The state of mining education;
What does the future hold for the next generation

by Mining Engineering Staff

Editor's Note: During the past year *Mining Engineering* conducted interviews with a number of topic experts to get a range of thoughts about the state of mining education and the looming skills shortage. In the October issue of *Mining Engineering* a condensed version of those interviews was published. This ME Online Exclusive includes the complete interviews with the 14 subject matter experts interviewed. The editor's of *Mining Engineering* recognize that education is one of the most important topics facing the industry and we would like to hear thoughts from members and readers of this special section. Please send comments to Steve Kral, Editor, *Mining Engineering* to kral@smenet.org.

Those who were interviewed for this project are:

- Emily Sarver, assistant professor, Virginia Tech University.
- Mary Poulton, distinguished professor and department head, Department of Mining and Geological Engineering, University of Arizona.
- Mike Nelson, chair Mining Department, University of Utah.
- Samuel Frimpong, professor and Quenon Chair, Mining Engineering Department, Missouri University of Science & Technology.
- Courtney Young, professor, department head, Metals and Metallurgical Engineering Department, Montana Tech.
- Dale Elifrits, visiting professor of geology, Department of Engineering and Environmental Geology, Northern Kentucky University, ABET representative.
- Hugh Miller, associate professor, Colorado School of Mines.
- Mike Moats, associate professor, Missouri University of Science and Technology.
- Jon Kellar, professor, South Dakota School of Mines.
- Jaye Pickarts, chief operating officer, Rare Element Resources.
- Mick McCaslin, director, Mineral Testing Center, FLSmidth.
- Mike Garska, senior process engineer, Simbol Materials.
- D.R. Nagaraj, research fellow, Cytec.

Despite the recent pullback in metal and mineral prices, and the associated market adjustments, the mining industry is still facing a serious issue with the declining availability of graduate expertise. This is due to a combination of an aging workforce, retirements and retrenchments, coupled with a lack of suitably qualified graduates entering the workforce. The issue has certainly improved since 2004 when the industry picked up the rates of hiring graduate engineers and mining/mineral school enrollments picked up in response. This hiring effort has helped to cover the "gap" years from about 1985-2000, when industry demand for graduates was particularly poor. However, the recent market pullback is likely to set back this progress, as recruitment and hiring wavers as a result of cost cutting measures and economic uncertainty.

A key issue for the mining industry is how to ensure the survival and growth of relevant "core" degree programs. Such programs include mining, metallurgical, mineral processing and geological engineering. The mining industry needs a healthy, high-level education program to ensure an adequate supply of appropriately qualified graduates for the mining industry. Two-thirds of the professionals entering the minerals industry who graduated within the past 40 years graduated prior to 1985. Since 1985, we have been living off the legacy of graduation classes from the mid-1970s and early 1980s. It is estimated that we have been producing graduates at approximately 40 to 50 percent of the sustaining rate since about 1985. Further growth in the domestic industry would increase graduate requirements significantly, and the export of U.S.-graduates to other parts of the world (as is currently occurring) also impacts the total graduate requirements.

To maintain a healthy education system, we need qualified and experienced faculty who want to teach and are rewarded for teaching to ensure the long-term success and viability of our industry. I believe there are three critical issues that must be tackled to address this crisis:

1. Ph.D. funding and support.
2. Faculty retention and faculty career development.
3. Appropriate post-graduate research funding.

SME is working on a plan to address these issues, and we expect to roll out an initiative to address items 1 and 2 in early 2015. Item 3 is a more complex and far reaching issue that will require an effective and sustained effort over a longer period of time to secure the needed industry and federal/state funding for research.

The following interviews by prominent industry professionals and academics at key U.S. schools offering core mining and mineral programs serve to highlight and underscore this critical need. The perspectives offered by these interviews provide a number of important insights into the problems universities face in maintaining the programs. It is imperative that we work together within SME to address these issues as a high priority.

John Marsden
2014 SME President

Emily Sarver
Assistant professor
Virginia Tech University

Mining Engineering: What's your perspective on the coming crisis in mining engineering education as a young professor?

Emily Sarver: I'm definitely concerned. Even in our department, two to three professors will probably retire in the next five years at Virginia Tech, and in a department of only nine faculty, that impact will surely be felt – particularly since on an R1 campus like this, we're already being pulled in in two directions all of the time.

On the one side there's industry, whose primary need is for us to turn out good bachelor's students who can staff and sustain the industry. On the other side is the university, which, is constantly pushing to increase the rankings, increase the research dollars, publish and turn out Ph.D.s. The mining industry itself doesn't have a huge need for Ph.D.s, but is realizing it of course, needs Ph.D.s to staff the faculty of universities to produce more bachelor's degree students.

But turning on the tap to the faculty pipeline isn't easy. Since there are few fellowship positions in our field, research dollars are the primary means of support for ME Ph.D.s, and there are few research dollars out there. It's very competitive. If I want to take on a Ph.D. student, I need to be able to secure $40,000 a year for four years to cover stipend, tuition and other costs. This is very difficult to do.

At Virginia Tech, research funds are balanced between industry and federal funds. The industry is pretty straightforward: it has applied projects where it has questions that need answered. And, rightfully so, industry members turn to institutions and faculty they know and trust for help with research. In terms of federal funds, CDC through the NIOSH Office for Mine Safety and Health Research is really the only agency that has specific solicitations for mining engineering research – and at Virginia Tech we've been pretty successful in competing for these awards. For other federal funds, you generally have to be creative. There is no longer a U.S. Bureau of Mines and the Office of Surface Mining often funds projects related to site reclamation or restoration, and the folks working in these areas are not traditionally mining engineers, but rather environmental scientists and engineers. NSF funding is difficult to get. It funds basic science, while our work is really applied, plus the funding rate is somewhere around 10-15 percent. And then there's the issue of subject matter. In reality, "mining" is often perceived very negatively and there is no doubt that politics can influence funding. For Department of Energy (DOE) funds,ME faculty that can apply their expertise to fuels and critical materials supplies and carbon sequestration have also been successful. These are not within the traditional domain of mining engineering, but the willingness and ability to branch out has paid off in terms of large projects at Virginia Tech and other ME programs.

ME: What kinds of pressures do you feel? Does it come from within the department or beyond?

ES: There is definitely pressure. Not so much from within the department, I feel like I have pretty good support, good mentoring. But the reality is that the Mining Engineering department is very small in terms of numbers of bodies (faculty and staff) – and yet we still have to do what bigger departments, likemechanical and chemical engineering, do. So despite having fewer folks to support the work load – research dollars, publications, student advising – we have to remain competitive within our College of Engineering. Also, there is additional pressure in that at Virginia Tech, the College of Engineering is the main source of research dollars, which is a main source of funding for the entire university. You get down to what's the personal motivation that drives you to run in a certain direction every day. As a department, we've got to stay focused on big research and putting out grad students, and all while still maintaining a top notch undergraduate program.

ME: What kinds of pressures come from industry?

ES: We have an advisory board that we meet with once a year and they are very supportive." They talk about how to tweak the curriculum to

improve communications skills or create graduates with more preparation in traditional business topics like finance or administration. The pressure comes more from the job market itself. It's hard to know where students are going to be placed from one year to the next. It used to be they would reliably place 20 percent in coal, but no one's hiring in coal right now. Thus we need to prepare graduates that well rounded enough to go to any sector of the industry – and I do think the breadth of our undergraduate curriculum has been a real strength for our program in this way.

ME: How big is the department at Virginia Tech right now?

ES: Nearly 200 undergraduates, which is probably too big. It's hard to find classroom space for the bigger classes and hard to advise that many students. 150-175 would be better and more typical. There are currently nine tenure track faculty members, of whom two to three will likely retire in the next five years. There also some that will be eligible to retire in the next five years but hopefully won't yet. There are also some research faculty, on soft money.

Right now, many of our faculty have to cover two to three undergraduate courses plus at least one graduate course– and sometimes, there is more than one section of a particular course. Compare that with a very large department, maybe 70 faculty members, and the same number of courses that have to be covered – it's no small task justto cover the basic ABET accredited course load. Sebatical leave, that's not really an option for ME professors. If one of us is gone for a semester, it's pretty disruptive trying to shift responsibilities. We just don't have the luxury of extra bodies to pick up the load.

ME: What is the future for mining engineering education?

ES: We have flexibility right now if we wanted to make changes – and we are looking to do some tweaks while will allow our students take more technical electives in areas of particular intrest to them But the program is working quite well according to our stakeholders (alumni, industry, ABET) and so there's a bit of a sentiment to not fix what's not broken. It's also hard to commit to long-term changes without having the financial backing to keep it up – or a crystal ball to predict future needs. As a faculty, we are committed to more conscious development of leadership skills, and of other soft concepts like ethics andsustainability, and this will be reflected in curriculum changes we do make. The trick is figuring out how you teach these things? And how you know when your teaching has been effective.

