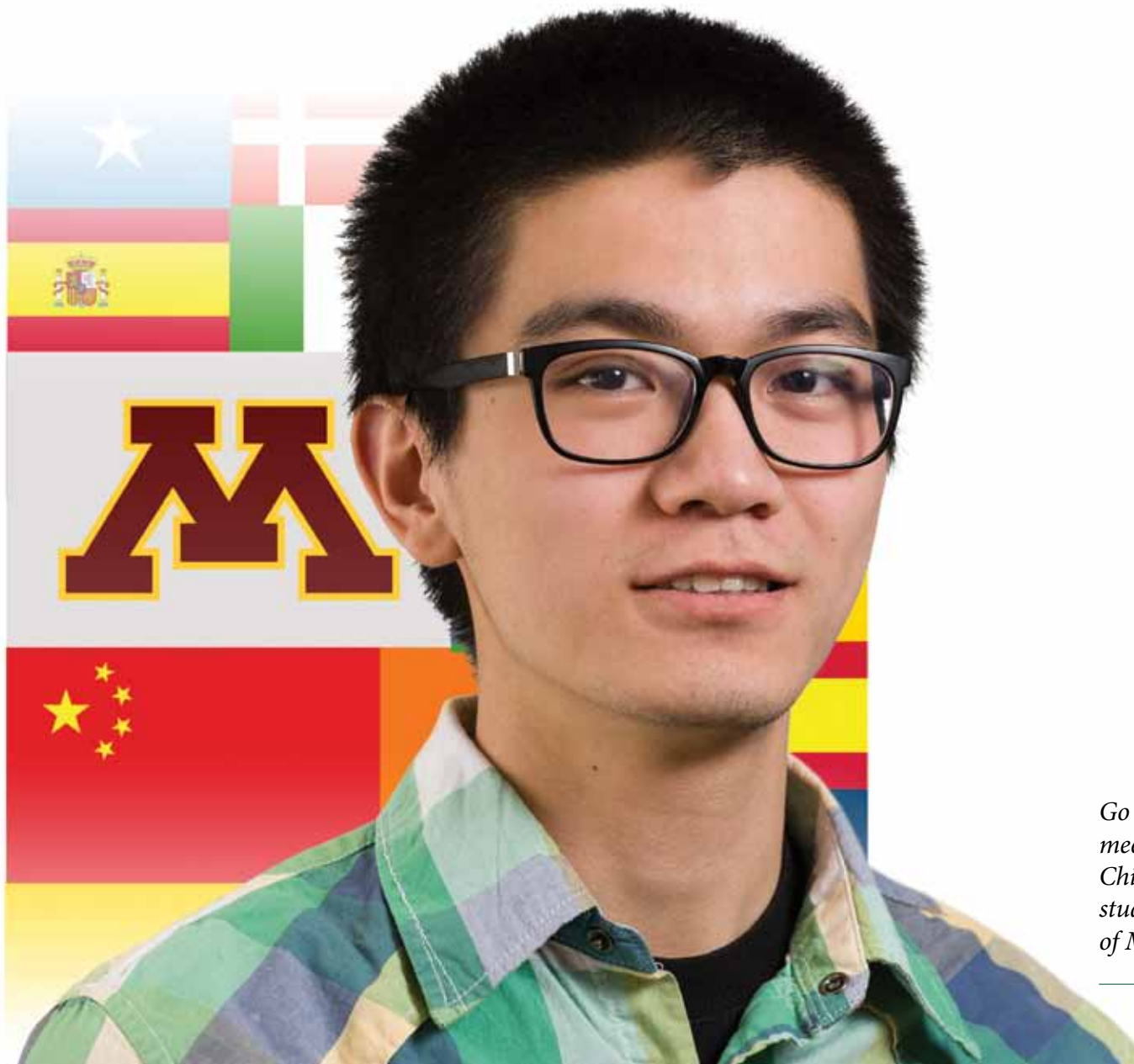
But such a foreign concentration isn't unusual for a technological university, according to Maximilian Seel, MTU's provost and vice president for academic affairs. The percentage of international students at Georgia Institute of Technology in Atlanta is 24 percent. "It is the technological nature of our programs that attracts them," he said.

