http://dx.doi.org/10.17159/2411-9717/2017/v117n6a7

The geoscience education pipeline in South Africa: Issues of skills development, equity and gender

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Synopsis

South African mining operations depend on the skilled professionals produced through the tertiary education sector. In geoscience courses at the University of the Witwatersrand, which lead into the mining sector, there has been a significant increase in student intake over the past 15 years. This increase has been characterized by a radical shift in demography: in classes where white male students once formed the majority, black female students are now in the majority. This demographic shift appears closely linked to policies addressing issues of social justice and transformation in post-apartheid South Africa. We document this change and consider the role played by employment equity legislation (as in the Mining Charter) and corporate social investment strategies in the mining industry, notably through bursaries offered to black female students. We also look at the changing needs of the industry, where the critical need for managerial skills, not just technical knowledge, is highlighted through data from surveys of past students and industry managers. Our findings indicate the need for a curriculum adjustment to meet these changing requirements, as well as more rigorous selection criteria for bursars than simply gender, race, and appropriate matric results.

Keywords
geoscience education, student demographics, skills development, equity, gender, bursaries.

Introduction

The South African economy has historically been linked to mining and the exploitation of mineral resources. South African mining operations are dependent on the professional labour that is produced through the tertiary education sector, with critical thinking, teamwork, and the art of negotiation having been identified as the crucial skills required for this industry (Sideropoulos, 2014).

Over the past three decades the South African system of education has gone through a period of dysfunction that it is struggling to rectify (Maphai, 2014). This has impacted on the levels of academic preparedness of students applying for places in higher education. Concurrently, government and university policies have widened access to higher education in response to the need to address issues of social injustice and transformation related to South Africa's history of apartheid. As a result, the number of students admitted to universities has increased dramatically. In the School of Geosciences at the University of the Witwatersrand (Wits), the increase in student numbers has been accompanied by a significant change in demographics: classrooms which in the past were dominated by white males have given way to classrooms in which black females are often in the majority. This demographic shift is related to legislation such as the Mineral and Petroleum Resources Development Act and the Broad-based Socio-Economic Empowerment Charter, developed to reshape the socio-economic and equity frameworks of the country (Botha and Cronjé, 2015). Requirements aimed at transformation in terms of management, skills development, and employment equity, together with corporate social investment (CSI) requirements, have resulted in bursaries being made available to attract students from designated groups, which in turn has increased the number of black students, and notably black female students, taking courses in geosciences. However, due to the economic downturn, instability in the mining industry has recently resulted in the downsizing of some mines, with international investors pulling out of South Africa. This instability resulted in devastating strikes across all sectors of the mining industry (Stewart, 2013) and in Marikana, an important platinum mining area, the strike culminated in a deadly shoot-out between miners and police. The resulting tensions spilled over into the gold mining sector, resulting in further strike action, shaft closures, and retrenchments. These challenges have implications not only for the mining industry in South Africa, but for the tertiary education providers whose graduates would have been absorbed into the mine-related workforce.

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 ISSN 2225-6253. Paper received May 2016; revised paper received Aug. 2016.

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Background

Mining in South Africa has traditionally been recognized as 'man's work'. However, mining supports a white-collar industry in addition to the blue-collar labour force, and it is the white-collar work that students seeking tertiary qualifications now aspire to. Job opportunities include mining or rock engineering, geology and technical valuation, consulting and management. To maintain the required supply of skilled personnel, large mining companies have recognized the need to support students, firstly by assisting them to meet the entry standards required by universities, and secondly, by providing bursaries for those who make it into the system. A research report commissioned by Anglo Platinum (Besharati, 2014) has revealed, however, that massive investment in education by mining companies (for example R100 million in the period 2010 to 2014 by Anglo Platinum) has had little impact on schooling throughput rates or the quality of learning. Such investment has been undertaken, as explained by Maphai (2014) in the keynote address at the presentation of the report, because '... the country cannot address equality without addressing the economy, and we cannot address the economy without addressing education'.

Although the mining industry is not required by law to involve itself in education, it is required, in the context of addressing equity and social justice in South Africa's post-apartheid democracy, to fulfil quotas related to gender equity. Mines are also required to fulfil corporate social investment (CSI) obligations. One way to address these needs is to supply students with bursaries, and our records in the School of Geosciences at Wits report a steady increase in the number of students enrolling for degrees that are geared to take them into the mining sector. Students are keen to earn qualifications that will lead to perceived sustainable livelihoods and are thus willing recipients of bursaries, even when they have no intention of following a career in the mining industry. This is not a new phenomenon, however. Hillman (1996) referred two decades ago to the poor throughput rates in mining engineering at Wits, which were associated with failure or dropout rates. He indicated that mining bursaries were taken as a stopgap while the recipients settled into the university and explored the availability of bursaries for other degrees, notably in commerce, law, and medicine (Hillman, 1996, p. 80). At that time of writing, however, the demographic patterns were different to what they are today. Classes are now not only dominated by black students, but significantly, black female students are usually in the majority. These changes in South African student demographics are in stark contrast to the American geosciences experience, as reported by Huntoon and Lane (2007), where the lack of students from diverse ethnic and racial backgrounds is lamented.