Furthermore, the mining industry is experiencing a lot of the same demographic shifts that the university is, with large numbers of the workforce retiring without enough people to replace them. My classmates – 10 years out from a BS – are already rising to upper management ranks in the industry. This provides great opportunities for this generation, but they're getting less experience. This wasn't the situation 20-30 years ago.

As to replacing faculty, if say all five that are eligible retire in the next 5 years, it would be nearly impossible to replace them with straight ME or mineral processing backgrounds. There aren't enough Ph.D.s out there. And if they're there, they won't all want to work at an institution like Virginia Tech.. When the department hires and, more importantly when the college hires, they work very hard to hire people that are going to succeed in this particular academic environment. It takes a certain kind of person. . The university doesn't frown on industry experience – that would be a plus, really – or on applicants that don't have enough prior publications or research dollars; it's the whole package. To be successful in getting tenure at a research university, a candidate has to be able to teach, advise graduate students get research dollars, participate in industry outreach, etc. etc… and do all of these well. And whether or not we're supposed to say it, research is the top criteria for many faculty at an R1 university. Running a research program is like running a company: there's a constant pressure to bring in dollars and support people. But in this case, your whole goal is to develop talent for the larger community – so you're people don't stick around forever, when they graduate, you start that part of the process all over again.

ME: What would be one thing that could fix this state of affairs?

ES: A funded Fellowship program would be a start. We need support for Ph.D. students while training them in the skills they will need in academia: pedagogy, research and administration – not to mention communication and stakeholder engagement. It's a goal to train Ph.D.s for the job of academia. Right now we are not able to focus on that as much as we need to be sustainable. We're fighting every day to get funding for students, but it can't all be research grants and contracts.

The money to fund that will most likely not come from the federal government. Possibly a private foundation or industry. The question is, does the industry support the undergraduate programs enough to support the faculty? Somebody has to value the program as a whole, and what this means is valuing and supporting faculty and aspiring faculty.

Mary Poulton
Distinguished Professor and Department Head
Dept. of Mining and Geological Engineering
University of Arizona

ME: What is your perspective on this issue?

Mary Poulton: One of the things that struck me when SME did the pipeline survey a few years back was that none of the Ph.D. students who wanted to teach wanted to teach right away, and none of them wanted to do research. So the problem at the heart of the sustainability crisis is not just about teaching, it's about research and creating researchers.

Part of the problem is that, in the past, industry jobs were seen as high risk. Now university jobs are seen as high risk, as the government cuts back funding. Also we just have this smaller group of qualified people tugged on by more attractive forces.

The mining industry is not going to change how academia is run – it's too small. That said, we've always been a bit leading edge in terms of coming up with solutions. The issues we're having are not unique to mining. All across the university, in the engineering disciplines, the same challenges are cropping up.

We've seen that undergrads respond to market forces: if there are well paying jobs and scholarships to support study, they will come. Do Ph.D.s and professors respond to market forces? That's less clear. But it seems that if you have the funding, you will find people who want to do the work.

It's a complex problem, and it would definitely help to have a steadier pipeline of research dollars and an ability to fund tenure track faculty. It's hard to do that, though, without government support.

ME: Is that government support for education in general, or support for research?

MP: Government support at the research level. The research support at the federal level has just dried up. There used to be the U.S. Bureau of Mines, which had a broad-based research portfolio – most programs around the country had funding from them. Then again, NSF used to fund applied research in the 1970s. It doesn't any more. There is a lack of overall vision for mineral resources at the national level. Fortunately NIOSH has been very supportive of extramural research funding for mining engineering faculty but they are limited to topics that fall within their mission and scope of safety and health.

ME: That brings us to the role of the SME Foundation's Minerals Education Coalition (MEC). Can organizations like MEC influence or affect this situation at all?

MP: It's this big continuum. Professors come from grad students, grad students come from undergraduates and undergraduates come from K-12 students. That's the challenge, and SME is still a very small organization.

However, MEC is not just about K-12. It is also about getting parents and decision makers to understand the value of minerals and mining. It can also raise the awareness of jobs. That's back to those market forces again: if parents see the jobs out there, they will be more likely to push their kids toward mining. It's also the creation of knowledge that is important for the industry and the nation. What SME is able to do very well is bring that national need to the attention of decision makers – at both the state and federal levels. It's important to include the states, too. Most of the mining schools are state schools, state funded. The mines are in states. But that aspect is less emphasized. Plus, there is a crisis at in government, too. The U.S. Geological Survey, the Bureau of Land Management, the U.S. Forest Service and state agencies also need to replace large numbers of mining people who are retiring.

The mining engineering department at the University of Arizona currently has 117 undergraduate students and 50 graduate students, 18 of whom are Ph.D. candidates. The rest are Masters candidates — most of them industry funded — working full time. There are nominally 10 faculty positions; two positions are non-tenure track professors of practice focused on teaching. .

There is a pressure on the tenure track faculty. Tenure track faculty members have about five years to prove themselves. They must develop industry contacts, get students, funding and publish. If funding was easier to identify, it would be easier to get students and start producing publications. Fundamentally, the job of the tenure track faculty member is to create and disseminate knowledge and that takes time and money, both of which are in shorter supply for mining engineers than other disciplines.

The subject of mineral resources is bigger than just mining. We've developed an interdisciplinary program in which we intersect with geosciences, economics, social sciences, business, health and law to create a broader talent pool for industry. This brings a bigger perspective to the table. Mining, metallurgy and economic geology are the hub in this hub-and-spoke model. With the spokes, you get a much bigger reach. Plus, we emphasize that mining is a global business: you need to be culturally competent and proficient in another language. We hire international

faculty intentionally in order to emphasize the importance of a global outlook.

ME: What about mining engineering education in other countries?

MP: In the English speaking countries — Canada, Australia, South Africa and the United States – there are the same pressures, the same age demographic issues. These are less of an issue in India, China, Russia and Latin America (although Latin America does have trouble recruiting faculty, just because the industry is doing so well). So it's not just funding. It's demographics and it's the commodity price cycle. The United States is unique in the disinterest from the government in helping solve the problem. In Australia, the industry and government have stepped in and created a good model, a model that is difficult to emulate in the United States. We also have to consider that fewer and fewer metal and nonmetal mining companies are actually headquartered in the U.S. When decisions are made at corporate headquarters in other countries, education support tends to go to those countries.

ME: What's the future of mining engineering education? Are we just in a downturn, or is it going to go away altogether?

MP: I am a bit pessimistic about whether all programs will persist. Universities are becoming more and more like businesses, and they are aware down to the penny the cost and benefit .of each professor. The return on investment for mining faculty tends to be lower since the programs and departments are smaller. The research dollars are also less. With the greatly reduced state support, universities no longer have the cushion they had in the past to see mining programs through a protracted downturn. The government grants allow smaller indirect costs, and industry doesn't like paying indirect costs either. There are fewer student credit hours and fewer graduating seniors and graduate students per faculty member for mining departments.

ME: What's the solution? The one thing that could turn this around?

MP: Money is the number one thing in neon lights. Another is more interdisciplinarity within schools and cooperation between schools including shared courses, collaboration and distance courses. It's not a perfect solution but it addresses some of the biggest problems. The scarcity of the kinds of well-rounded faculty we need is the biggest threat to Mining education in the United States.

Mike Nelson
Chair of Mining Dept., University of Utah

Mining Engineering: What's your perspective on the looming crisis in ME education?

Mike Nelson: The age distribution of ME professors is like that in the industry, only more extreme. At Utah for example, of five tenure-track faculty, two are over 65 (72 and 68), one is 62 and two are much younger (34 and 26). A lot of experience is will be retiring in the next few years. Often the older professors have several years of industry experience, which the younger professors may lack. This creates two problems, first, replacing the retirees with qualified people, and second, getting those people through the university tenure system before they give up. Also,

Salary is major problem. I can hire a newly minted Ph.D. into a professorship at a 9-month salary of $80,000 to $85,000. A new engineering student with a B.S. can make an $80,000 starting salary at a mining company. Recently I was working with a faculty candidate who had a Ph.D. and had worked in industry for several years. He knew he'd have to take a pay cut to become a professor, but he wanted to teach and was willing to make that sacrifice. Then his company heard he was looking into the job and offered him a 20 percent raise. I couldn't compete.

To address this challenge, Utah recently developed a five-year B.S./M.S. program, making it easier to get a master's and easier to move into the Ph.D. program. Four of our recent top graduates have entered this program. The idea is to get more master's students, some of whom will continue to the Ph.D. and, of those, some may become professors.

At one time, it was possible to get a tenure-track engineering faculty position with a master's degree and 10 years of industry experience. You cannot do that now. The tenure system is difficult. Besides having the "terminal degree," you have to demonstrate excellence in research, teaching, and public service.