Foreign enrollment at the University of Minnesota-Twin Cities neared 6,400



last fall, according to university figures. It's the largest destination for international students in the Ninth District and "in very high demand" because of its Carnegie rank as a so-called Research 1 institution, according to Barbara Kappler, assistant dean of international student and scholar services. That gives it a global reputation and provides a lot of opportunities for research assistantships, a way for foreign students to cut costs dramatically while giving them an opportunity to assist faculty with cutting-edge research.

Nonetheless, enrollments by international students seeking advanced degrees at Minnesota's flagship university have not grown much in recent years. Since 2005, the graduate student population has remained stable at about 2,500, according to Kappler. The number of students studying for law and other profes-



*Go online at [minneapolisfed.org](http://minneapolisfed.org) to meet Yizhou Ben Ma, from Xi'an, China, and learn why he came to study food science at the University of Minnesota.*

sional degrees has increased, but these programs have smaller enrollments.

Instead, the biggest increase in international students at the university—by far—has been among undergraduate students. Less than a decade ago, Kappler said, “we ranked at or toward the bottom of our comparison group” of universities for foreign students seeking bachelor’s degrees. Despite the fact that the university was promoting itself as a world class institution, “you could be an undergrad and not meet any international students,” said Kappler. Starting in 2008, the university made a greater effort to attract foreign undergraduates, and the school’s population has tripled.

Minnesota is part of a larger trend. From 2009 to 2012 (the last four IIE surveys), international undergraduate enrollment nationwide has grown from 274,000 to 340,000 students (a 24 percent increase) and now outnumbers grad students, whose population grew 6 percent (294,000 to 311,000) over the same period.

The IIE does not provide enrollment breakdowns for individual institutions, but sources suggest that foreign undergraduate growth is occurring at many district institutions. Montana State

University-Billings has gone from a few dozen foreign students to 152 in the span of three years. The school offers everything from master’s to associate degrees, but “the vast majority study in our undergraduate programs,” according to Paul Foster, director of international studies and outreach. Less than 5 percent are in graduate or associate degree programs.

Foster added that the school also attracts students to an intensive (but non-degree) English-language program. Not coincidentally, nondegree programs have surged by 34 percent (19,000) nationwide during this period.

## WeWant U

Some, even much, of the enrollment growth has occurred by sheer momentum and a virtuous enrollment loop: More students are seeking education outside their home country, and those that make the leap tend to tell their friends of their experience.

Since 2006, international enrollments have surged by 41 percent nationwide. According to Foster, “Most accredited U.S. universities can easily attract international students.”

Some schools do very little in terms of recruiting, satisfied to focus on quality education and the student’s general experience while on campus, because there is no better recruiter of foreign students than one of their own back home.

“We actually see retention as a recruitment tool,” said Thy Yang, director of Michigan Tech’s international programs and services. “If you ask our international students how they found out about Michigan Tech, an overwhelming majority will say that they knew somebody who knew somebody that went to Tech. If our students were not satisfied with their experiences in and out of the classroom, we will not have the success we have with enrollment.” MTU’s foreign enrollment has grown 15 percent since 2009 despite a shoestring recruitment budget compared with its peers, Yang said.

But not all schools are leaving such matters to geographical chance. Kappler, for example, said that the University of Minnesota “has been proactive in the past seven to eight years in recruiting international undergraduates,” and it has paid big dividends with a “dramatic change in our population.”

At MSU-Billings, Foster said that the school “has actively begun to recruit stu-

dents and to develop and implement an internationalization program.” Foster himself was hired last summer, and there are six full-time employees working in the office supporting foreign students as well as U.S. students and faculty abroad.

It’s a similar staffing story at SDSU, where the international office was reorganized and enlarged to centralize all activities—admissions, advising, recruiting—in a single office, rather than spread through several offices. Where there were once roughly two full-time equivalent jobs related to international students, now there are five, including Song Hoffman’s position.