The Anglo Platinum research report (Besharati, 2014) also alerted us to the skills that the industry seeks in employees. We have become increasingly concerned about the poor performance of black male students in our courses, and the report served to make us reflect on how our programmes were preparing students for the conditions of work they would encounter. We became interested in how access to bursaries might have affected students' choice of university courses and wanted to find out what mining companies other than Anglo Platinum saw as critical skills for the industry. We wanted to be able to establish how our courses met these needs and whether there was a need to redesign the curriculum. We were interested especially in the views of female students regarding what kinds of challenges they anticipated they would encounter in the mining industry.

These concerns led us to investigate changes in demographics and throughput in geoscience courses at Wits. We begin in this paper by reporting on how these have changed between 1992 and 2013. We then look at the role of bursaries and scholarships in relation to these shifts in demographics and examine the consequences of such changes in terms of performance (throughput) and 'fit' for the industry. We further report on what senior managers from different sectors of the industry believe are the most important skills required by graduates. We compare their views with those of current and former students regarding the most important skills needed in the industry and how these skills are/were developed through their courses at Wits. This leads to a discussion about the current geosciences curriculum and how courses could be redesigned to more explicitly develop the skills identified as critical by industry, especially in relation to issues of equity and the increase of females in the geosciences education pipeline. These curriculum concerns are raised at a time when universities are hard-pressed to maintain standards as well as the throughput rates required by the state, and also when higher education policy in South Africa requires the alignment of courses into a national framework for the purposes of articulation (HEQSF, 2015). This alignment does, however, provide the opportunity for curriculum responsiveness in higher education in relation to changing needs.

Research method

Three research questions were used to guide this study:

- How has student diversity changed over the past 15 years, especially with regard to the geosciences?
- How have bursary allocations been affected by social justice issues, particularly in relation to CSI requirements and gender equity?
- What are the skills required by the industry and how are these being met by current geosciences curricula, particularly with regard to female students?

To respond to the first research question, data on student intake from 1992 to 2014 was obtained from the Wits Academic Information on Students Unit (AISU). These data were analysed to establish the changes in admissions with reference to race and gender over the 15-year period. Data on throughput, also linked to race and gender, were also obtained from the School of Geosciences records. A decision was taken for the purpose of this paper to focus on black and white students only, as the numbers of students from other population groups taking courses in geology is very small.

To gather data on our questions related to bursaries and skills, we selected three groups of respondents. The first group was made up of students taking a third-year course in Ore Body Modelling (GEOL 3028). This sample was purposely selected as the course they attend is a compulsory course for mining engineering students, but is taught in the

School of Geosciences by Geology lecturers. It is a course that was developed in collaboration with the School of Mining Engineering in response to industry needs, and was first offered in 2002. The second group of respondents was made up of students who had graduated from Wits, and had worked, or were currently working, in the mining industry. The third group comprised senior managers in the industry who had employed graduates from the Wits School of Geosciences. Representatives from the gold, coal, platinum, and diamond sectors, as well as independent consultants, were included in this group. The second and third groups were convenience samples (Patton): since contact had been maintained with these people, they were accessible for the purposes of this research.

Three sets of questionnaires were created to survey the different sample groups (see Appendix). These questionnaires were submitted for non-medical ethics clearance to the Wits Ethics Committee, together with the required information regarding the process that would be used to collect the data, *i.e.* that respondents would be informed of the purpose of the survey; that their participation would be voluntary; and that their responses would be anonymous. Having been granted ethics clearance (Protocol H14/08/01), the questionnaires were distributed by e-mail to former students and senior managers, and through a paper-based survey to students enrolled in the Ore Body Modelling course in 2014 at a pre-arranged time after a lecture. The return rate on this survey was 91%, with 115 students out of a class of 126 completing the survey. Five former students and nine industry employers responded to the questionnaires e-mailed to them, with four of the nine managers electing to respond in narrative form rather than by answering each of the questions individually.

Results

Student diversity and throughput

Diversity: changes in student demographics 1992 – 2014

Between 1992 and 2014, black students dominated the intake into first-year Geology (GEOL 1000), the start of the Geosciences pipeline. There were significant swings in the intake of black male students from 1992, but overall the trend for this group was one of increase, with black male students usually making up more than half the class. Figure 1 shows that from representing more than half the class in the 1990s, the number of black male students increased in the early 2000s to over 60%, and then declined.

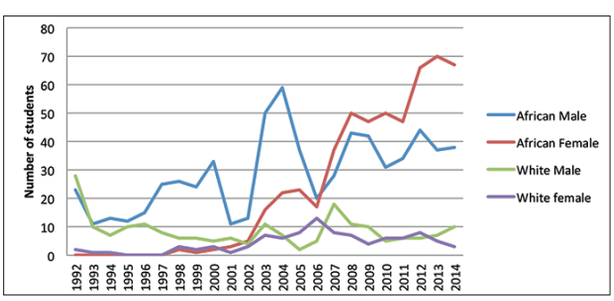

Figure 1—Changes in student demographics (race and gender) in GEOL 1000 (first-year Geology), 1992–2014

The most striking demographic change, however, was in the number of black females enrolling in Geology. The first black female students were enrolled in 1998, and ten years later they were the dominant group in the class. By 2013, black females represented nearly 60% of the class. The number of white students remained relatively low, but there was also a slight increase in the number of white females registering for first-year Geology. The number of Coloured and Indian students enrolling for these courses was very low, so data on these groups have been omitted.