The importance of teaching and public service are acknowledged, but universities often place more emphasis on research, defined by how much money you bring in and the number of refereed papers you publish. This is a problem in the mining industry, for two reasons. First, there is very little funding at the federal level and it can

be difficult to meet expectations of the university. Second, there are relatively few refereed journals in mining, and those that exist are not widely read. For ME, if they want their papers to be read, they should probably publish in *Mining Engineering*, the CIM Bulletin, or in specialized proceedings, like those of the ventilation symposia. These are what the people who make decisions are reading. (I hate to say it, but not many people read the Transactions.)

A new model for funding mining research is needed. Australia has a system that works well. For every ton of coal sold, the industry donates a few cents to a research fund. This generates $6 million in annual research funding. About 70 percent of Australian research dollars goes to university researchers; the rest goes to business, often small businesses and entrepreneurs.

The industry in the United States is more diverse than Australia's, so it's historically been harder to set up cooperative research similar cooperative research funds. The current effort of the SME Foundation, spearheaded by John Marsden, is right on the mark. The managed fund set up by the SME Foundation draws from lots of sources and offers a promising source of research funding for new academics.

ME: What will mining engineering education look like in 20 years?

MN: In the United States, there will still be mining engineering education, but there may be fewer mining schools. The schools and universities that are forward thinking will share graduate students and share subject experts, especially those with graduate-level expertise. Distance learning and online courses will be common.

Also, U.S. schools will work a lot more with mining schools in developing countries. For example, there are about 6,000 mining students in Peru. Faculty members at Pontifica Universidad Catolica de Peru (PUCP) tell me that they would like to expose their students to education and mining operations in other countries — especially in North America — to help prepare them for employment in the global mining industry. We signed an exchange agreement with PUCP that we hope will soon include mining companies, in which students will study and do an internship abroad — U.S. students in Peru, and Peruvian students in the United States.

Mining engineering education has seen similar transformations in the past. At one time, the mining schools in Europe were dominant, with a well-established but largely theoretical approach to the discipline. When the Columbia University School of Mines was founded in 1864, its students were encouraged to spend their summers gaining hands-on experience in the mines in the U.S. and elsewhere, Columbia quickly became the world's premier mining school. Other schools in the U.S. followed suit. I think we'll see another transformation, and mining engineering education in the future will have certain locations with recognized, focused excellence that cooperate, within the United States and internationally, to provide students with the theoretical and practical skills they need to work in an industry that operates worldwide. With well-designed, distance-learning courses, this approach will be even more practicable.

Samuel Frimpong
Missouri University of Science & Technology

Mining Engineering: How does the current Mining Engineering education system prepare students?

Samuel Frimpong: The program combines academic work and professional and leadership development to prepare graduates for industry and academia. First, there is the coursework in the basic and fundamental sciences that undergirds the degree. Then there are the basic engineering courses, followed by the applied sciences and core mining engineering courses, and finally the general education courses, which include the social sciences and the humanities. The curriculum is designed to satisfy the ABET program criteria for mining engineering education for professional practice. Through internships and COOP opportunities, and memberships in extra-curricular activities, graduates are shaped as leaders for industry.

ME: Can you speak to the importance of the degree?

SF: The B.S. degree program develops mining engineering graduates with the required knowledge and skills to become critical thinkers, problem solvers and leaders. The program exposes and enforces technical competence, culture of safety, leadership and management, social responsibility and a passion for the mining industry and the importance of lifelong learning in the career of a mining engineer. Overall, the program prepares graduates to become qualified as entry-level engineers ready to become useful engineers and leaders in industry.

ME: How do these experiences change the perspective of the students?

SF: Exposure of students to industry practices via internship and COOP opportunities allows students to catch a glimpse of the nature of the industry. It helps them to appreciate the various components of the industry, the major players, the processes, and how the pieces fit together to make everything work appropriately. Hands-on experience at the Experimental Mine, laboratories and industry internships are core values at Rolla. This is Rolla's philosophy, "If a mining engineering student graduates with a perfect cumulative GPA of 4.00/4.00 without at least one internship or COOP opportunity, s/he is improperly educated and not ready to be introduced into the industry as an entry-level engineer." Availability of these industry opportunities is, thus, a critical component of the processes for educating mining engineers. We are partners with industry for educating highly qualified engineers for industry, and the need to avail internship and COOP opportunities is all the more important.

ME: If industry was to address the coming shortage in B.S. in mining engineering students by developing their current new employee training programs to encompass mining engineeringg training, what would students lack?

SF: Industry can train a certain class of employees to become operators but it is not set up to formally educate students toward a mining engineering degree certification. The curriculum for educating mining engineers, as outlined earlier, requires several components derived from the ABET program criteria (on curriculum and faculty), which cannot be addressed by industry. During their basic education, undergraduate mining engineering students learn to dissect, disseminate, design, build, compare options, look at consequences, experiment, simulate and analyze in experiential learning environments. They also interact with students from other disciplines and universities in a number of activities that strengthen the learning process. These processes also build critical thinking and problem solving skills in them, without which, a student will lack these skills.

ME: What is the size of the mining engineering program at Rolla?

SF: The Rolla Mining Engineering program consists of 220 undergraduates and 115 graduates, 11 tenured and tenure-track faculty, six non tenure-track teaching faculty and seven adjuncts from industry, who contribute significantly to the teaching mandate of the program. For example, a recent course developed and taught by the former President and CEO of Centerra Gold, Stephen A. Lang, focuses on global leadership in the mining industry. Steve brings into the classroom his experience as a leader in diverse positions in the global mining industry and students enjoy that perspective.

ME: So your department is really pretty healthy.

SF: Yes. In addition to a healthy enrollment, the Rolla programs graduate significant number of graduates for the US mining industry every year. In the academic year 2014, Rolla graduated 36 undergraduates and 36 graduates and generated over $6.3 million in research expenditures. But the future is critical. In order to create a sustainable growth in the future, we developed the FY 2020 Strategic Plan in 2010 to focus on five strategic initiatives. Part of this was to put in place a strong industry board. Currently, 33 top industry leaders from all parts of the mining industry serve on the mining engineering board. This board meets once a year with agenda items focusing on the current state of the programs, critical areas requiring improvements and growth opportunities. For example, one critical component of a healthy mining engineering program is the state and capacity of the laboratories. A review of these labs in 2007-2008 emphasized the need for renewing and expanding capacity and building new ones to cater for the needs of the growing programs. The board led the effort to raise capital investments for this purpose. Today, the Rolla program boasts of two new computer learning facilities, a virtual surface mining simulator facility, and a mining survey facility. A new building is under construction at the experimental mine. Capital has also been invested to renew the rock mechanics lab, with efforts underway to construct the virtual underground mining simulator facility. All these expansions and renewals happened because of the board's leadership for which the university is very grateful.

The school has also developed a diversified portfolio of mining engineering programs. In addition to the B.S./M.S./Ph.D./D.E. programs, Rolla has introduced a distance education program leading to the M.E. certification in mining engineering, the M.S. and Ph.D. degrees in explosives engineering and has joined with Business to develop the M.B.A. program for mining executives. Mining engineering is also collaborating with chemical and metallurgical engineering to develop the M.S. in mineral processing, and with economics to develop the M.S. in minerals and energy economics

ME: Can you speak to the situation in other countries?

SF: Mining engineering has a strong global

presence with a 3+2 program with the University of Botswana (UB). Under this program, UB graduates transfer into the third year at Missouri S&T after completing two years of fundamental and applied science courses to undertake a structured program leading to certification with the B.S. degree in mining engineering. Missouri S&T has also been selected by Saudi Arabia to help develop a two-year program to educate personnel for its emerging mining industry. We have also completed Memorandum of Understanding with universities in Indonesia, Mongolia, Dominican Republic, Peru and China to develop the 2+2 programs that bring diversified student population to Missouri S&T. Peru is one of the leading mining countries in the world, with 60 percent of its gross domestic product attributable to mining. In Peru, we are working with Instituto de Securidad Minera (ISEM) and other universities to strengthen mining engineering programming activities in selected core areas.

It is important to note that the industry challenges are global. What is certain, though, is that the world still needs mining engineers and academia must partner with global industry and academia to develop and offer programs that respond to these needs.

ME: Where do you see mining engineering education in 20 years?

SF: The fundamentals and the core mining engineering courses will still be the same. However, the technological directions in industry will require students to be experts in other disciplines like automation, intelligent maintenance engineering and advanced technologies on board mining machines. Mining engineering education requires graduates to be knowledgeable in several areas and it will continue to do so and even more. Currently at Rolla, we are discussing initiatives with electrical and mechanical engineering and computer science departments to introduce automation, robotics, intelligent maintenance courses into our program as minors and emphasis areas.