The increase in staff and general activity has also meant more services for these students once on campus. A school’s international reputation is seen as resting on its students’ experience, and a growing undergraduate population brings a host of new challenges. For example, for many students this is the first time they’ve lived outside their home country and their first collegiate experience, both of which can be big adjustments. For this reason, Kappler’s office is in the process of creating online modules for students prior to their arrival that help with academic

Flying colors from page 11

orientation and address common challenges like finding housing.

Wymer said SDSU has “definitely increased services” to its international students. Two years ago it started an airport pickup service three weeks before classes started for foreign arrivals in Sioux Falls, about 40 miles away. “We have a ‘no student left behind’ policy,” joked Wymer. The university has also created a student mentor program “to help new students adjust to life both at SDSU and in the U.S.,” and significantly upgraded its online resources, all in an effort to ensure that the student experience is “second to none compared to other (universities) around the U.S.,” he said. “This will have a direct impact on attracting future students. One of the best ways to attract new students is to treat our current students well. News travels fast.”

## International benefit\$

Universities seek out foreign students for many reasons. Many of them relate to the mission of higher education in exposing students to a variety of experiences—cultural as well as academic. In a global economy, the thinking goes, a university has to bring the globe to campus.

SDSU, for example, has a largely homogenous, white student body. “Ninety percent [of SDSU students] have not stepped out of South Dakota” or neighboring states, Wymer said. “Our goal is to break down cultural barriers ... by making the halls of SDSU more culturally diverse.”

At the University of Minnesota, the influx of international undergrads has given the campus an “awakening,” Kappler said. “I think it’s wonderful to have students from around the world come here. People learn about the world from interactions with these students.”

There are other perks for universities, like the fact that these students are paying customers—well-paying customers. Most state universities and colleges charge nonresident students higher tuition on the theory that state residents support the institution with their tax dollars. International students typically pay nonresident rates, and sometimes even a little extra to cover the cost of the additional services that are provided to these students. On its website, the University of Minnesota lists current undergraduate resident tuition at \$13,600 compared with out-of-state tuition of \$19,800 and international tuition of \$21,400 per year.

At Michigan Tech, international undergraduate and graduate students pay the nonresident rate—\$14,175 per semester, which is more than double the resident rate—plus an additional \$150 fee per semester, according to Seel. Since many grants and other forms of financial aid are restricted to U.S. students, he added that “international students pay a much higher

## An international quilt of students

There is both consistency and variety in the home countries of international students.

China, far and away, is the biggest exporter of students to both U.S. and Ninth District colleges and universities, followed by South Korea and India. Canadian students have a larger presence in district institutions than in the nation as a whole, mostly because of proximity.

The University of Minnesota-Twin Cities has the largest population of foreign students in the district, at 6,400. China sends the most students to the university—more than 2,600—followed by India and South Korea with between 700 and 800 each. No other country is represented by more than 170 students.

But students from all corners of the globe make up a huge cultural quilt on district campuses. There are students from 145 different countries at the University of Minnesota. At South Dakota State University (SDSU), 600 foreign students come from 71 countries.

There are unexpected, even quirky concentrations of international students in certain states. For example, Nepal has an outsized share of foreign students at Ninth District universities. The country—poor, isolated, with a fraction of the population of many other countries—ranks in the top five in three of five district states, ranking as high as fourth in South Dakota, with 7.5 percent of students.

Among the reasons for this high share is the general affordability of Midwestern universities like SDSU, where Nepalese students make up slightly more than 10 percent of the international class. The country’s colder climate also makes for an easier winter adjustment once on campus. And that’s important when students are walking brochures for the university back home.

Song Hoffman, from the school’s international office, said that getting a foothold in most countries is “developed from scratch” through positive experiences of students, which then turns into invaluable word-of-mouth marketing. That’s been happening for years with Nepalese students. “We actually have a brand in Nepal,” Hoffman said.

