# Building International Capacity in Mining Engineering: The NUST-WITS Mining Educational Collaboration

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## Abstract

*Pakistan has not developed its mining sector to its full potential. This is despite its quality mineral resources. Mining in Pakistan is mostly 'artisanal' and 'small-scale', and for this to change, the country must develop the skills to support a flourishing formal sector of significance in the twenty-first century.*

*Pakistan has good quality universities with some of them already providing courses in mining. Building on this platform, NUST University approached the School of Mining Engineering at the University of the Witwatersrand (Wits Mining) in 2011 to start a collaboration that will result in greater sector benefit for Pakistan. The outcome of the discussions was to do capacity building for mining professionals in Pakistan at postgraduate and post-doctorate levels. The approach used was to identify university staff requirements to support a teaching, learning and research programme for a 21st century mining sector and then to match these with the qualifications of the lecturers who were identified to deliver the programme at NUST. The collaboration has proved to be successful because of leadership, energy and carefully selected 'champions' on both sides. One of the many highlights of the collaboration was the establishment of an excellent laboratory doing research on how the fourth industrial revolution is affecting the mining sector. The Digital Mining Project formed the core of the research, and it still allows for regular exchanges of students, staff and post-doctorates on a consistent research theme.*

**Keywords:** *university collaboration, Pakistan mining, South African mining; capacity building, twenty-first century mining*

## 1. Introduction

Mining in Pakistan is mostly 'artisanal' and 'small-scale', and for this to change, the country had to develop the skills to support a flourishing formal sector of significance. To overcome these problems, the National University of Science and Technology (NUST), embarked upon a journey in 2011 to establish a substantive mining education and research program in Pakistan at a higher degree level. From an industry perspective, the program would foster meaningful Academia-Industry-Linkage, cover existing mining practices and include innovation to bridge the knowledge gaps in critical specializations for mining. In the absence of an accredited undergraduate mining engineering and recognized postgraduate mining research program, it was decided to build such capacity using the existing NUST engineering staff. A major strength is the existence of quality undergraduate programs in the other engineering disciplines. The broad nature of mining engineering allows for a broad range of specializations in mining. The NUST-WITS model matched the required specializations with the first degrees of NUST staff so that for example, a mechanical engineer could be 'converted' into a ventilation engineer and a geotechnical engineer into a rock engineer. This matching of existing engineering backgrounds of NUST staff with mining specializations accelerated the benefits of the programme significantly. This benefit was not limited to Pakistan, because Wits Mining suddenly had access to the multidisciplinary capacity to build a digital mining research laboratory of significance. The Sibanye-Stillwater Digital Mining Laboratory (DigiMine) developed a common research agenda with strong capacity on both sides so that the NUST-WITS partnership is substantive and sustainable. The approach is special because of the mutual benefit that extends to the benefit of the national economy. In addition, it addressed the need for formal qualifications, skills and research capacity in Pakistan while at the same time addressing the macroeconomic mining policy issues for the sustainable economic development of Pakistan. The new program is concentrated in a new School at NUST, called the School of Advanced Geomechanical Engineering (SAGE). The establishment of SAGE in 2017 allows Pakistan to offer postgraduate degrees in mining engineering, including mineral economics. In addition, the link with DigiMine allows both sides to do cutting-edge applied and hands-on research on South African mining problems, which is of great benefit to the industry. SAGE is also linked to the rest of Pakistan's undergraduate mining education system, so that first, all aspects of mining qualifications, skills and research could be coordinated nationally and second, there is a sustainable intake for SAGE's postgraduate program.

This introduction is followed by a contextual analysis of issues in Pakistan, focusing on its mineral abundance, contribution to the economy and an overview of its educational system. The engineering programs at NUST at the time when the collaboration started, along with the mining offerings at other universities in Pakistan are described so that the reader can understand what the situation was before the collaboration. Section 3 gives an overview of the postgraduate mining