Courtney Young
Montana Tech

Mining Engineering: Your perspective on the crisis in extractive metallurgy/mineral processing education and how it is affecting your institution.

Courtney Young: That is a big question. I am going to try and answer it is simple terms but, by no means, is it complete. Fifty years ago or so, schools across the country offered degrees in extractive metallurgy and/or mineral processing. Around that time, the demand for new materials was increasing; markets for ceramics, polymers, plastics, rubbers, advanced alloys, glasses, composites, etc. were taking off. Federal funding began to shift to these areas and research universities chased the money. Extractive metallurgy/mineral processing programs started to close but the nail in the coffin came when the Clinton Administration shut down the U.S. Bureau of Mines. It was the last source of major funding. A few programs held on as options in, or even changing their names to, chemical engineering, metallurgical and materials engineering, and materials science and engineering.

To the best of my knowledge, Montana Tech, CSM, SDSM&T, U of UT, Missouri S&T, and UNR are the survivors. Montana Tech is in Butte, which sits at crossroads of two interstates. But even then, it is out of the way and small with approximately 3,000 students. It has different challenges and opportunities than other schools in places like Denver or Salt Lake City. When I joined Montana Tech's Department of Metallurgical and Materials Engineering, it had about 35 students and has slowly grown to 70 students where it is now. It has six faculty members, one of whom is supported by an annual donation from Newmont. This person teaches and does research in mostly extractive metallurgy/mineral processing classes. In brief, I have to say that the effect has been positive.

ME: So what is the department doing to address this crisis?

CY: A lot! This industry is a good industry. It gets unfairly attacked on emotional grounds by environmentalists. But still it's an industry that we have to have. Countries are built on its resources, predominantly human and natural. But, there is an image problem that must be overcome; fortunately, that is starting to be the case.

As a department, we recruit students from all over the world. The tendency is that they come from rural areas. In Montana, even the urban is rural so it's a good fit. It's nice, but a rare occasion when we get a kid from the big city who doesn't mind going to work in exact opposite places. Such graduates are more than happy to go work anywhere.

With recruiting, our approach is mostly three-fold. When we have high school students visiting, we do hands-on demonstrations in our labs. We have more advanced demonstrations for on-campus students and, in fact, will be doing this more frequently when the Freshman Engineering Year is implemented. Lastly, we just had a

successful inaugural Summer Camp for 22 high school teachers. Now, they serve as internal HS recruiters. We expect it to develop into a camp for high school students in the near future.

We have also been able to maintain the hands-on labs in our program. They do at least 15 labs by the time they graduate. Graduates hit the ground running. Having 100 percent placement with high paying jobs adds to the appeal.

All of us now have Congress's attention. For example, when China obtained control of 98% of the global rare earth market, some red flags in Washington D.C. were raised. It got Senators communicating and helping one another. Montana Tech, SDSM&T and CSM have some collaborative projects with the Army Research Lab (ARL) and the Office of Naval Research (ONR). More is coming with U of UT. CSM is heavily engaged in the Critical Materials Institute (CMI). These entities, of course, are part of the Department of Defense. Their concern is with the safety of the soldier and protecting our country. Numerous products comprised of rare earths and other critical materials are made with just that in mind. The same can be said of the private sector. In my opinion, that's just the first domino; the last one will be when the National Science Foundation (NSF) starts responding as well.

ME: So you're saying that federal funding is critical to reviving mining departments in the United States?

CY: Yes. Faculty need to have activities, and research is one of the most important. Research has a wonderful way of working its way into the classroom and enhancing education. It's also a matter of deep pockets and fixing a wrong.

ME: What about other solutions – sharing faculty, etc.?

CY: On one hand, Montana Tech has its first Ph.D. program. It is in Materials Science but is a collaboration with and UM-Missoula. The 20 core credits developed for the program will be taught by long-distance with the first classes offered this Fall. On the other hand, MT and SD currently share seminars. We have discussed sharing courses, but that crosses state boundaries and raises some economic issues — how do you share tuition? At the department level, of course, we're like who cares? They teach a course, we'll teach a course. But the university is a business that cares about maximizing income and minimizing expenses. Bottom line: we will do what it takes for this industry to survive but it's going to need industry support to continue and increase.

ME: So, what then is industry's role?

CY: The industry has to help out and they do, often in extraordinary and different ways. It's pretty simple to say that we all benefit but the truth is: We do! They benefit by hiring an educated workforce. We have a job to provide them that educated workforce.

We are also employed to do research. I am one of those lucky faculty who has been able to bridge the gap and do research at both the federal and industrial level. My federal research has often been tied to industry. With industry, I get to tackle problems that they just can't get to. Those projects have been done with senior design as well as undergraduate and graduate research. It's win-win.

As another example, Newmont annually sponsors a faculty position at Montana Tech. It insures that both of our mineral processing labs are offered along with several others including fire assay and processing of precious metals. With the latter, Newmont supplies about 15 guest lecturers from their labs in Denver and operations in Nevada. It's a course that is a student's favorite. Companies like Freeport-McMoRan, Cliffs NR, Nucor Steel, Rio Tinto/Kennecott, Gold Corp., Stillwater, FLSmidth, Barrick, etc. are reaching out to everyone, not just us. My apologies for only being able to mention a few companies but my sincere thanks are offered to all that do. There is a strong need for endowed professorships on this campus and many others.

ME: What will mineral processing education look like in 20 years?

CY: I don't see it shrinking. I think the federal government is waking up to the damage done to it by environmentalists. The issues surrounding the rare earth markets was just a tipping point. We've got to make sure that industry survives; otherwise, this country is in trouble. This is true for the timber industry and several others as well. We cannot become too dependent on imports; perhaps, we finally learned from OPEC.

I see education getting broader, starting to include health and safety and environmental issues. It's certainly broader than it was just a few years ago. Where there's a need, there's a market. I also see it retaining the hands-on but with state-of-the-art equipment. Graduates will continue to hit the ground running but even harder as a result.

I have heard numbers that are exciting. Our graduates take two to four months to become fully trained. By comparison, a chemical engineer hired into the same position can take upwards of two years. Both disciplines are about processing, but the direct education is paramount. It's well worth industry's investment. Not only that, our graduates tend to be faithful about staying put.

C, Dale Elifrits
Retired Director of Pre-Engineering and Visiting Professor of Geology, Department of Physics and Geology, Northern Kentucky University; Professor Emeritus, Geological Engineering, Missouri Univ. of Science and Technology
ABET Alternate Board Representative for SME

Mining Engineering: First, can you briefly explain the ABET accreditation process to me?

Dale Elifrits: First, it must be understood that ABET accreditation of a degree program is voluntary. The program and its host institution invite ABET to send a program evaluator as a part of a team of program evaluators to visit and evaluate the program's suitability to be accredited by, in the case of engineering programs, the Engineering Accreditation commission of ABET. The accreditation process is used to assure quality of the education for the graduates of a degree programs. These are accredited independently of the institution in which they reside. Degree-granting programs may be in a traditional department, or "housed" by something else, such as a multi-disciplinary department, or managed by a multi-disciplinary committee. But they must have dedicated faculty, budget, facilities, quality assurance, be able to deliver on their promised outcomes, and grant the degree.

ABET was originally called Engineers' Council for Professional Development (ECPD) and was formed in the 1930s by mechanical, electrical, chemical, civil, and mining engineers to create baseline criteria that students would have to meet in order to be ready for the work force. These general criteria are basic standards that graduates must meet. This developed somewhat in concert with the state boards of licensure of professional engineers. ECPD changed its name to ABET in the late 1970s.

Until the late 1990s, ABET degree program accreditation was essentially an audit process, based mostly on input numbers: number of classes, number of credits, numbers and kinds of courses, number of faculty, number of lab stations, etc. During the late 1990s, the accreditation process became focused more on the outcomes: can the students at the time of graduation actually perform at a particular level? ABET expanded around the same time to include computing and computer science and applied science degree programs.

ABET accredits degree programs based on two related sets of criteria. First, there is are the general criteria, for which all engineers everywhere need to be proficient. Then, for most but not all disciplines, there are the discipline specific criteria. Mining engineering has these, as does geological engineering. Geophysical engineering does not. Mineral processing is only addressed by SME ABET volunteers by invitation. We examine mineral processing programs as our expertise is deemed to be appropriate. New Mexico Tech, for example, has a mining engineering based mineral processing program and is visited and evaluated by SME ABET volunteers. Also, international programs will sometimes request accreditation, but this, too, is by invitation only.

To be ABET accredited, the faculty of the program must be of sufficient number to offer the coursework, so that students can make timely progress to graduation with their degree requirements met. There is technically no minimum number of faculty required, but they must cover the breadth of expertise. They must be able to follow through on what they promise in their program.