—Ronald A. Wirtz

### Top five home countries for international students

(Percent of state’s international student population)

<b>Minnesota</b>	China 29.2	South Korea 9.8	India 9.2	Nepal 5.1	Saudi Arabia 4.2
<b>Montana</b>	Saudi Arabia 18.4	Canada 11.1	China 9.2	Japan 9.1	India 7.3
<b>North Dakota</b>	China 20.4	Canada 19.2	India 13.6	South Korea 4.6	Nepal 4.1
<b>South Dakota</b>	China 15.3	South Korea 13	India 12.9	Nepal 7.5	Saudi Arabia 5.8
<b>Wisconsin</b>	China 36.8	South Korea 10.9	India 7.5	Saudi Arabia 5.3	Malaysia 2.9

Source: Institute of International Education

percent of the sticker price than U.S. students.”

There are exceptions to this rule, however, because many foreign graduate students also receive assistantships, where students either teach or conduct research in exchange for free or greatly reduced tuition and a small stipend. But lower tuition revenue from these foreign students is offset by the considerable value they offer universities in terms of net human resource costs for teaching and research.

High retention rates are another benefit of increasing foreign enrollment; fewer international students drop out or transfer to another institution. Before coming to SDSU, Wymer also worked in international programs at Southwest Minnesota State University and Minnesota State University-Moorhead. He said retention rates for international students are typically about 90 percent, compared with 70 percent to 75 percent for domestic students at most universities.

“This is pretty typical because many times, international students are choosing universities based on price, major and whether they have friends or relatives at an institution for support. As a result, there isn’t much movement of international students. ... They sort of feel like, ‘I started here and I’ll finish here.’” They also tend to have high completion rates and earn those degrees faster than the rest of the student population because “there is often pressure back home to get through” due to the high relative cost of U.S. schooling.

The case for courting foreign students becomes even more attractive in light of smaller high school graduating classes. In Minnesota and Wisconsin, the total number of high school graduates fell by about 5 percent (or about 3,500 students) in both states from 2010 to 2013. That trend is tumbling into higher ed enrollments, which declined at public universities in the fall of 2012 in both Minnesota and Wisconsin, while foreign enrollment grew by close to 10 percent in both states that same year.


## Future U

In some respects, the country has a lot of room for growth in international enrollments. Despite a stellar global reputation for U.S. higher education, foreign students make up less than 4 percent of the student body; that figure is 17 percent in the United Kingdom and 24 percent in Australia.

The good news for Ninth District universities and colleges is that the international spigot of students is likely to stay open for the foreseeable future.

According to World University News, for example, an estimated 900,000 foreign students are expected to enter U.S. institutions this year, roughly 80,000 more than in 2012. A report by the National Association of Foreign Student Advisers projects that the number of foreign students leaving their home countries to study will more than double by 2025 “to well over 7 million students annually, and perhaps substantially more.” The report expects that the U.S. share of these students will fall, but adds, “The U.S. remains a highly attractive destination and the raw numbers of incoming students will likely continue to increase.”

That’s why SDSU’s Wymer is optimistically targeting growth of 100 new foreign students per year on campus, with a goal of attracting 1,000 such students by 2018. That might sound aggressive, but not to Wymer.

“There’s no secret here. We’re creating an environment where students feel cared about. The rest will take care of itself,” he said. Given a growing global population of students, “we’ll grow by default. I don’t think there’s a doubt.” 

# Climate change and Ninth District ag

*An interview with North Dakota's state climatologist*

From flooding in Bangladesh to desertification in Africa, climate change is altering landscapes around the world, but the impact varies widely. Here in America's breadbasket, there is a lot of concern about how agriculture will be affected by changes in temperature and rainfall.



One person interested in this matter is Adnan Akyuz, North Dakota's state climatologist. Prior to his current role, he worked for the National Weather Service and served as the state climatologist for Missouri. He earned his doctorate in atmospheric science at the University of Missouri-Columbia.

In talks to a variety of audiences, from farmers to insurance companies, he has been highlighting how climate change is affecting farmers in the region, and not always for the worse.