Throughput rates

Two sets of data were accessed to provide a view of throughput rates affecting the Geosciences education pipeline in relation to gender and race.

The first set of data (Figure 2) focuses on throughput rates for Geology 1 (GEOL 1000). This data shows the relative success and failure rates with regard to race and gender at the start of the Geosciences tertiary education pipeline. Failure is most pronounced in the case of black males; 44% of these students failed over the years considered in this study. In contrast, the failure rate for white males was 12.5%. The average failure rate for black females was 37%, while that for white females was 8%.

The second set of data obtained in order to highlight specifically throughput rates for a course leading to careers in the mining industry, came from the Ore Body Modelling course (GEOL 3028) (see Figure 3).

Black male students were consistently the dominant group taking the Ore Body Modelling course over the period 2002 to 2013. From 2006, however, there was an increase in the number of black females, with this group being more successful academically than their male counterparts. As is evident from Figure 3, few white students take this course.

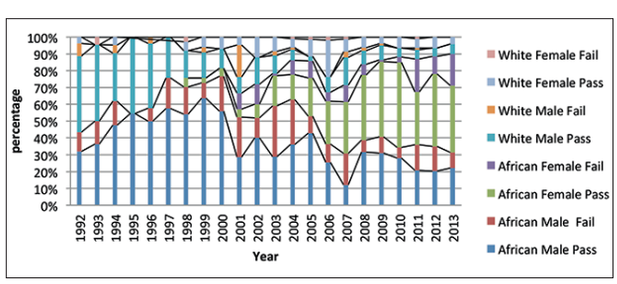

Figure 2—Throughput rates for first-year Geology (GEOL 1000) by race and gender, 1992–2013

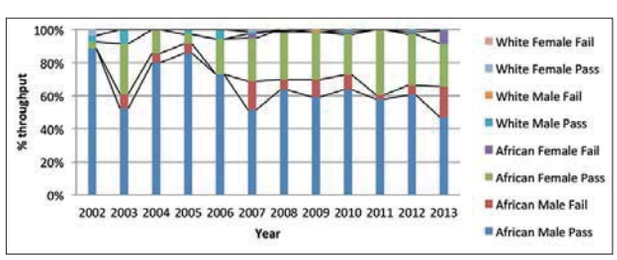

Figure 3—Throughput rates for 'Ore Body Modelling' (GEOL 3028) by race and gender, 2002–2013

Table I

Gender distribution of bursaries allocated to students taking the Ore Body Modelling course

Bursary obtained	Yes	No
Female	23	12
Male	50	30
Total	73	42

Bursary allocations and factors influencing career choice

Bursaries

The students taking the Ore Body Modelling course were asked to indicate whether they were the recipient of a bursary, and if so, which company or organization was the sponsor. Of the 115 who responded, 73 (63%) were bursars (see Table I).

Bursaries had been obtained from a wide variety of sponsors, including the gold, coal, copper, and platinum sectors, Eskom and Sasol, and even foreign companies such as Platinum Australia. The greatest number of bursaries (in terms of both male and female students) was secured from the Mining Qualifications Authority (MQA).

Students were asked in the survey to explain the process that led to their being granted a bursary. The most notable feature from the responses, particularly as far as the female students were concerned, was that there was no procedure other than simply submitting an application. Of the remaining students, some had been invited for an interview and one or two noted that they were required to take medical and psychometric tests. This indicates that in most cases, neither the mining companies offering bursaries nor the MQA had any idea of the suitability of the recipient.

Proximity to a mine as a factor influencing career choice

One of the significant observations in the Anglo Platinum report (Besharati, 2014) was that proximity to a mine had an influence on students choosing to study for a career in this sector. We were interested in whether this applied to our students. Responses to the questions regarding this are shown in Tables IIa and IIb.

Thirty-one of the 115 students in the sample confirmed they grew up close to a mine, while 49 indicated they had not. Fifteen of the male students indicated that growing up close to a mine had significantly affected their choice of career, while eight said this had no influence on their choice. Of the eight female students who grew up close to a mine, six indicated that proximity to the mine had influenced their choice to go into mining. The one female student who did not live near a mine, and did not have a bursary, explained that 'most of the mining companies prefer students from the mining community', indicating her belief that not living close to a mine had put her at a disadvantage in obtaining a bursary. However, the two female students who claimed that growing up near a mine had made no difference to their choice of a career, had nevertheless applied for and had obtained bursaries relating to mining. Although our sample is small, it shows agreement with the findings of the Besharati (2014) report, that growing up near a mine serves to heighten awareness of mining as a possible career option.

Skills: requirements and development

The three most important skills required for success in the workplace that were identified at the presentation of the Anglo Platinum report were critical thinking, teamwork, and the 'art of negotiation' (Sideropoulos, 2014). Students in the Ore Body Modelling course, as well as the former students, were asked to indicate how well they were prepared in the development of these skills during their undergraduate years. Results are shown in Table III.

Most students (both current and former) reported that they had been at least reasonably prepared for teamwork and critical thinking, as the majority ranked these skills above 5 (midway on the scale). In contrast, there was a wide range of ranking for development of the 'art of negotiation'.