Tab. 1. Mining sector contribution to the country's economy – 2013 (UNIDO, 2020)
Tab. 1. Wkład sektora wydobywczego w gospodarkę kraju - 2013 (UNIDO, 2020)

| Country | Contribution to GDP | | Impact on the national economy | |
|---|---|---|---|---|
| | US$ billion | Percentage | Employment (000) | Percentage of export earnings |
| Australia | 121 | 10% | 787 | 54 |
| USA | 232 | 5% | 2 112 | 9 |
| Canada | 53 | 8% | 418 | 20 |
| South Africa | 27 | 5% | 500 | 23 |
| Chile | 35 | 16% | 60 | 59 |
| Botswana | 59 | 34% | 13 | 76 |
| Ghana | 17 | 7% | 500 | 37 |

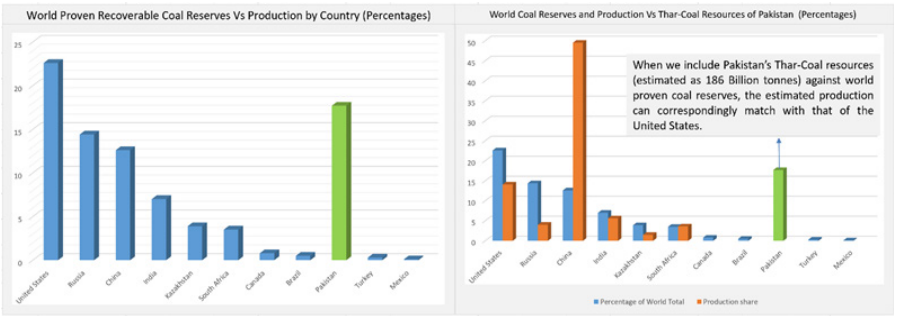


Fig. 1. Comparison of selected countries coal reserve and coal production with Pakistan and the estimated effect of including Thar-Coal resources of Pakistan (USGS, 2020)

Rys. 1. Porównanie rezerw i wydobycia węgla w wybranych krajach z Pakistanem oraz szacowany efekt uwzględnienia zasobów Thar-Coal Pakistanu (USGS, 2020)

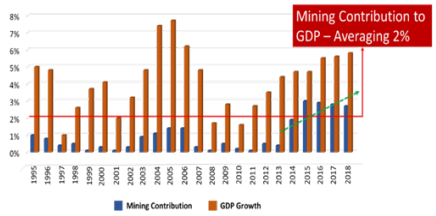


Fig. 2. Yearly GDP growth rate and mining contribution for Pakistan from 1995- 2013 (GHDX, 2020)

Rys. 2. Roczne tempo wzrostu PKB i udział górnictwa w Pakistanie w latach 1995-2013 (GHDX, 2020)

program at Wits. Section 4 describes the NUST-WITS collaboration in detail, ending with the lessons for other, similar collaborations.

## 2. Pakistan Contextual Analysis

Pakistan has significant mineral resources of economic potential. However, at about two percent of GDP, the mineral sector's contribution to the economy does not match its geologic potential. Causal factors include a lack of clarity on its mineral policy, a volatile socio-political environment, a shortage of mining qualifications and skills for large-scale mining, and research capacity to support a twenty-first century mining industry. The link between the extractive industries, universities and skills development for sustainable growth was emphasized by an African Development Bank study (AfDB, 2015). Fundamentally, the hypothesis is that with specialized skills and relevant research, mineral resources can transform economic sectors from mostly informal to formal, resulting in sustainable economic development nationally. For this to happen, university partnerships in mining engineering must also have strong links with the mining sector (Pertuze, J.A et al., 2018, Mitra and Genc, 2019).

### *2.1 A review of the mineral sector of Pakistan*

Pakistan is host to significant mineral resources that hold considerable potential to generate revenue. A total of 52 minerals are mined, but on a relatively small scale. Considerable resources of coal (186 billion tonnes), copper (6 000 million tonnes), gold (1 656 million tonnes), silver (618 million tonnes), lead-zinc (24 million tonnes), manganese (600 000 tonnes), chromites (3 million tonnes), iron ore (1 million tonnes) and precious and semiprecious stones have been identified in different parts of the country (Ministry of Petroleum, 2013). Pakistan's geology is grouped into two broad categories, namely the hilly (mountain) areas that constitute about 60% of the total area, and the plains (40%). Pakistan has significant inferred copper and gold resources at Reko Diq and coal resources at Thar (Hammarstrom et al., 2016). The well-known Tethyan copper belt enters Pakistan at Chagai Arc in Balochistan Province.