**fedgazette:** Tell us a bit about your research and how you got into the topic of climate change and agriculture.

**Adnan Akyuz:** My latest research was to look at the growing-degree days for corn. It started out to be just North Dakota and the Northern Plains, but it got really broad-ranging interest, and so we extended the research to the entire United States. Now we are able to compile the data for the entire United States and see how the growing-degree units for corn have changed. All of the locations we have go back to 1890, including several locations in North Dakota.

**fedgazette:** In a recent talk at the annual meeting of the North Dakota Association of Soil Conservation Districts, you suggested that "climate change is not

really all bad" for North Dakota agriculture. Can you explain what you meant by that?

**Akyuz:** I was talking about the research, and I was taking a positive angle and letting the audience know something that they haven't heard before. North Dakota has the greatest warming trend in the lower 48 states, with a 0.26 degree Fahrenheit per decade increase since 1890. When you compare this result to the other states with a similar approach, you will find this trend to be the highest trend in the United States. In North Dakota, in general, we are 2.6 degrees warmer today than we were 100 years ago. But I have to mention that's only the average; if you look at these annual fluctuations, you will find much variability from one year to the next. At the

meeting, I also added that the warming in North Dakota has some positive implications in agriculture and talked about those.

**fedgazette:** Do you have any sense for why that is, that North Dakota has the most dramatic temperature increase? Is it because of location?

**Akyuz:** We are right in the middle of the continent and, in fact, the city that is right at the center of the continent is Rugby, North Dakota. That makes our climate very tough in the summertime, since we are far away from the protective nature of the oceans. It takes nearly five times as much energy to warm a gram of water compared to a gram of land, so in the summertime, we get warm very fast. In the wintertime, we get cold very fast.

Because of the region's geographical position with respect to the oceans, the warming trend is accelerated here.

**fedgazette:** So what does this warming trend hold for North Dakota agriculture?

**Akyuz:** In the latest research that we did on growing-season length in North Dakota, we found that the state has gained, on average, 1.2 additional days per decade in which the crops can grow. So we can say that we have 12 additional days today compared to 100 years ago that were suitable for crop growth. I can do this with each city; in Fargo, averaged over time, we have 17.5 additional days in which our crops can grow today compared to 100 years ago.

Moving one step further, in North Dakota, if you look at the map, you will

## Interview from page 13

see about five zones, starting from the south and going to the north. The farmers in the southernmost zone normally plant [corn with] 92 to 102 days relative maturity, and that type of corn matures when growing-degree days—the necessary heat units for the corn to reach maturity—reach 2,250 to 2,500. And to the north of the state, relative maturities are less than 75 days, and these types of corn require only 1,850 to 1,950 growing-degree days. So, yes, corn is possible, even in North Dakota, as long as you can plant the type of corn that grows in that region. But the problem is that when you select the variety that matures in less than 75 days, your yield is going to be very little compared to the varieties that mature in 90 to 102 days.

As for Fargo, we notice that 335 additional heat units are available today for corn development compared to 100 years ago. That 335 [units] happen to be 16 percent of the total heat units that are necessary to mature corn in Fargo. That is more than a three-category jump in relative maturity class from 70-day corn to 85-day corn, and 85-day corn has a greater yield capability than 75-days. So maybe 100 years ago, planting 85-day corn in Fargo was almost a dream. But because of our changing climate, this all of a sudden becomes possible. Even though the 335 additional heat units seem to be a meager 16 percent of total, it could be the decision factor a farmer will need to plant or not to plant corn in a given season.