ME: What happens on a national basis if there is not enough faculty members?

DE: I see mining engineering education in the United States as a single organism, or ecosystem. A certain number of faculty flow out through retirement, etc., and a certain number flow in by from Ph.D. programs. I did a survey in January (2014) of the programs, and there were approximately as many Ph.D. students in the pipeline that had self-identified as being interested in pursuing tenure-track careers as there were openings. Right now, that system appears to be in equilibrium. But I see a time, perhaps five years, when that equilibrium will not be the case. There won't be enough full time regular faculty members to teach the required classes. It is possible to meet that requirement through adjunct faculty members or other means, but students don't like that. ME students are particularly sensitive to wanting to see faces in the classroom and on campus. They want faculty, not adjuncts. I think this won't lead itself directly to loss of accreditation, but to a loss of students, which leads to program closure by the university.

ME: How do you envision the state of ME education in the next 20 years?

DE: It could be pretty bleak if we don't find a way to fill faculty spots positions. The average age of faculty in the nation's programs likely is between 50 and 60.

ME: What would it take to turn it around?

DE: Three things are in play. First is the salary situation. Professors aren't poorly paid. But at the start it's not much more than what you'd make as

an entry-level engineer with a bachelor's degree in many cases. But I don't think it's as big an issue as two other things.

Second is the morass of the tenure-track process. Tenure used to be a given if the new faculty member was diligent as a teacher with some research funded and papers published, and outreach to the industry. Now it is not. Critical issues are how much grant money you bring in and what specific journals accept and publish your papers. Teaching, research, service – these are not really important to the university in the same way that the money is.

Third is how much of your life are you going to own? I think there's an idea that the life of a professor is a cushy, easy job, and it's not. As an engineer especially, you're going to be expected by the university to bring in the big bucks. Now if you contribute well to your company at Newmont or somewhere, you're going to advance in the company. In academia that is less true. This combination scares people.

ME: Half of the mining engineering programs/ departments in the country have closed in the past 30 years. Can you talk a little about how that came about, what the process looked like? Was it related to accreditation?

DE: In all the cases I can remember, it's been the state legislature action or a state agency or university administrative decision that has caused the closings. It has had nothing to do with the quality of the program. The state "boards of higher education" has have said that the program/ department didn't have enough graduates for a certain number of years in a row. In many cases, this costs the state/institution money. As part of the agreement with ABET, institutions are required to support the juniors and seniors in the program through to a degree in the field they choose should the institution close their program of progress toward graduation. In most cases, this has meant paying the out-of-state tuition costs at other universities for the left behind students.

So far, no program has closed due to faculty attrition. It's been some "bean counter" at the university or in the state saying something like, "You haven't had more than say 12 graduates in two years, and we've decided that that's not enough." Some administrator or agency officer decides there's a magic number and all of a sudden that's the number that must be met.

There may have been some that closed due to low faculty, but I don't remember any. Closure decisions are often not related to what's going on in the program – that's very disturbing to a lot of us.

ME: Another solution that universities have come with is to share faculty between institutions. Is it possible to get accreditation for a program like this?

DE: Yes. Some European universities do this – I believe in England and the Netherlands.

What's important to remember: Accreditation is not a roadblock. The university says what it is doing and then proves that it doing that, with documentation.

Hugh Miller
Associate Professor, Colorado School of Mines

Mining Engineering: What is your perspective on the ME education crisis?

Hugh Miller: The challenges facing mining higher education are a lot more complicated than it appears, and stems from fundamental changes in both the industry and academia over the last 30 years. There are several interdependent reasons for why we've gotten to where we are now. The biggest threat I currently see is the lack of a viable pipeline to produce candidates to replace aging faculty. This isn't a U.S. or Canadian problem, but is universal throughout the developed world. The second major issue is the way mining departments are viewed and evaluated by university administrators. Given the current assessment criteria used by most universities (student credit hours, Ph.Ds generated, scholarly publications, and research volume), mining programs will never do well in two of the four criteria.

Trying to attract high quality candidates that possess both the academic and professional qualifications necessary to be successful as a university professor is becoming increasing difficult. To recruit potential candidates with industry experience into Ph.D. programs – there must be a motivating reason and it's certainly not compensation or work load. Usually these individuals enter academia because they enjoy working with students or they have an entrepreneurial bent that can't be readily met in industry.

In industry, you're often focused on tangible results associated with the current reporting period. Academia, however, allows an individual to take a bit longer-term outlook, particularly with regards to technology and research, and the freedom to pursue areas of personal interest.

Most of the time, individuals who pursue careers in academia do so because of their love of working with students and it affords them a unique ability to collaborate with others.

The normal professional progression for individuals in mining is different than most industry sectors, where the B.Sc. is the working degree. While those interested in a career trajectory that involves management or advancement in a technical field they will often pursue a Master's degree in finance, business, or mining. That said, it is rare that an individual would want to earn a Ph.D. in mining. The opportunity costs are too high and the simple fact that the industry doesn't recognize the benefits of the degree in most career applications. Furthermore, it is rare to see the straight B.S.-M.S.-Ph.D. degree progression common in most other engineering and science disciplines. I believe industry experience is important because it brings a unique perspective and insights of the faculty into the classroom.

Put simply, the United States is not producing enough mining Ph.D. students and there is little incentive to attract them to these programs.

ME: Why aren't more students getting Ph.D.s?

HM: A well-respected industry executive recently told me that "a person would have to be insane to get a Ph.D. in this market" and he has a valid point. It is a major commitment of time and money to earn a Ph.D. degree and the remuneration of a starting assistant professor is often less than $90,000. Given that a traditional faculty candidate may have 5-10 years of professional experience, in addition to a Ph.D., this represents a major financial disincentive. As the salary disparity between industry and academia grows, this incentive will only become more pronounced.

In the past, traditional academic programs relied on professors who went back to academia after some time in the industry. These individuals would often form the nucleus of the core faculty, and would be surrounded by adjuncts and teaching faculty who were either retired or actively working in the industry. These part-time faculty members would then teach one or two courses per semester and provide an occasional seminar or lecture. This type of scenario provided a department's curriculum with depth and breadth, as well as a direct connection to industry and a means for providing student mentoring. Unfortunately, this type of program structure is quickly disappearing in most universities due to pressures associated with accreditation, national ranking, and economics.

ME: What are the challenges for the universities/how does mining fits into the big picture?

HM: University administrators often assess the health of an academic program by the number of PhDs generated, where mining is never going to look good relative to other engineering majors. They also look at student credit hours, where again the enrollments of most departments prohibit the numbers from looking very good. Similarly, the limited number of referred journals applicable for many mining subjects (exclusive of rock/soil mechanics and geotechnical issues) in which faculty can publish has also adversely impacted academic scholarship and emphasizes the importance of SME, *Mining Engineering* and *Transactions*. Where mining departments do look good is relative to research volume per faculty member. As compared to civil, chemical, and mechanical engineering, mining is at an inherent disadvantage in most of these assessment criteria. Overall, the dynamics of mining education is hard to support in a traditional university setting. Our programs are small and expensive.

It extremely important to note that there is a general belief that if the number of accredited mining engineering programs drop below a certain threshold nationwide, it is likely mining as a distinct discipline would be merged into general engineering for the purposes of ABET accreditation. This would be catastrophic for many departments.

The typical fate of a program or degree granting department that has been blended into a larger department is a loss of identity. There are numerous examples over the last 30 years of where mining departments have been merged with civil engineering resulting in their collapse. Smaller programs usually lose resources, identity, and their constituency base.

The other big issue is that most mining degree programs rely extensively on industry constituencies for their survival which is very different than other engineering disciplines. In the event these constituencies fail to support a particular academic program(s) for whatever reason, these programs generally cease to exist.

ME: What about the Ph.D. pipeline problem:

HM: Coupled with the scarcity of viable Ph.D. candidates interested in pursuing a career in academia, the attrition rate of newly hired tenure-track faculty within existing programs is significant.

One of the challenges in the traditional model of recruiting new faculty from industry is that they seldom have research and publication records. When compared to other disciplines

where candidates begin publishing early in their career, recruiting Mining Faculty in the 30s and 40s puts them at a distinct disadvantage.

It's important that companies understand that if they want a professional workforce (undergrads with a BSc. degrees in mining) they need to invest in these academic departments and support faculty research. Unfortunately, many companies don't understand the connection between research and teaching. If a professor isn't successful in attracting research, regardless of how good of a teacher they are, they won't achieve tenure which will effectively end their academic career. Given the challenges of finding new faculty, this directly impacts the capacity of a department to produce graduates.

ME: What about research funding?