The specific courses identified by the Ore Body Modelling students as best serving their development of the three skills were as follows:

- Critical thinking skills: A first-year course (MIN1001) entitled 'Critical Thinking'
- Teamwork: A second-year course, Mine Ventilation and Transportation (MINN 2004), and a third-year course, Surveying (MINN 2002) were identified by many of the students as contributing to the development of this skill. Both courses have joint projects and practical work which require students to work in groups

Table IIa

Influence of proximity to a mine on career choice of students taking the Ore Body Modelling course. The first number in each category refers to the number of students without a bursary, while the number in brackets refers to the number of students with a bursary. The numbers in bold indicate the total for each category

Home location		Close to mine		Not close to mine	
Gender		Male	Female	Male	Female
Influence on career choice	Yes	6 +(9)=**15**	1+(5)=**6**	1+(3)=**4**	1=(0)=**1**
	No	2+(6)=**8**	0+(2)=**2**	11+(19)=**30**	5+(9)=**14**

Table IIb

Influence of proximity to a mine on career choice of students taking the Ore Body Modelling course, where responses were not given in full. The first number in each category refers to the number of students without a bursary, while the number in brackets refers to the number of students with a bursary. The numbers in bold indicate the total for each category

Did not grow up close to a mine but response to influence on career choice was not given	Male	7+(10)=**17**
	Female	6+(3)=**9**
No response to location given, but student indicates that location where they grew up had no influence on career choice	Male	3+(3)=**6**
	Female	0+(3)=**3**

Table III

Student opinions on skills development offered in undergraduate geology courses. Values in the table represent the number of students scoring each skill at that level

Skill	Scale	1 (no preparation)	2	3	4	5	6	7	8	9	10 (excellent preparation)	No response
Critical thinking	Female	0	1	1	1	5	4	8	9	3	3	0
	Male	1	1	0	3	6	10	13	20	12	13	1
	Former students	0	0	0	1	0	1	0	0	2	1	0
Teamwork	Female	0	0	0	2	3	3	9	9	7	2	0
	Male	1	2	0	2	7	11	0	13	12	13	1
	Former students	0	0	0	0	0	1	3	1	0	0	0
Art of negotiation	Female	3	2	2	4	6	2	5	6	3	2	0
	Male	7	1	1	5	12	11	15	10	6	8	4
	Former students	1	0	1	1	0	1	0	0	1	0	0

Current students: females n = 35; males n = 80.
Former students (all female) n = 5.

- Art of negotiation: No particular single course was identified that had been of assistance in developing this skill, and several students indicated that it had not been developed at all. Many students did not offer input in relation to this skill, which may indicate that they did not fully understand what was meant.

The former students had not undertaken the same courses as the current students, as there had been ongoing changes in the structure of the degree over the period covered by the study. Thus students in the Ore Body Modelling course felt that the Mine Ventilation and Transportation and Surveying courses had contributed significantly to their teamwork skills, whereas the former students, who had not done these courses, referred to the importance of fieldwork in developing both teamwork ability and critical thinking. Senior industry managers extended the skills mentioned by Sideropoulos (2014) to include other skills, such as interpersonal, communication, and technical skills, and emotional intelligence.

Discussion

Student diversity and throughput

Over the period 1992 to 2015, the overall demographic profile of the university shifted profoundly with regard to race and gender. The number of female students gaining admission increased from 1999 and now outnumbers males: from being in the minority, black students have become the dominant race group, comprising 75% of the student body in 2015 (Kupe, 2015). The Science Faculty intake has reflected similar trends. With regard to students entering the Geosciences pipeline, admission to training for the mining industry was initially dominated by male students, with more or less equal numbers of black and white males being accepted into first-year Geology between 1992 and 1996. From 1997 the pattern changed, with the number of black male students increasing and the number of white males decreasing. As with the overall trends, the most significant shift in diversity in the Geosciences has been in relation to black female students: from 2003, their numbers steadily increased and by 2007 black females were the dominant demographic group taking the introductory Geology course. Over the years, there has been little change in terms of the few Coloured and Indian students registering for courses in the Geosciences, as mining has not been a preferred career choice for either males or females in these groups.

The demographic shifts outlined above are associated with changes in South Africa's political landscape, as education and industry have responded to the need for transformation, particularly with regard to race and gender. New policies and legislation introduced to bring about this transformation include the Mining Charter, which addresses the need to include women in mining and to distribute wealth across a broad a spectrum of previously disadvantaged South Africans. In recognition of the new opportunities that were opening up in South Africa's post-apartheid landscape, a number of women have been appointed to serve at Ministerial level in the field of Minerals and Energy: Phumzile Mlambo-Ngcuka was the first female appointed to this position in 1999, followed successively by Lindiwe Hendricks, Buyelwa Sonjica, and Susan Shabangu, whose appointment ran until 2014, ending 15 years of continuous female leadership. The Skills Development Act (No. 98 of 1999) led to the establishment in 2010 of Sector Education and Training Authorities (SETAs), and levies from these, and corporate social investment programmes, led to money being invested in bursary programmes. This was to encourage and assist young people from designated groups to enter tertiary education institutions and thus provide a pipeline of graduates back into industry. The past two decades have thus seen a significant increase in not only black students, but especially black female students, as previously disadvantaged individuals gain access to, and the financial means to engage in, tertiary education.