### *2.2 Mineral Potential and Growth*

The relationship between mineral development and economic growth is well known. While some authors believe that dependence on natural resources has adverse effects on the overall economic growth (Wright and Czelusta, 2003), others acknowledged its positive contribution, citing the example of United States (US), which was a leading mineral-based economy in the past and over time became a global industrial leader (Wenar, 2013). This illustrates that the mining sector is a positive contributor to economic development under the right policies. Recent studies amplify that countries like Aus-

Tab. 2. International best practices and measures for Pakistan leading to best practice
Tab. 2. Najlepsze międzynarodowe praktyki i środki dla Pakistanu prowadzące do najlepszych praktyk

| Category | International best practice | Pakistan | Measure leading to best practice |
|---|---|---|---|
| Enabling institutional framework | Widely accepted model for the mineral ministry is presented in Fig. 3 | Policy formulation is at the technocratic level instead of the political level. Policy formulation of Petroleum and Minerals are separate. | A separate Ministry for Mineral development (Fig. 3) with Inspectorates of Mines Health and Safety; Inspectorate of Land and Mineral Rights; Sustainable Development Directorate; and Mining Cadaster System and GIS Database. |
| Political economy | Politically stable, growing free market economy. Democratic government. | Pakistan has a fragile political and security environment, not attractive to foreign investments. | Pakistan should strengthen its governance and institutions. A free market economy with clear rules and regulations with better infrastructure. Connect the CPEC transport corridor with the mineral rich areas of Pakistan. |
| Legal Framework - | Security of tenure protected in law. Foreign investment laws and incentives. | Provincial regulation of mining, while federal government do geological survey and international coordination. | Single mineral policy covering all aspects of mining throughout Pakistan. All the minerals should be the property of the State. A clear law on foreign investment incentives should be legislated. |
| Regulatory framework | Regulated award of concessions. | Ministries at Federal and provincial level. | The mining concessions should be awarded on fair, clear legal principles. |
| Treasury and fiscal regime | Taxes, Royalty and specific mining tax | 1-10%25-35 % 6-15 % | Reduce royalty to 6.5 % for five years. Leave corporate income tax and specific mining tax at current rates. |
| Stakeholder participation | Stakeholder involvement during policymaking and implementation. | Stakeholder participation is very rare or non-existent. | Inclusion of local representatives in stakeholder consultation processes. Military should be part of stakeholder's consultation process. |
| Sustainable development issues | Employment. SHEC and security issues. Formalize ASM activities. | Sustainable development initiative is almost non-existent. | Integrate mining with local, regional and national economies. SHEC and ASM regulation. Regular reporting and compliance checks. No permitting in areas of active armed conflict. |

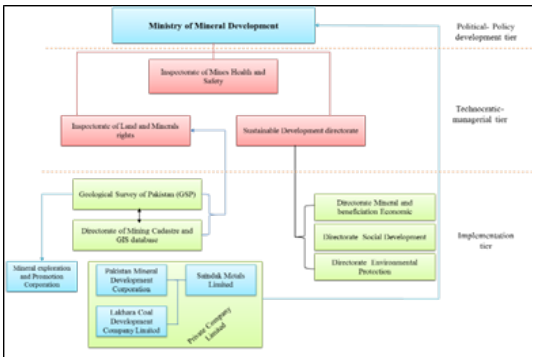


Fig. 3. Generally accepted scheme of organizational structure and a suggested organization of the Ministry of Mineral Development for Pakistan
Rys. 3. Ogólnie przyjęty schemat struktury organizacyjnej i sugerowana organizacja Ministerstwa Rozwoju Minerałów Pakistanu

tralia, Chile and Botswana have earned a major contribution to their GDP from their mineral sectors (Ozah, A et al., 2011). Table 1 illustrates the importance of the mining sector in selected economies at the start of the 21st century.