HM: There has got to be research funding – the Bureau of Mines closure was devastating to many U.S. mining departments. Once established, mining faculty are pretty proficient in attracting research funding. The same can't be said for new faculty. As such, the influence of career grants for these individuals can't be understated. Most universities establish expectations for externally funded research ranging annually from $150,000-$350,000 per faculty member.

Mining Engineering and *Transactions* are critical to this as well.

ME: Where do you move forward?

HM: Collaborate across institutions – sharing faculty and resources, especially in areas requiring specialized expertise. It's important to look for synergies between programs. In addition, academic programs can consort together in order to solicit company and government support. Programs should not try to compete with each other but rather, work together to achieve win-win propositions.

Companies need to re-evaluate the way they contribute to universities. Many companies in the mining industry fail to contribute to higher education at rates typical of other industry sectors. This is particularly true of petroleum engineering. In addition, many fail to hire students or invest into academic programs when times are bad: that's when the programs go under or they lose significant student enrollment. When times are good and companies need engineers, the departments that they let fail or have significantly contracted are the major reasons for workforce shortages.

"It's conceivable that the United States could lose four or five programs in the next 10 years. While this is problematic, there are opportunities for the surviving departments to collaborate and reinvent themselves. The goal is to be proactive and be one of the surviving departments.

Despite very different funding models, this situation is not unique to the United States. There used to be four very prestigious mining schools in the UK – now there is one. A host of other countries have experienced the same major consolidation.

Program survival will be a function of collaboration between departments and establishing substantive industry partnerships.

Mike Moats
Missouri University of Science and Technology

Mining Engineering: What's your perspective on the crisis, especially as a mineral processing person?

Mike Moats: The mining engineering education crisis is well-documented and easier to measure. The mineral processing crisis is harder to measure. It falls in the cracks between disciplines. There are eight metallurgical engineering departments – which is where mineral processing usually lives – but these have been subsumed by materials engineering departments.

The decline in mineral processing as an identity has been the result. Some professors specialize in it within the larger departments but it's not the same. There's less focus."

The B.S. in mineral processing does not exist at very many institutions. There are other related disciplines that offer degrees and even maintain departments: metallurgy and extractive metallurgy. The latter can live in SME, TMS, AIST.

To me, this decline means fewer faculty that specialize in mineral processing or extractive metallurgy.

As mineral processing was absorbed into materials departments, those departments had to make sure professors could get dollars. With no more U.S. Bureau of Mines or any other clearinghouses for mineral processing research funding, departments tended to focus their hires on nanotechnology and computational modeling or whatever was popular and likely to get funded. With no clearinghouse for funding and the loss of stand alone departments, mineral processing specializing professors are getting rarer and rarer. Materials science is also a small department: they can't have faculty that aren't

bringing in the research dollars.

It comes down to university economics. There's no federal funding, and industry either can't or won't fund young faculty. Older, established faculty, yes. Young, no."

All of my research money comes from industry. But it's competitive: you compete for industry funds on a worldwide basis, and that puts U.S. researchers at a disadvantage. Canadians and Australians both have access to matching grants programs in their governments, so that $60,000 to $80,000 it costs to fund a grad student at my university costs the company $30,000 to $40,000 at a Canadian or Australian institution. This is especially true for international companies like BHP Billiton, Rio Tinto, etc.

So there is the lack of sustained research funding. If the mining industry wants to support mineral processing, they're going to have to step up.

ME: What role does ABET play?

MM: ABET accredits mineral processing but not mineral processing programs. At MS&T, mineral processing is in the mining engineering department, which affects accreditation of the program. Mineral processing coursework is required for the mining engineering degree, so that keeps some mineral processing safe. But then there's the funding issue still: When you hire faculty, you have to be able to bring in research dollars.

When I was at Utah, they tried to hire a mineral processing professor for the department for seven years. They finally had to hire a newly minted Ph.D.

If I could wave my magic wand? Federal matching of industry dollars. How much money do we need in order to establish a research fund? There's the Petroleum Research Fund generated in 1930s as part of the breakup of the oil monopoly that funds young people and senior people, which is where we need the dollars. A mineral mining research endowment to fund industry and the feds kick in money to it, house it in a place like SME. If the industry kicks in, commits to a certain amount of annual pain for 10 years, get to an amount like $100-$200 million for an endowment fund.

ME: Other solutions?

MM: I'm wondering if there aren't enough mineral processing engineers to hire, if industry will just end up hiring electrical, chemical, materials engineers are retraining them. Maybe SME figures out how develop an educational consortium to help with this retraining, aid industry. Of course the problem is that if the courses are developed by university faculty, universities want the course money.

Some departments are developing online courses and online degree programs

Some institutions are developing courses between institutions

The problem with these solutions, is that this type of coursework will tend to become generic: the basics will be covered, but any one university isn't going to have the depth of research.

ME: What about overhead costs? Why is it not a waste to pay these?

MM: Overhead costs are a negotiated rate between the university and the federal government. Everyone has to pay them. They're mandatory. Sure, you can request not to pay them, but at some point you're going to lose eligibility.

The project funding does not pay for electricity. Does not pay for hazardous material disposal. Mining and mineral processing research generates a lot of chemical waste. That's something the university takes care of so that the company funding the grant doesn't have to. Overhead costs pay for the fact that I am sitting here waiting to do research. Industry doesn't pay my salary. Industry does not pay to train the B.S. graduates. Industry does not pay to maintain the lab, keep the lights on, pay the IT and cleaning crews, etc. Industry does not pay for the environmental ramifications of my work – the university does, so the company doesn't have to worry about it.

Part of it's the university system: more of MS&T's funding (this is true of many universities) comes from private rather than public sources.

Remember: when you pay overhead, you can still retain control (subject to negotiation) over the research output, intellectual property, etc. Donations cede all rights to the work products. At MS&T, a granting body can even pay 15 percent more overhead and all rights to the IP, even control over publication.

Jon Kellar
South Dakota School of Mines

Mining Engineering: What's your perspective on this crisis?

Jon Kellar: I trace a lot of this back to the elimination of the U.S. Bureau of Mines in 1996. One, it created the impression that mining and mineral processing were no longer critical to the national interest. Two, the Bureau was an avenue for faculty to conduct in support of the industry..

The Bureau also served to hire graduate students – the elimination made it harder for these students to get jobs outside of academia. Now we're left with no real pipeline for many graduate students and limited avenues to pursue research funding. Also around the same time there was a National Science Foundation (NSF) program that funded research in extractive metallurgy. Unfortunately, that went away, too.

ME: What is the cost of the loss of graduate education?

JK: There is the time and money to retrain. There is also the lack of Ph.D.s created: eventually "you'll run out of people to train the trainers." You can only do this so long without long-term consequences: the research isn't being done. You lose that ability to innovate, to have breakthroughs in the industry (that work will shift to other countries.)

Other countries, especially those in South America are more willing to invest in those academic programs because it's a larger part of their economy.

It seems that some U.S. institutions are restarting mineral processing programs, but that is a difficult thing to do given the circumstances..

ME: Where does the problem originate? With weak state support, or…?

JK: Ultimately, it's a state problem, but it's also a problem at the university level.

ME: What one thing could be done to address the situation?

JK: I think it's happening, albeit somewhat slowly. There are people in the industry who are aware of the past neglect of academic support for the mineral industry. I believe the mineral industry needs to look 20 years down the road and see what the grand research challenges will be and articulate them to the federal government. For example, that long-term research approach happens routinely with the semiconductor industry. And when they do that, the federal government pays attention and federal agencies like the National Science Foundation support their research need to keep their industry on the cutting edge technologically. In this approach, the research issues are fundamental in nature, and fit within the mission of agencies like NSF. Historically, in my opinion, the mineral industry has not thought in those terms, it's more along the lines of the near term research needs. ..

Another option might be to bring back some revised version of the Bureau of Mines. In 2010, the National Research Council (NRC) came out with the Critical Minerals and Metals publication, and that has seemed to attract the attention needed to spur fundamental research for the mineral industries.

ME: Other things that can be done?

JK: Locally, we (SDSM) were able to survive. In 1980, there may have been 70 metallurgical programs in the United States. These have now been absorbed into materials science programs, and many have completely disappeared. We [at SD] survived, and I believe we have carved out a niche academic area in support of mineral processing and extractive metallurgy. There's a real need for our graduates. But there are still challenges. It's really difficult to find faculty. Of the last two searches, the problem is a combination of [lack of] quantity and quality – you have to find people who will make it through the university tenure process. For example, during tenure review our faculty are compared against faculty in chemical engineering and other engineering disciplines that have avenues for research funding that are not readily available to our faculty.

When I started, the emphasis at SD was on teaching. The emphasis was to be a good teacher. Now there's still the pressure to be a good teacher, but it's changed – you also need to demonstrate research.

We're all under the same pressure in terms of attracting students – maybe more stress on the teaching here [at SD]. But with the small pool of faculty candidates, it's hard to find quality faculty.