However, the pass rates highlight that access and finance alone do not lead to success. The reasons behind the high failure rates, particularly among black students, have been the subject of much research in South Africa. The legacy of apartheid and the ongoing dysfunction in state schooling have been well documented (DBE Diagnostic Report, 2014). Consistent with national statistics, our data shows the

highest failure rate is among black students, with black males performing at a lower level than black females with failure rates of 44% and 37% respectively. The lowest failure rates are among white females (8%), and white males (12.5%), but few white females register for Geology and the number of white males who do so is declining.

Our interest lies in what may underlie the significant increase in black females in a preserve traditionally dominated by white males. We believe the answer lies at least partially in the availability of bursaries as a result of national policies and CSI regulations that require investment that addresses South Africa's gender and race inequalities.

Bursaries

The results from the 2014 Ore Body Modelling (GEOL 3028) course survey indicate that bursary opportunities are a major factor behind students choosing a career in mining. In our sample, 21 of the 31 students who grew up near a mine indicated that proximity to the mine had influenced their career choice. Clearly, knowledge of the mining environment plays a role in awareness of the opportunities and lifestyles associated with mining, and consequently in the choice of a career, as suggested by Besharati (2014). Our data show that whether they grew up close to a mine or not, in each case the students with bursaries outnumbered those without, with 65% of the male students and 70% of the female students holding bursaries. Thus out of the 115 students in our sample, 72 held bursaries. The 2004 Mining Charter set a target of 10% representation by women by 2009, but only 6% was achieved by that time (Mining Charter Assessment Report, 2015, p. 28). A new target of 10.5% by 2014 was then set, with bursaries as one of the mechanisms to enable achievement of this target. Bursaries offered, for example, by the South African Department of Mineral Resources for the start of study in 2017 were restricted to female South African citizens from a disadvantaged background, with preference given to those from rural areas, and with Grade 12 results that included a 75% pass rate in Mathematics and Physical Science and 60% for English (http://www.dmr.gov.za/bursaries.html). These specifications accord with our analysis of responses to the questionnaire by the GEOL 3028 students, who indicated from their own experience that bursaries were closely tied to matric results; coming from a previously disadvantaged background; and gender. In contrast to students in the 2014 sample, our former students (all female) described a very rigorous bursary application process. They went through mine visits, internships, interviews, and medical tests before being awarded their bursaries. One of the former students recalled how she was exposed to deep-level mining as a test of whether she would be able to cope: 'They [the geologists] took me to the worst possible places underground just to see if I was really into the whole mining scene'. This rigorous screening has now been replaced by criteria that are more closely aligned to equity agendas than the needs and realities of mining. One of the GEOL 3028 students explained: 'The bursary (sic) was short of people around the time I applied. I just got called.'

In our view, however, many female students over the past few years, including a number in the 2014 class, will not satisfy the medical requirements for underground work. The guidelines on thermal stress given by the Department of Minerals and Energy (2002, p. 47) indicate that a body mass of 50 kg or less makes a person 'unsuitable for work in hot environments'. Equally, if the body mass index (BMI) is greater than 35, the person concerned is deemed unsuitable for work in the environments experienced in mining. BMI is an important measure of body fat, with a high BMI being associated with low heat tolerance. At the same time, a small body frame and lack of physical strength is compromising in the physically demanding underground environment, which also requires heavy protective clothing (Fox, 2016). Students who are slightly built thus carry a limiting attribute that would have been noticed had the bursary allocations required both an interview and a medical. Students who otherwise meet the criteria but are overweight could also be limited, but have opportunity to meet the criteria through weight-loss programmes. Of all the 73 students in the sample group holding a bursary, only five underwent a medical examination (three females and two males). In terms of the 'soft skills' highlighted by senior managers as critical for success in the mining industry, none of the 2014 class described undergoing aptitude tests that would screen for suitability and attitudinal fitness for the mining industry.

The drive to recruit students from the appropriate groups to enable large corporations to meet their Broad Based Black Economic Empowerment (BBBEE) obligations appears to have translated into a 'loosening up' of the bursary application and award processes. Our understanding is that in the current context, the allocation of bursaries is driven by corporate social investment requirements and social justice agendas, and that the follow-through to students actually entering the mining industry is of less consequence than the need to satisfy transformation agendas. The increasing numbers of females accessing bursaries and requiring training for employment in this industry also places a responsibility on higher education to take account of the environment in which they will work. We noted in the introduction to this paper that mining has traditionally been a male-dominated environment. With the increase in the number of females entering the industry there is a need for appropriate curriculum development that will help them achieve success in their work. At the same time, bursary providers need to allocate bursaries in a way that leads to return on investment, not only for them, but for the lecturers who invest time and effort in developing the intellectual capital and the skills necessary for career success, and who themselves are judged according to student pass rates. Thus students who have not been carefully selected with regard to suitability and intention to go into mining make return on investment problematic, for the mining companies and the MQA, who award the bursaries, and for the lecturers who teach the bursars.