Minerals in the ground are no guarantee for economic growth. Pakistan is a case in point. It has the world's second largest coal resources (Siddiqui, F et al., 2015), which equates to 618 billion barrels of crude oil. It, therefore, has oil resources comparable to Saudi Arabia, but the economic impact is not the same. By plotting the coal resources of Pakistan against the coal reserves of the selected countries, it is estimated that Pakistan's production share can match that of the United States and India combined (Fig. 1). There are also 6000 million tonnes of copper resources in Pakistan, which can also bring copper production on par with the leading copper producing countries in the world.

Despite the presence of such significant deposits, Pakistan has been unable to get the required economic benefit compared to some other developing mineral-based economies in the world. Fig. 2 illustrates the GDP growth rate and contribution of the mining sector to the economy of Pakistan from 1995 to 2018. It suggests that it has not done well (averaging 2%) and there is a mismatch considering its mineral potential. The recent positive trend in mineral sector contribution to the economy (Fig. 2) could be attributed to the 18th amendment to the Constitution of Pakistan, which allows the provinces to own and administer mineral resources within their territories. However, it is too soon to make predictions on long-term impact because such cyclicality happened before – just to fall back to previous lows (Fig. 2).

### *2.3 A progressive mining industry with enabling institutions*

For the mining industry to grow and attract investment, it requires an enabling environment backed by strong institutional, political, legal, and fiscal frameworks, which must provide for more stakeholder participation and sustainable development. A comprehensive gap analysis between Pakistan and eight developing countries was done (Ashraf H, 2017) as part of the NUST-WITS Collaboration. The six developing countries selected for the gap analysis were Chile; Mexico; Brazil; Peru; India and South Africa. In addition, two Islamic countries were selected, namely Turkey and Kazakhstan. Ta-

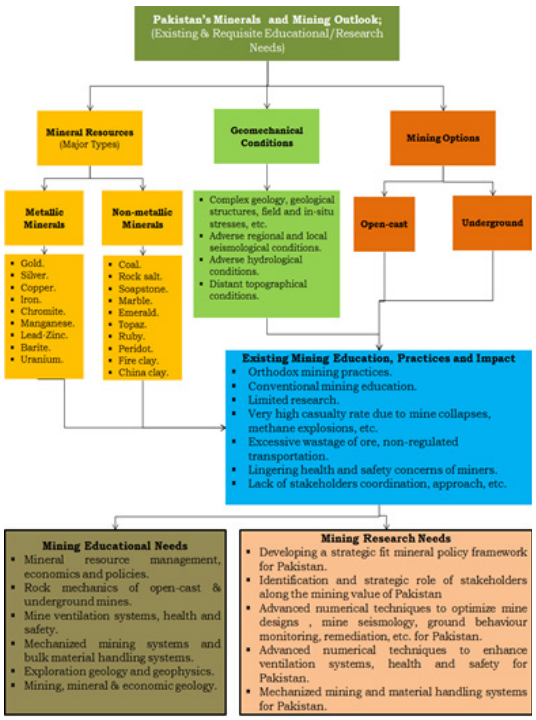


Fig. 4. Pakistan's mineral diversity and industrial mining impediments

Rys. 4. Różnorodność mineralna Pakistanu i przeszkody w przemyśle wydobywczym

ble 2 presents the leading practices based on the analysis of the eight countries selected in the research.

### *2.4 Overview of Pakistan's educational system, NUST and mining programs at other universities*

Established in 1991, NUST is a young university. The university was mandated to commence both undergraduate and postgraduate studies in applied sciences and engineering (without allowing for mining engineering) with a view to match the need for the rapid industrialization of Pakistan. The university has high standards in teaching, innovation and academia-industry-linkages. It is already regarded as the premier university in Pakistan. Today it plays a significant national role in enhancing the industrial practices of mandated engineering disciplines such as mechanical, civil, chemical, electrical, metallurgical, avionics, environmental, etc. In 2011, the mining ministry and government departments in Pakistan approached NUST with a mandate to include mining engineering. The Rector of NUST decided to first, evaluate the substance of existing mining programs in Pakistan, second, formulate a strategy to build faculty capacity and third, implement the strategy and establish the NUST mining program. The responsibility to conceptualize, formulate and implement the NUST strategy for the establishment of a mining school was assigned to Sarfraz Ali, at the time an assistant professor in civil engineering.