Jaye Pickarts
Rare Element Resources

Mining Engineering: What is your perspective on the crisis?

JP: We're a small mining company, with a seasoned management group. We try to do a lot of work with universities and utilized their skills. For example, we recently sponsored several students, both graduate and undergraduate. We sponsored a graduate processing student at Montana Tech, served on thesis committees, had supported many summer interns, and provide both funding and materials for research. We support geology, processing, geophysical engineering programs, primarily in the western United States and particularly those close to the mine itself, in northeast Wyoming, like South Dakota and University of Wyoming (have a geology and geophysics deptartment).

ME: Have you had trouble finding good people to hire?

JP: Yes. Two years ago we conducted a search for a Director of Science and Technology, and couldn't find anyone in North America who was qualified. We ended up hiring an individual from France who is great.! I wrote a followup letter to Montana Tech questioning why they weren't offering a Ph.D. program. I am sure that it wasn't just my letter, but they have just started offering a Ph.D. program.

We've done a lot of work with the South Dakota school of Mines with its mining and geology departments and their processing department. We provide materials (ore samples) for this research.

ME: In your opinion, what's the cause of the crisis?

JP: Most young engineers want to work in the big cities, they want to work with clean stuff, where they can have a social life – mining is typically remote and dirty.

When I worked in consulting [in Denver], we had a hard time getting the younger engineers to work more than 40 hours a week. There's this social divide between the work ethic coming out of school vs. the expectations that the industry has for new engineers. It is just a different mindset. The solution? Getting young engineers out in the field early to apply what they have learned and then to expand that knowledge from the challenges that only an operating mine can provide.

ME: What about solutions?

JP: Training. If a graduating student can obtain the basic engineering skills, they're going to pick up the rest of it hands-on anyway. When our operations start [at the mine in Wyoming, we'll probably hire more local graduates as much as possible. We'll only need about a half dozen professionals, but retention is better if we hire locally.

If I can't hire the skill set that we need from the United States., we will look to hire internationally. It's hard – if there's a better solution, let me know.

Part of the problem is the low priority given to research. When I got out of school, all the big companies had their own R&D departments or we relied on the U.S. Bureau of Mines. Some of the larger mining companies still maintain those programs, but not the smaller companies. They rely on the universities or consultants. A lot of the innovation in the mining industry comes from the suppliers.

Many companies are developing their own training programs. At this year's Colorado MPD conference, Bob Seitz gave a talk on developing a training program for new mineral processing engineers at Freeport. I went through a similar program with Kennecott back in the 1980s – less formal than what they have now.

During the recent explosive growth in the mining industry, there was a lot of personnel turnover and employee stealing. Companies had to provide a lot of fancy benefits/incentives and pay increases to keep their good engineers.

What I will say about the U.S. mining schools: the students that are graduating these days are the best of the best. The professors are still turning out good students and good research.

Mick L. McCaslin P.E.
Director, Minerals Testing Center

Mining Engineering: What does the crisis look like from your perspective?

Mick McCaslin: Bleak. I should note that I am not the official FLSmidth spokesperson on the topic – I just have a passion for it. But there are some serious challenges.

ME: What are you doing at FLSmidth to address these challenges?

MM: We are largely focused on mineral processing, so take that into consideration. The number of schools that do anything with mineral processing is small – and the number of programs that are solid is very small.

ME: What would you define as a solid Program?

MM: We do have a biased viewpoint, a certain focus. There are other mining schools that have expertise outside our area of need, but that doesn't help us. We look for schools that produce mineral processing graduates who are ready to come to work and start contributing immediately. Some schools are better than others – so FLSmidth tries to find those schools and partner with them.

Regarding the idea that some schools might disappear altogether – I see it differently. I worry that if we try to increase the number of schools too quickly, we'll just water down what we already have. There are very few quality mineral processing faculty out there. We don't have a lot of professors. In order to start a new program or bolster the curriculum, you pretty much have to hire faculty away from an existing program. So that creates the potential to have two watered down programs instead of one strong and another that should perhaps change focus.

ME: What's the solution to the impending crisis?

MM: It's challenging. Is a 26-year old right out of graduate school going to be a good professor? Maybe not. I would want someone with industry experience. But someone who's been in the industry 10 years is used to that paycheck and schools can seldom match the compensation package. There are not a lot of easy answers.

Industry has to get involved and find some way to make these [professor] positions more attractive. We have a vested interest in keeping the existing programs sound – how else are we going to have a workforce to hire?

One solution is to look offshore. With current immigration laws though, that is difficult.

ME: What do you see happening to the industry in 10 years? How has FLSmidth begun to prepare for the possible closure of schools?

MM: To my knowledge, FLSmidth has not officially looked that far ahead. Those kinds of conversations need to be more front burner. But it's hard to get a vice president in any company to look at a problem that's five to 10 years in the future.

The bottom line: money talks. Without some financial infusion, things are going to keep going downhill."

Many universities seem to be focused on research. Nothing fundamentally wrong with that, but it does appear as if it has led them away from what we need most.

Industry needs to step up – and that means money. We can participate in other ways; hiring interns, sitting on committees and advisory boards, etc., but in the end you have to support the universities financially.

ME: Is industry ready to commit?

MM: Well, obviously these comments stem from my own experience and perspective. It's still an uphill struggle. There are usually one or two people in a company who take it on and are committed to putting together funding, etc. I do see evidence of companies increasing focus, tuning into the problem and helping. Industry is beginning to look at education as an investment in its future, not just a nice thing to do for the community – and that's healthy. It will lead to money, time and energy being infused into the system. A countering challenge is determining the payback on the investment. It's difficult to apply a dollar value and it is a longer term venture. Many companies are still tied to a five-year cycle or forecasting window.

ME: How are the schools reacting?

MM: I find them willing to talk, adjust and cooperate – which I think addresses the main concern on that front. Resolution has to come down to concrete support from industry. On the university side there has been a bit of mission drift. This is true across all departments by the way not just mining, but schools are driven to do more research and other activities outside of teaching. Because of that, when we talk to schools about what industry needs, I sense a gap between what they are doing, what's valued in the university system, and what we are after.

They get it. In my experience the schools understand when we tell them that we need well-trained graduates, but they can't always make it happen.

I'd say there's still five to 10 years before there will be effective change.

Mike Garska
Simbol Materials

Mining Engineering: What's your perspective on the crisis?

Mike Garska: There is definitely a shortage of mineral processing engineers at the moment.

ME: What do you see as the causes?

MG: There are two main causes:

1. The cyclical nature of the industry (some years mineral processing grads don't have anywhere to go, which is followed by a reduction in the number of students seeking degrees in mineral processing, which means that when the industry rebounds, there are fewer students to fill positions).
2. Mining schools are caught in a squeeze in which education is getting more expensive, state funding is dropping, and the departments get caught in the numbers game because they're pretty small.

ME: How has this crisis impacted your company, either directly and indirectly?

MG: Simbol is a materials company, so it's kind of a hybrid between mining and chemical engineering. It hasn't had a big impact until this year, because we're a startup – but now we are feeling it. I have been out there trying to find students even just for the summer and I'm having trouble finding them.

It's much easier to find chemical engineers. However, it isn't ideal to fill mineral processing positions with chemical engineering people: the mindset is different, and the way that they approach the job. Chemical engineers tend to overcomplicate things, wanting to get the highest purity, get a higher degree of control than is possible in the mining setting. Mining engineers recognize that you're not going to have as tight a control on the inputs. Some of the chemical engineers have a hard time accepting and understanding this.

However, a lot of times it comes down to the school – Montana Tech, for example, really focuses on hands-on labs and internships, so that the students are really prepared. They're pretty much ready to step in and start doing something. A lot of the chemical engineers haven't had the summer internship experience.

ME: It's nice to hear that mining schools are doing something right.

MG: Some people have unrealistic expectations and don't remember back to when they were just out of school. No matter how well you're trained, you're going to take several months to get used to the culture. I don't care where they graduate from, they're going to need a little bit of orientation.

People get too busy and don't want to take the time. That's a real problem in our industry. That's why I'm on the board of Montana Tech – to make sure that they're teaching the things we need to have.

ME: What will the future of mineral processing education look like?

MG: I was a little worried that it would start trending downward – the mining companies were getting retrenched – but now it seems to be on the upswing. I feel like colleges have hit their low point – I haven't seen any close in a several years. Things seem to have stabilized. Also there has been talk of revived programs. MIT is reviving a program, as is another east coast school. I'm not sure where the funding is coming from – I think the United States is starting to wake up and see that raw materials are important and we need to start paying attention to where things are coming from. As ore deposits get lower and lower grades, we'll need more training in order to extract and process them.

The industry needs to step up and fund endowments for the professors – it would make these less of a tempting target for shutting down.