Skills needed in the workplace

The concerns noted by senior industry managers about how graduates adapt (or do not adapt) to the world of work indicated that there are many more skills required than those mentioned at the Anglo Platinum presentation. Given the opportunity to express their views about what is needed of incoming graduates, the managers had great difficulty in restricting themselves to just three important skills, which was what was asked for in the survey. They went to great lengths to describe what they believed was needed, and how they experienced the attitude of incoming recruits. 'There is a great need for realism and modesty, and acknowledgement that their qualification is merely a certificate to get into the

field of play' was a comment made by one of the managers and echoed by others. The harshness of the environment was also pointed out: 'Mining is still dominated by an autocratic, mostly insensitive leadership style. Therefore a graduate needs to be mature enough to absorb the pressure without reaching breaking point.' Additional skills identified were 'tempered expectations' and 'personal adaptability and accountability'. One of the managers, the chief geologist at an Anglo Platinum mine, wrote extensively about the need for interpersonal skills, emotional intelligence, good communication skills, adaptability, and technical skills. Other challenges that had little to do with the content knowledge associated with a degree included frustrations related to 'the expectation new recruits have for acknowledgement'; an 'air of expectation and deserving'; and the 'sense of being better than the next person'. All referred to attributes of maturity and a willingness to continue to learn, which appeared to be lacking.

Our analysis of student responses to the development of the three core skills identified in the Anglo Platinum presentation revealed that students believed they were being trained in the first two of the skills, *i.e.* critical thinking and teamwork, but that the 'art of negotiation' was not covered in the courses they were taking. However, we question the validity of this response. We believe that students, the majority of whom are second-language English speakers, may have made a superficial connection between the name of a course and the skill that was being sought. The MIN 1001 course, for example, which is called 'Critical Thinking', was identified by many students as having developed their ability to think critically. In the same way, 'teamwork' was associated with courses where they were required to work in groups.

There were some important mismatches between the students' expectations of what a future in mining would hold for them and the senior managers' expectations of attributes that graduates would bring to the workplace. Most of the male students indicated that they would remain in the mining industry, rather than use their degrees to transfer into another line of industry as was noted by Hillman (1996). They anticipated attaining management positions and were clear that their intention was to 'make money'. Most of the female students indicated they did not intend staying on in the mining sector. The few who indicated that they would stay were like their male counterparts in seeing themselves in management positions, driven by the idea of making money. Ironically, the group least likely to stay in mining is now the only group eligible for bursaries, at least from the South African Department of Mineral Resources.

However, a few of the female students were committed to the career they had chosen. One of them said 'I am privileged in that I am a black woman pursuing mining. That is what the mining sector wants.' This indicates awareness of the potential and power in this field for women, inherent in their gender and race, but the majority of the female students were worried about the instability and violence that had affected the mining sector, much more so than their male counterparts. They felt that despite efforts to change the profile of mining, it was still a 'hostile place' dominated by males. This 'place', according to the mine managers, requires self- and interpersonal management; emotional intelligence; technical and communication skills; tempered expectations and ambitions; realism and modesty. But for the female students, additional skills were needed. One wrote: 'I have grown a good set of balls (not literally) in the sense these courses challenged me, but I manned up and met the challenge. I fought with them and fighting symbolises strength'. Another commented '… most important: develop a thick skin! The mining environment is a harsh and abrasive one, with a culture that is still significantly different to that of big cities. A strong personality is needed in order not to get personally affected. Secondly: strengthen your backbone. It is important to have confidence in your work. Do not allow yourself or your work to be undermined. Find yourself a mentor. If you love what you do, you will be just fine.'

Curriculum development to address industry recommendations

National legislation in post-apartheid South Africa has served as a catalyst for change, not only with regard to industry, but also in education. In a drive to facilitate articulation between institutions and to provide for the recognition of prior experience and learning, universities are required to make their curricula not only 'more relevant, while remaining internationally competitive' but should be 'transformative, innovative, relevant and appropriate, (speaking) to our national and continental issues and priorities' (Kupe, 2015, p. 1).

The failure rates in geoscience courses affect especially black students. The failure rates (averaged over 21 years) are 22% for black males, 27% for black females, 12.5% for white males, and 8% for white females. This has a substantial impact on the subsidy earned by the university. Female students are more likely to graduate than male students, but they are also less likely to go into mining as a career. Curriculum change needs to address the fears that were expressed by female students, the declining throughput rates of male students, and the issues raised by the former students, to prepare them to deal with the environment they will encounter. But there is also need for change in the culture of the industry. Former students who were speaking from experience made the following remarks: 'It was a huge culture shock. The reception of African females coming into the mining industry is not always a warm one, especially from the older generations'. 'I have been assaulted in the cage and nothing was done by the company or human resources'. 'Retrenchment was a reality; the alternative was being put into an unfamiliar position'. The former students also spoke about the need to 'think on your feet, be adaptable and flexible' and noted that a sense of 'discrimination and being looked down upon' was common. What is disturbing is that of the five former students who responded to the survey, one had already left mining, and of the others, only one wanted to remain in the industry. The Mining Charter therefore needs to address not only issues of gender representation in the sector, but the conditions of service. Transformation in the industry requires not simply an increase in the number of women in mining, but rather a shift in culture, where human dignity and respect for all people prevails, whether they are male or female. However, this is not a new phenomenon. It has been an issue since the mining industry started in South Africa (Ncube-Hein, 2016)

The benefit of having embarked on research that sought to document and understand the needs of the geosciences education pipeline, with a view to aligning more closely with industry needs, is that such curriculum development is now

underway, driven by the Higher Education and Qualification Sub-Framework (HEQSF). The objective of the HEQSF is to create a single, integrated national framework for learning achievements (CHE, 2013). The curriculum development that has been undertaken for this national objective is incorporating the needs highlighted by industry, but also has to take into account changes in the tertiary education sector, including increases in student numbers without significant increases in teaching staff. The focus by industry on the development of soft skills is particularly challenging in that many of these skills are affective, requiring relationship development and additional time.