In 2011, four universities in Pakistan (Lahore, Jamshoro, Peshawar, and Quetta Universities of Engineering and Technology) were offering undergraduate mining engineering programs with an annual collective count of about 200 graduates. Unfortunately, most of the undergraduates had to change their profession due to the non-availability of good jobs in the struggling formal mining industry. The evaluation of mining programs and the economy concluded that the following findings must inform the NUST capacity-building plan:

- Sub-optimal national mineral resource policy framework and laws at National and Provincial levels;
- Lack of rigorous plans for mineral resource management at micro and macroeconomic levels:
- An absent mining cadaster, resulting in limited mineral resource data and sub-optimal exploration and exploitation of minerals:
- Inadequate mine design and management skills
- Absence of a "common and effective platform" to realize, analyze and resolve stakeholders (government, industry and public) interests in a collective manner:
- Non-requisite mining education and site or problem specific research programs and facilities. Some postgraduate work was vaguely aligned to the problems of the industry and demands of the government departments; and
- Absence of a strong academia-industry linkage program and international collaboration with other mining schools and programs.

## 3. Wits University and Mining

The University of the Witwatersrand, Johannesburg (WITS) is a South African public research-intensive university. WITS is one of the two top Universities in Africa; it is ranked at number six in the BRICS and Emerging Economies Rankings, in the top 300 in the Shanghai Jiao Tong University ranking (first in Africa) and in the top 200 in the Centre for World University Rankings (CWUR). WITS is in the city of Johannesburg, also known as the city of gold. WITS' roots are in mining as it grew from the South African School of Mines, originally established in Kimberley in 1896 and moved to Johannesburg in 1904 (Murray, B.K., 1982).

### *3.1 School of Mining Engineering*

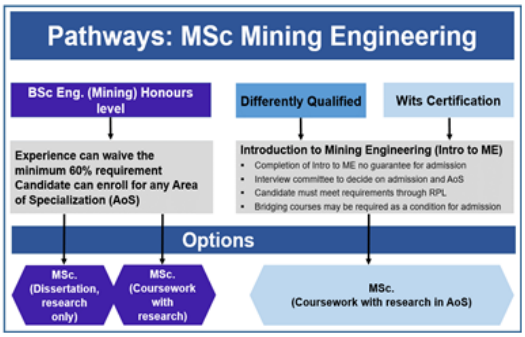


Fig. 5. Pathways to obtain a postgraduate specialization in mining engineering at Wits Mining
Rys. 5. Ścieżki do uzyskania specjalizacji podyplomowej z inżynierii górniczej na Wits Mining

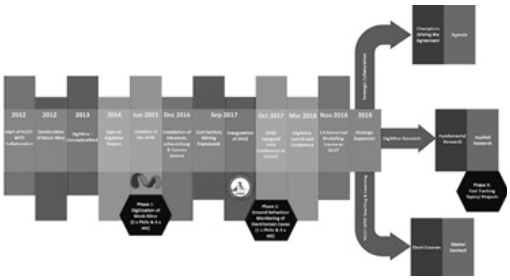

Fig. 6. Timeline and growth of NUST-WITS partnership
Rys. 6. Harmonogram i rozwój partnerstwa NUST-WITS

WITS Mining is recognized as one of the top mining engineering schools in the world. The program is expansive with one of the highest growth rates of any engineering schools. In addition to its undergraduate program, the school has in conjunction with the South African mining industry, developed a substantive certificate and postgraduate programme with several specializations within the broad Mining Engineering spectrum. Fig. 5 illustrates the Wits Mining program at the time when Professor Asghar Qadir and his delegation visited the school - consisting of qualifications at Levels 6 (Certificate in Mineral Resource Management), Level 8 (BSc Mining Engineering), Level 9 (MSc Mining Engineering) and Level 10 (PhD Mining Engineering) on the National Qualifications Framework (NQF). The program allowed differently qualified applicants to progress to MSc and PhD Levels, which made it possible for NUST Faculty with appropriate engineering degrees to do higher degree specializations after completing an Induction module on Introduction to Mining Engineering. Fig. 5 illustrates the provision for differently qualified individuals to progress to an MSc and PhD specific Area of Specializations (AOS).