**fedgazette:** That's certainly consistent with the increase in corn production we've seen in the Dakotas.

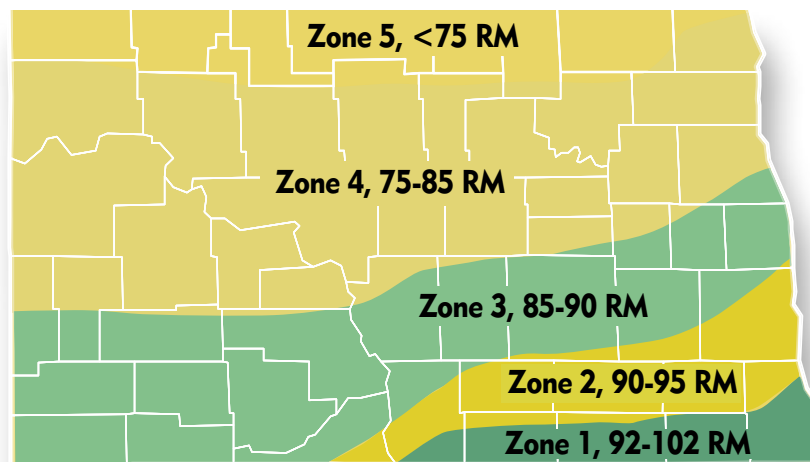
**Akyuz:** There is a significant trend toward corn production in our area. A big shift from small grains or other traditional crops to corn is observed more and more lately.

**fedgazette:** So, can you generalize that trend to the broader region? Is that true, for example, of Minnesota and South Dakota as well?

**Akyuz:** I wouldn't go too far from the Dakota area. I may be able to generalize to the Northern Plains, North Dakota, northern Minnesota and South Dakota. Farmers, at the beginning of the season, are trying to make a decision—what if I plant corn this year, would I make it by the end of the season? If I planted a higher relative maturity type of corn to improve my yield and profitability, would I put myself at risk of not reaching maturity by the end of the season? It gets to be an easy decision if you live in a state that has the highest warming trend.

**fedgazette:** So what about variability? You said that there's a clear warming trend

## Corn growing regions of North Dakota (by relative maturity)



Source: North Dakota State University

year over year, but has the variation from year to year changed at all as well? Are there more extremes between warm and cold years now, say, than there were 100 years ago?

**Akyuz:** Yes, absolutely. North Dakota is also the state that has the highest annual temperature range swing. In 1936, for example, the state's highest temperature and the lowest temperature ever recorded happened in the same year. On July 6, we had 121 degrees in Steele, and in the very same year on February

15, in Parshall, which is less than 100 miles away, a low of -60 degrees. That is actually the highest annual temperature range in the world: 181 degrees Fahrenheit. Some of the other locations that might challenge this are in Siberia, and they have similar records, but those ranges are within 100 years; North Dakota broke this record in the same year.

North Dakota farmers are already familiar with this variability and, yes, you're right. One year it might be very warm, warmer than normal; the other year is much cooler than normal. But if

you look at it in general, there's a warming trend, especially starting in 1970.

**fedgazette:** Does that introduce a new element of risk to farmers who are experimenting with warmer weather varieties of corn?

**Akyuz:** Yes, absolutely. At the same time, I don't see any farmers going too crazy about selecting, for example, in the Fargo area, 95- to 100-day relative maturity of corn. They are still cautious. They are still sticking with the climatological normal, say, 85-day corn. You might find some farmers taking risks by putting in even warmer varieties, and those are the types, for example, that last year did not make it. Most corn in North Dakota did reach maturity, but it was so late in the season and some of this corn did not get a chance to dry in the field. Then we ran into propane problems. Some farmers decided to leave their corn in the field; they just couldn't get the chance to harvest before the snow came.

There is also an upper threshold for corn, which is 89 degrees, and then the accumulated growing degrees for corn just stop. At other locations, like the South, the temperatures are so high, it impacts your crop negatively. So, if you have a field in Missouri, Iowa, Indiana, Kentucky—those regions are having no problem reaching that threshold and might be impacted negatively. North Dakota is not going to have that kind of problem with the upper threshold. So, it is possible that the warming trend might be bad news in the other states that already reached that threshold. But for locations such as North Dakota, the shift from small grains to corn will continue.

The portion of the variation that scares me the most is the last day of the spring frost, which is occurring earlier and earlier. Some years, you'll have a very early spring and the warming trend will start from that point on. A very late frost in the Midwest in 2007 caught most flowering plants and trees much later in their developmental stage, causing extensive total losses in Missouri and neighboring states. The temperatures dipped down to killing-frost points and killed very much of everything that was flowering. This risk is always there. Even though the last day of the spring frost is occurring earlier in general, that doesn't guarantee a later frost the next year. Year-to-year variability will always be a risk.