Conclusion

The general understanding of higher education in the sciences is that it will serve to develop the knowledge and skills of students to a point where, upon graduation, they are deemed fit for the relevant workplace. Bursaries and scholarships are awarded by industry to worthy students to enable them to pursue dreams of higher education and provide a pipeline of appropriately trained students for the industry. But this ideal does not always work out. Nearly two decades ago Hillman (1996, p. 77) recommended that, in terms of mining students, it was a 'matter of urgency' that some method of assessing students' commitment to the industry be instituted, which would benefit both industry and higher education. He was concerned that applicants for bursaries are 'stretching this opportunity to the point of dishonesty, and are, in effect, milking the system dry' (p. 80).

Hillman was writing of the situation before the advent of the Mining Charter in 2002 and the BBBEE scorecards that have resulted in the drive to recruit women, through bursaries, into work environments known to be hostile to women. While one of the senior managers claimed from his experience over the past 10 years that 'females were more intelligent and consistently derived better results than the male students', finding a fit between the workplace environment and the aspirations of students, especially in regard to challenges related to women in mining, requires more than bursaries being allocated on the basis of gender, economic disadvantage, and minimum Grade 12 results.

In this study, which looked at how student diversity has changed over the past 15 years with regard to the geosciences education pipeline, we have shown how equity and social justice imperatives have impacted on bursary allocations, significantly increasing the number of female students registering for mining engineering. Our findings indicate that in the current economic environment, male students are more likely to actually go into mining than female students, but that bursaries for male students are now harder to come by.

We recommend that a more rigorous process is put into place before students are awarded a bursary—one that involves mine visits, internships, interviews, and medical tests, for both male and female applicants. At the same time, mine owners and managers need to address the hostility encountered by women in the mining environment, and universities need to impart the skills needed for success through curricula that take into consideration the many affective attributes needed for success in mining—whether these relate to men or women. Assessing students more carefully in terms of admission and the allocation of bursaries will also create a better teaching and learning environment, resulting in a supply of graduates more suited to an industry that continues to be vital to South Africa's economy.

References

Besharati, N. 2014. The impact of mining operations, corporate social initiatives, school interventions and other social-economic factors on education outcomes in South Africa. Challenges in evaluating development effectiveness. Platinum and Passes. *SA Mining and Education Stakeholder Conference*, Wits School of Governance, Parktown, Johannesburg, 23 May 2014.

Botha, D. and Cronje, J.F. 2015.: Women in mining: A conceptual framework for gender issues in the South African mining sector. *South African Journal of Labour Relations*, vol. 39, no. 1. pp. 10–37.

Council on Higher Education (CHE). 2013. The Higher Education Qualifications Sub-Framework. Pretoria.

Cornish, L. 2013. Women climb the ladder: Equality, it's the name of the game: women in mining. *Inside Mining*, vol. 2, no. 2. pp. 40–43. http://reference.sabinet.co.za/webx/access/electronic_journals/sh_mining/sh_mining_v6_n2_a14.pdf [Accessed 18 June 2015].

Cornish, L. 2014. Transformation muse - Anglo American: women in mining. *Inside Mining*, vol. 7, no. 2. pp. 32, 33. http://reference.sabinet.co.za/sa_epublication_article/sh_mining_v7_n2_a14 [Accessed 18 June 2015].

Department of Education. 2014. National Senior Certificate Examination Diagnostic Report. Pretoria.

Department of Mineral Resources. 2016. Bursaries. http://www.dmr.gov.za/bursaries.html [Accessed 22 February 2016].

Department of Mineral Resources. 2015. Mining Charter Assessment Report. http://www.dmr.gov.za/publications/viewcategory/262-mining-charter-assessment-report-2015.html [Accessed 22 February 2016].

Department of Minerals and Energy. 2002. Guideline: thermal stress. Mine Health and Safety Inspectorate. Reference number 16/3/2/4-A2. h [Accessed 22 February 2016].

Fox, F. 2016. South African Society of Occupational Medicine. Personal communication, 8 February, 2016.

Hillman, J.C. 1996. Increasing black representation in mining engineering: the need for a new approach. *Journal of the South African Institute of Mining and Metallurgy*, vol. 96, March/April. pp. 77–81.

Huntoon, J.E. and Lane, M.J. 2007. Diversity in the geosciences and successful strategies for increasing diversity. *Journal of Geoscience Education* vol. 55, no. 6. pp. 447–457.

Kupe, T. 2015. Progress on the implementation of Wits' transformation plan. VCO Circular, 1 October, 2015. University of the Witwatersrand.

Le Roux, T. and Naude, A.M.E. 2009.: Communicating with diversities: female employees in the South African platinum-mining industry. *Communicare*, vol. 28, no. 1. pp. 24–49.

Maphai, V. 2014. Keynote address. *SA Mining and Education Stakeholder Conference*, Wits School of Governance, Parktown, Johannesburg, 23 May 2014.