### *3.2 The WITS digital mining project*

The sudden influx by NUST faculty with different first degrees provided an excellent opportunity for Wits Mining to learn as much from NUST faculty than NUST faculty learned from WITS. It was a win-win situation from the start, and the additional capacity made it possible for Wits Mining to venture into research with a focus on the fourth industrial revolution (4IR), which digital mining research became a living laboratory for multi- and transdisciplinary research in mining (Renn, 2018). A significant sponsorship from Sibanye-Stillwater accelerated its growth, and soon the Sibanye-Stillwater Digital Mining Laboratory (affectionately known as DigiMine) were working on several technologies for underground mining in support of the safe and efficient mine of the future. This innovative model, which started as a direct result of the NUST-WITS partnership, continues to do 21st century multidisciplinary applied research – mostly on mining problems identified at Sibanye-Stillwater and other mining partner operations.

DigiMine became part of the Wits Mining Institute (WMI) in 2015, which institute does apply research on 21st Century mining. The primary focus of the WMI is the production of research of the highest quality on large multidisciplinary and complex questions. Within the WMI DigiMine is a one-of-a-kind facility inside the Chamber of Mines building with its simulated mining environment that is equipped with leading digital practice systems. The mock-up mine is complete with a surface (using the flat roof of the building); a vertical shaft (using a stairwell in the fourth quadrant of the building) and a mock underground mine and control room in the basement of the building. DigiMine is equipped with digital systems to enable hands-on training and research for the mine of the future. The research agenda is to transfer digital surface technologies into the underground environment, enabling a mine that can observe, evaluate and take action. The objective is to use technology to put distance between mineworkers and the typical risks they are exposed to on a daily basis, in addition to a mine that is efficient. This includes systems for communication, monitoring, positioning, navigation, detection of abnormalities and risk management.

In conclusion, this section illustrates how important shared value and mutual benefit are in international collaborations. By tapping on each other's strengths, it was possible to add substantive capacity at both NUST and WITS. The friendships established over time caused the collaboration to continue as real and virtual teams of post-doctorates continue

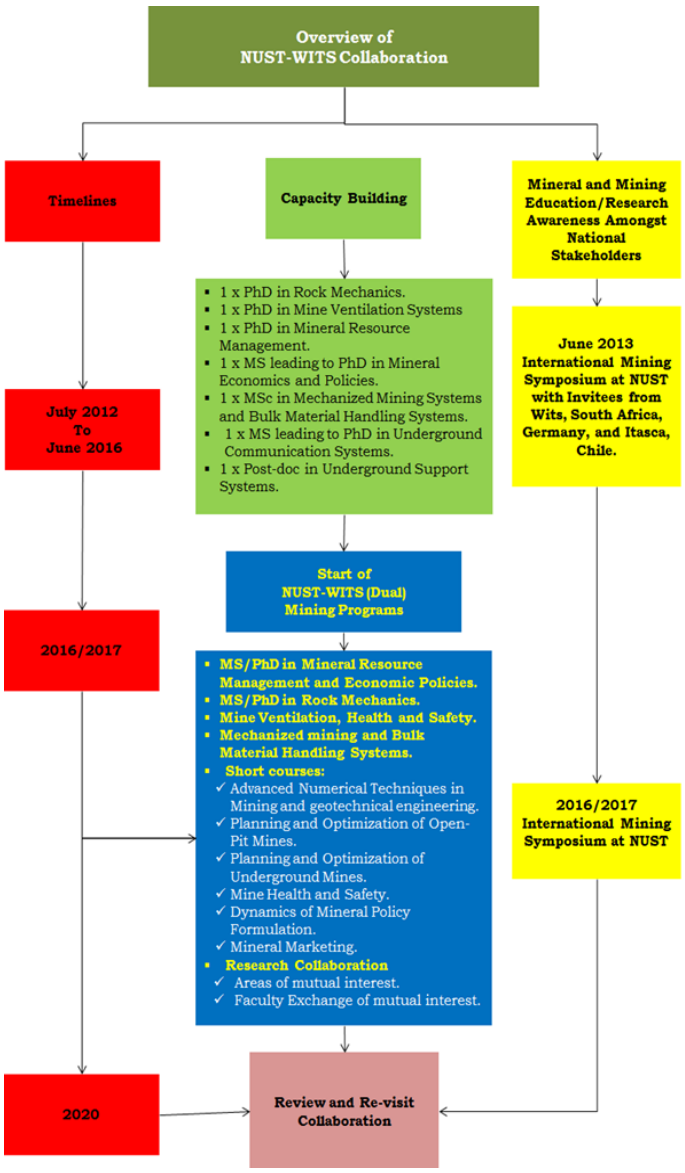


Fig. 7. Conceptualization of the NUST-WITS collaboration
Rys. 7. Konceptualizacja współpracy NUST-WITS