In North Dakota, however, we have mostly row crops and not many trees. We have climate variability like no other state because of our continental properties. 2012, for example, was the second-warmest year since 1890, but following that was the 33rd-coldest year of the same period. So I think by nature North Dakota citizens and farmers are more resilient to changes because season-to-season fluctuation is a part of our cli-



mate and we expect it. When somebody says “normal,” it has a different meaning elsewhere than it does in North Dakota because “variable” is what’s normal in North Dakota.

**fedgazette:** What does the change that you’ve observed in temperatures imply for some of the traditional crops that have been grown in North Dakota, like wheat and canola? Are those crops in any way threatened by this, or do you see this transition as just more profitable to corn?

**Akyuz:** Some of the other small grains—wheat for example—do not require as many heat units as corn does. However, corn became very popular and profitable and marketable. Farmers can market their corn for food, fuel and feed. I don’t think any farmers will have any problem marketing their corn. You have a set amount of acreage in your field, and you know corn is going to grow and it is more profitable. As long as the demand for corn exists, the market proves to be more profitable and the climate continues to be favorable for corn production, the trend to move away from other traditional crops to corn will continue. Therefore, it is not only the climate that is threatening traditional crops, it is the market.

**fedgazette:** So far, we’ve been talking about temperatures and the length of the growing season. Have you looked at all into precipitation? Don’t some forecasts suggest that the Great Plains could become drier?

**Akyuz:** We are continental. That means we are very vulnerable to water sources, and the biggest water source is precipitation. Our precipitation amounts are very meager. Our precipitation total in southeast North Dakota is 21 inches, northwest is 15 inches, and most of our precipitation falls in the summertime. That 21 inches in the southeast is almost just enough to have any crops grow. If I look at the precipitation records in the past, just like I did the temperature, I would notice a 1.12-inch-per-century increase since 1890. In North Dakota, precipitation has actually increased in time. In 2013, North Dakota had the wettest year in its history with 24.64 inches. Our driest year was 1936 with 8.67 inches of rain. These are very small numbers compared to some of the other corn-producing states.

Any time you increase the temperature, you can hold more water vapor in the atmosphere. Not only this, but corn

has deep roots and is able to tap into the lower parts of the soil and draw that moisture back through the stem and into the atmosphere through a process called transpiration. We started seeing high dew point temperatures lately in this area, and I believe the main reason is the trend of corn production in this area is putting a lot of moisture that would otherwise remain in the soil back into the atmosphere. The greater amount of water vapor in the air translates into greater amounts of available water for rainfall. So you have warmer temperatures, which allow corn to grow, and at the same time, corn taps into deeper portions of the soil to bring more moisture back into the atmosphere, which also can increase precipitation because air can hold more water vapor in it as the temperatures are higher.

**fedgazette:** Finally, what’s the long-term outlook between climate and agriculture in North Dakota and the broader region?

**Akyuz:** I think farmers are going to respond to what the climate allows them to plant. We will see the migration of popular plants from southern locations

to northern locations. In our latitudes, more and more farmers are going to keep planting profitable plants, such as corn, and small grains, such as wheat and barley, will continue to move northward into Canada, for example. If the warming continues, we might see some Canadian neighbors start planting what grows in Fargo.

As far as climate prediction is concerned, farmers are not generally interested in knowing the 100-year outlook; they are mostly interested in the next growing season. I need to make a decision, and I want my decision to be science-based. When am I going to be able to get into the field, and how long do you think the growing season is going to last? Are the fall temperatures going to be warm enough so I don’t have to use mechanical drying? These are the decisions that farmers are up against. Climate change itself makes it very difficult to make a forecast that farmers can rely on. So I think that as meteorologists and climatologists, our challenge is to improve our forecasting skills for the next growing season so that farmers can be ready.