Ntombela, D. 2014. Women in mining face challenges: women in mining. Inside Mining, vol. 7, no. 6. pp. 30-31. http://reference.sabinet.co.za/print_document?printFT=true&printMD=true [Accessed 18 June 2015].

Ncube-Hein, K. 2016. School of Geosciences, University of the Witwatersrand. Personal communication.

Patton, M.Q. 1990. Qualitative Evaluation and Research Methods (2nd edn). Sage Publications, Newbury Park, CA.

Sideropoulos, E. 2014. Introduction to the SA Mining and Education Stakeholder Conference, Wits School of Governance, Parktown, Johannesburg 23 May 2014.

Stewart, P. 2013. The 2012 strike wave, Marikana and the history of rock drillers in South African mines. http://www.global-labour-university.org/fileadmin/GLU_Column/papers/no_121_Stewart.pdf [Accessed 18 June 2015]. ◆

Appendix

Student Questionnaire

The Geoscience Education Pipeline: issues of Skills Development, Equity and Gender

Please Note: *Participation in this survey is voluntary. All responses will be treated confidentially and all correspondence will be protected. Data collected will be used for the purpose of a research paper only. No individual student names will be mentioned in the paper. Thank you in advance for your participation.*

1) Which course are you currently taking in the School of Geosciences?

_____

2) Why did you choose to do this course?

_____
_____
_____

3) Do you have a bursary to study this course? If so, which company is sponsoring you?

_____
_____

4) What was the process you went through to obtain this bursary (i.e. how did you secure this bursary)?

_____
_____
_____
_____
_____
_____
_____
_____

5) What are your plans once you graduate?

_____
_____
_____
_____
_____
_____

6) South Africa has recently experienced the longest strike involving the mining sector in its history. How does the uncertainty associated with this aspect of mining contribute to how you see your future in the mining sector?

_____
_____
_____
_____
_____
_____
_____

7) How well do you think you have been prepared by the University in the following skills areas? (which have been identified by the mining sector as the 3 most important attributes necessary for their employees)

Tick the most appropriate answer (0 = not at all, 10 = excellent preparation).

SKILL	1	2	3	4	5	6	7	8	9	10
Critical thinking										
Team work										
Art of negotiation										

8) Which course/topic in your curriculum best prepared you for.....?

a. Critical thinking_____
_____

b. Team work
_____
_____

c. Art of negotiation_____
_____

9) Please comment on what it was that you gained from these courses/topics that prepared you for critical thinking, team work and the art of negotiation.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

10) What kind of work do you anticipate you will be doing once you graduate?

_____
_____
_____
_____
_____
_____
_____

11) What kind of challenges (as a woman) do you anticipate you would need to overcome once you join the work place?

_____
_____
_____
_____
_____
_____

Thank you for your participation and good luck for the future!

Gillian Drennan (School of Geosciences)
Ann Cameron (Science Teaching and Learning Centre)

The geoscience education pipeline in South Africa

Past Student Questionnaire

The Geoscience Education Pipeline: issues of Skills Development, Equity and Gender

Please Note: *Participation in this survey is voluntary. All responses will be treated confidentially and all correspondence will be protected. Data collected will be used for the purpose of a research paper only. No individual names of past students will be mentioned in the paper. Thank you in advance for your participation.*

1) Why did you choose to study Geology?

_____

_____

2) Did you have a bursary to study Geology? If so, which company sponsored you?

_____

_____

3) What was the process you went through to obtain this bursary (i.e. how did you secure this bursary)?

_____

_____

4) What is your current position? What work do you now do?

_____

_____

5) South Africa has experienced the longest strike involving the mining sector in history. How does the uncertainty associated with this aspect of mining contribute to how you see your future in the mining sector?

_____

_____

6) How well do you think you were prepared at University in the following skills (which have been identified by the mining sector as the 3 most important attributes necessary for their employees)?
Tick the most appropriate answer (0 = not at all, 10 = excellent preparation).

SKILL	1	2	3	4	5	6	7	8	9	10
Critical thinking										
Team work										
Art of negotiation										

7) Can you remember which course/topic in your curriculum best prepared you for.....?

a. Critical thinking_____

_____

b. Team work

_____

_____

c. Art of negotiation_____

_____

Please comment on why you think these courses/topics made a difference in preparing you for the world of work.

_____

_____

8) What kind of challenges (as a woman) have you encountered once you joined the work place?

_____

_____

9) What words of advice / encouragement / warning might you offer to young female students who are currently studying in this field?_____

_____

Thank you for your participation and good luck for the future!

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Company Questionnaire

The Geoscience Education Pipeline in South Africa: issues of Skills Development, Equity and Gender.

Please note: *all responses will be treated confidentially and will be used for the purpose of the paper only. No company names will be mentioned in the paper. Should you wish to receive a copy of our paper we would be pleased to send you one.*

1) What do you think are the 3 most important skills necessary for a graduate entering your sector?

2) In terms of selection of students for bursaries, what are the criteria you use for allocation (e.g. matric results, gender, equity imperatives)?

3) Does your company see any return on investment with respect to bursary allocation, especially from females, and if so, how much return?

4) In your opinion, what is currently missing in the tertiary training that you believe would improve the articulation between university and industry?

5) Do Mining Houses see any difference between graduates from different curricula i.e from different Universities)?

6) Are there any BEE (or other redress/social justice) guidelines related to gender and bursary allocation?