to contribute to applied research on projects for the South African and Pakistan government and industries.

## 4. The NUST-WITS collaboration

International collaborations and partnerships between universities are not new (Drebenstedt, C., 2015 and Watanabe, K et al., 2015). Collaboration has become a necessity in the face of new, complex challenges, such as a shortage of critical high-level skills, budget constraints and appropriate laboratories to support mining engineering teaching and research. By collaborating, pooling and sharing resources, whilst tapping on additional multidisciplinary faculty, the NUST-WITS partnership provides researchers and students with unique opportunities to study and research fundamental and relevant applied mining topics.

### *4.1 Structure of the Collaboration*

NUST decided that it wants to establish deeper mining engineering capacity in Pakistan, with Wits Mining the potential partner. The reasons were two-fold. First, Professor Asghar Qadir (senior academic at NUST) had an established relationship with the WITS School of Mathematics, and second, Wits Mining is one of the top Mining Schools internationally. A delegation headed by Prof Qadir, supported by Messrs. Sarfraz Ali and Tariq Feroze, met with Professor Cawood at Wits Mining to discuss the reason for the visit. Collaboration for capacity development was not new for Wits Mining; in fact, the School has completed similar programs with historically disadvantaged universities in South Africa, in addition to international initiatives with Mozambique and Zambia. The NUST-WITS collaboration has been very successful because the sustainable capacity (through staff development) was created - in addition to bricks and mortar, which is the traditional model for quick-wins. After some deliberation, the meeting agreed that for NUST to develop a sustainable program, staff development in selected areas of specialization in mining engineering comes before physical infrastructure. The next step was to sign the usual Inter-Uni-

versity Memorandum of Understanding (MoU) followed by a Memorandum of Agreement (MoA), which stipulated the details of the partnership. The agreements between the two universities allowed for the following items:

- Staff development through higher degree studies and lecturer 'twinning' in the Wits Mining program, allowing for hands-on learning so that NUST faculty can service an accredited Mining Engineering programme at NUST upon their return;
- Contract, post-doctoral and postgraduate research in identified areas of importance;
- Co-supervision of students in areas of collaborative research;
- Exchange of faculty members and students to work on teaching and learning, laboratory work, research and strategic mining projects;
- Sharing of resources and laboratories, including computing facilities; and
- Mutually agreed financial terms after taking available budget and resource constraints into account.

Successful university capacity development through collaboration depends very much on a shared vision, setting of objectives for the partnership, obtaining high-level (sometimes government) support and mutual benefit. In the case of the NUST-WITS partnership, there were clear short- and long-term benefit for both institutions that were agreed upon up-front. The next step was to develop the specialist areas to support a mining program and to match these with the NUST staff identified for the program, and at which level (MSc, PhD or Post-Doctorate research) it must be. The partnership identified the following areas of specialization:

- Mining methods;
- Mine ventilation engineering;
- Rock engineering for mining;
- Mineral resource management;
- Mineral processing and metallurgy; and
- Mineral economics and sustainable development;

Masters degree studies were through a combination of course work and research, while PhD and post-doctorate development happened through research within a laboratory testing and industry application context. This gave exposure to relevant laboratories, equipment and staffing requirements of laboratories, in addition to working on fundamental and applied research topics in mining. Later on, after the first staff returned to NUST, government capacity development through consultancy-type research and short courses were added to the partnerships. This included work on:

- Mineral and Tax Policy frameworks;
- Mining policy and Cadaster design;
- National Resource/Reserve definition; and
- Inspectorate training.

Fig. 6. Illustrates how the partnership developed and grew following the inception meeting in 2011.