**fedgazette:** Thank you, Dr. Akyuz.  
—Joe Mahon



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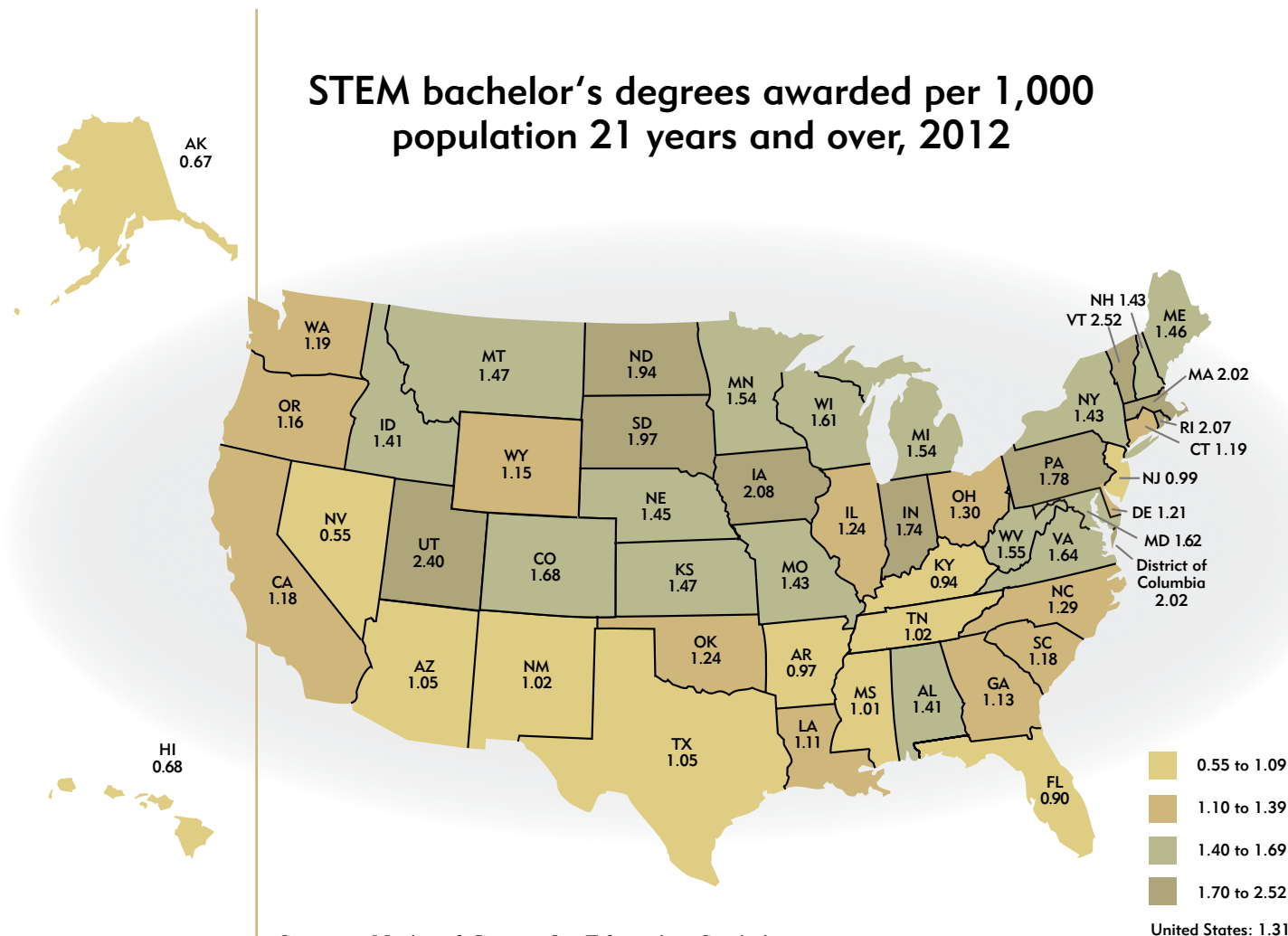
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## STEM education & jobs

April 2014

### STEM bachelor's degrees awarded per 1,000 population 21 years and over, 2012



Sources: National Center for Education Statistics and U.S. Census Bureau

0.55 to 1.09  
1.10 to 1.39  
1.40 to 1.69  
1.70 to 2.52  
United States: 1.31