ME: What is Simbol doing to cope with the looming crisis?

MG: I'm active with the universities, as is the vice president of chemical engineering. There is an acknowledgment of the situation and a lot of concern. We have a lot of people close to the retirement age. This is one reason we have this new emphasis on getting in some interns: we need to get these guys trained and get them permanent.

ME: So the industry wide demographic is reflected in your own workplace?

MG: Well, we're a startup. It's difficult for a startup to recruit someone midcareer – they tend to want a little more stability. It's typical to staff a startup with people close to the retirement age and just out of college.

D.R. Nagaraj, research fellow, Cytec.

Mining Engineering: What's your perspective on the crisis at Cytec?

Nagaraj: Our experience at Cytec is similar in many ways to that of the whole industry, with perhaps an additional challenge. We are a chemical company. For close to a hundred years we have been providing innovative solutions to mining industry problems using our expertise in chemistry. We generally seek young scientists that have a good foundation in both chemistry and metallurgy. This was not at all a problem in the past. But over the past 20 or so years, it has been a big challenge to find such resources in the U.S. There are of course young graduates with a strong competency in chemistry, but it has been difficult to attract them for careers in mining because of competition from biological sciences, nanotechnology etc. which are perceived to be glamorous. And we know very well how scarce metallurgists are in our country. There is not an adequate supply of them in the United States. And we are not satisfied by the quality and completeness of education in metallurgy and mineral processing, particularly with an additional chemistry bent. There appears to be a mismatch between skills taught and skills needed by the practicing metallurgist. So we end up seeking highly motivated graduates, with specialization in either chemistry or chemical engineering, and train them internally. Even the occasional metallurgists that we grab require intensive training. This is a short term solution. It is not sustainable. It is as if we are doing the job of the university. This takes a huge investment on our part in terms of money and time (a minimum of five years). It does not stop there. There is also a significant investment made in retaining professionals that we trained. I hear a similar story from other companies. Mining research and education in our country used to be very strong until about the mid-1980s. And the majority of the schools supplied well-rounded graduates that needed very little additional training. Come to think of it the companies had very knowledgeable mentors for these young recruits. All of this has significantly eroded over the years, and several factors have caused this. I strongly believe that we need the dedicated mining/mineral programs in the universities. Companies like Cytec would benefit greatly from such programs.

Many mining companies now do very little of their own research or outsource it altogether. Now they only have "firefighting support" – basic diagnostics and test work that support the plant's day-to-day needs. They rely on suppliers, vendors, universities to do research and create innovation. This puts extra burden on these institutions in terms of finding qualified professionals and financial investment.

ME: What is the driving force behind these changes?

N: There is a confluence of many confounded factors of course. I can mention a few

Government. Recent mineral statistics indicate that the contribution of minerals (including value-added products) to our GDP is about $3.7 trillion or 12 percent. Yet government support for mining/mineral education and research is negligible.

Industry support: I include industry covering mining, processing and value added products. Support for domestic programs is not adequate. A lot of this has gone overseas. It's a struggle for the universities – the industry financial support is inadequate, sporadic and unreliable. Such support is the first thing to go when there is even a faint sign of a slow down or profits are less than projected. It is as if the industry thinks that somehow the innovation, research and education will get done. There's no industry coalition like in some other countries.

Economic factors and competition from other fields: The severe downturn in the mining industry in the mid-1980s has had a huge long-term negative impact on the health of the mining industry, education and research in the United States. Many mining operations shut down. The industry didn't quite fully recover until about 2004 or so. In the meantime the industry lost a lot of expertise and experienced metallurgists. The mining schools fared much worse after about mid-1980s. Universities began closing mining and mineral programs. This happened to coincide with a large interest and investment in other fields such as bio, computer, material sciences and so on. The university management had a new business model. The schools that survived suffered erosion in faculty and competencies. Student enrollment from domestic pool declined. A lot of this had to do with the industry image and also competition from other fields that were perceived to be attractive. The end result was that both educational and research programs suffered a steady decline in the universities. They are now having a tough time rebuilding these and having a critical mass of both faculty and students. In my opinion, the mineral industry is in much better shape now compared to twenty years ago. Yet the mineral education is not.

ME: I wonder how much of this has to do with the fact that there is no direct source of federal

funding for mining and mineral processing.

N: There is no doubt that a lack of federal funding for mining/mineral education is an important reason for the current predicament. We need federal and state support in addition to industry support to rebuild our education and competencies. This must be viewed as strategic to us. Without a strong mandate and support from the government in terms of scholarships, attractive initiatives for companies to invest in schools etc. it would be difficult for the schools to attract qualified people to fill the faculty positions, attract a critical mass of students, and to justify reviving and maintaining mining and mineral programs. However, this is only a part of the story. There are other reasons for the current predicament as I mentioned before. The industry and the universities share the responsibility too. Securing federal funding does not guarantee high quality research and education. Even when there is funding, the quality of research and education can still be inadequate and may not meet the needs of the industry on the whole. As I said before these have eroded over the years. We have a gauge of that from the quality and completeness of the skillset of graduates and the research output in terms of papers and conference presentations. We need to rebuild these too, and this takes time and a concerted effort.

ME: Did you get the sense that this was a problem across the board, or were papers that came from countries with a better research funding system more relevant or better papers? Is the problem of decline in research a direct result of funding issues, or is it more a systemic problem related to the way science is conducted worldwide, with the emphasis on publication and the frequency of publication being valued and rewarded more than the quality of publication?

N: I see this as a problem across the board and I think it is systemic. There is so much pressure in universities to publish. It's all about impact factors, often at the cost of quality and relevance. I used to be an editor of *IJMP*. My experience was that about 70 percent of the submissions were below an acceptable standard and deficient in scientific/technical merit. This is not a lack of funding issue. Obviously there must have been funding for this research, but that seems to have not helped the quality of the research. It is true that the demographics have changed; there is a large increase in the number of manuscripts from rapidly developing countries, and these invariably had significant language issues. But even if I ignored the language issues, I was still left wondering about the quality of research in terms of scientific approach, rigor and merit, and most importantly practical relevance. What surprised me also was that many of the manuscripts from countries that traditionally had very strong educational and research programs have suffered too. This is a tough one to deal with.

Mineral resources development is an essential industry that is facing big challenges, especially in view of the dwindling quality of mineral resources, the high costs of water and energy and the environmental impact. I see this as a big opportunity that requires strategic support to develop innovative technologies. I have often heard people complaining that there is not much support for minerals program and that most of the support is going to other areas.

ME: Actually, NSF current funds less than 5 percent of all proposals, that the amount funded goes down every year. Even NIH is getting less.

N: That doesn't bode well for our country in terms of mining and mineral education. We need to fix it, and soon..

ME: So what's the solution?

N: There are multiple things that need to change. The universities need to step up and protect what they have. The university management has to make an important strategic decision to strongly support the existing departments to revive and rejuvenate mineral education rather than letting them linger in ill-health, which appears to be the current paradigm. Industry needs to help until the government can act – the government is very slow to act. Industry is our best hope for the short term. Industry has to come to the table as a coalition and make a commitment. The industry can also have a strong influence on the university management. Small industry grants to the university, say $5,000 to $50,000, does not help. The petroleum industry seems to do a much better job of funding schools.

Universities, in turn, need to listen to the industry and understand its needs. They have to work closely with the industry to rejuvenate the curriculum and to improve the quality and completeness of education, not just providing some research. This is a great way to address the relevance and competencies issues. Together, they can then influence the government to support educational efforts. The universities could recruit industry professionals to aid in teaching important courses. It is unlikely in today's environment for a single, self-sustaining department would maintain all the competencies. So cooperation between departments in a university and between universities would be good, though this is not a trivial task, and I'm not sure how likely this would happen. Much easier perhaps is to work with

industry to fill-in competencies. Industry folks are not subject to publish or perish, so they can truly focus on education, and they bring the practical stuff. Perhaps the degree programs could be four-plus-one or three-plus-two. In such a program the student spends one or two years in the industry as part of the degree. A more formal internship program can also be implemented.

Then there is the educational material. The available textbooks are rather outdated. They have to be rewritten to reflect the 21st century. This may include uses of non-traditional for-education media. This would help in rebranding our field and attract more students. The high school and college textbooks in chemistry and physics are good examples to follow.

The universities need to take a stand on the publication pressure and agree on a meaningful impact factor. The number of citations is not an indicator of the quality or relevance of the publication to the industry, at least not in our field. They have to fight the publication system a little – it has to come from a university coalition. The current university model is more focused on financial metrics than on education. There is so much pressure and demand on the faculty to raise money, pay huge overheads, fight the bureaucracy, and produce a large number of publications, that they have little time for research and education. We cannot afford to lose the remaining mining/mineral programs in the U.S. We need them and we must enrich them. ■