***4.2 Objectives***

The NUST-WITS implementation plan had the following objectives:

- Provision was made for one or two post-doctorates, PhD and MSc seats for 2012 and 2013 - funded by NUST;
- NUST faculty got support and advice to develop curricula for its future programs while lecturer 'twinning' happened for a more hands-on approach;
- Wits Mining encouraged its faculty member(s) to take sabbatical leave at NUST to help with the implementation of its mining programs; and
- Wits Mining advised and guided NUST on the establishment of laboratories for teaching, learning and research.

As planned, the collaboration commenced with Sarfraz Ali as the first NUST faculty to join Wits Mining as a PhD Scholar in 2012. Later, more NUST faculty kept joining over time, which included positions for two post-Doctorates, two PhD and two MSc candidates. Sequel to the success of the collaboration, the plan was revised in 2014 to admit more students from Pakistan. Later, in 2017, upon the establishment of the WMI at WITS and SAGE at NUST, a WMI-SAGE MoA was signed, which agreement set the following objectives:

- Contract, post-doctoral and postgraduate research in identified areas of interest;
- Co-supervision of students in areas of joint research;
- Exchange of faculty members and students to work on teaching and learning, laboratory work, research and strategic projects;
- Sharing of resources and laboratories, including computing facilities; and
- Opportunities for joint qualifications and research programs in areas of mutual benefit.

***4.3 Conceptualization and implementation of the collaboration***

Today there is a strong and significant international collaboration between SAGE and the WMI, which continues to grow in stature. Despite cultural and travel challenges, this partnership is fueled by consistency in leadership, friendship, passion and dedication on both sides. Without these ingredients for successful collaboration, the partnership cannot work - it needs a personal approach with shared ideas and goals. Once these attributes are in place, research productivity benefit because joint research is responsible for one in five scientific papers published internationally (QS, 2019).

*4.3.1 Conceptualization*

In August 2011 the then Rector of NUST requested Sarfraz Ali to join Professor Asghar Qadir for negotiations with WITS and to formulate a master plan for the NUST capacity building in mining program, summarized in Fig. 7.

*4.3.2 Implementation*

At the inaugural meeting in November 2011, both sides saw the value-add opportunity, which led to the first agreement of understanding referred to earlier. The meeting, followed by the agreement, marked the start of the capacity building program (Table 3).

The NUST faculty members were highly enthusiastic and commenced their assigned research areas with dedication. Mining faculty was also supportive of the program. Mr Sar-

fraz, as a lead member of the NUST Team, monitored the progress of each individual and kept NUST updated. Looking back, by having a dedicated champion at Wits as part of the faculty development program, contributed significantly to the success. NUST hosted a joint NUST-WITS International Symposium on "Innovations and Advances in Mineral Exploration, Extraction, Processing, and Sustainable Mining Practices" at NUST in June 2013 at the Islamabad Campus. A large delegation from Wits Mining and other schools at WITS (Geosciences, Chemical, and Center for Mechanized Mining Systems) – in addition to South African mining Industry executives, attended the symposium as keynote speakers and presenters. Delegates from Germany, the US and Chile participated in the symposium. The event provided an excellent opportunity for Pakistan mining stakeholders to interact with international delegates, which not only accelerated collaboration, but also transformed it into more industry participation.

In view of the skills and capacity of the NUST faculty, Wits Mining involved most of NUST team members in the school activities and DigiMine research project, which later made way for the NUST-WITS collaboration on strategic, sustainable and income-earning industrial projects. Though planned for in the collaboration agreement, NUST could not send more faculty to WITS because of first, financial reasons and second, some faculty were not willing to do multidisciplinary research and preferred to remain within their first degree disciplines. This problem was dealt with in an innovative manner, i.e. the team members took on additional coursework and off-university courses to develop the skills in the overlapping domains with a view to reduce the number of faculty at WITS, but still achieve the desired outcome. Such innovative and proactive management resulted in non-NUST graduates from Pakistan hearing about the collaboration, and soon a new stream of postgraduate intake followed, willing to add mining qualifications to their first degrees to become part of a multidisciplinary team. By this time, DigiMine could afford to offer more bursaries to postgraduates with the right first degrees for its industrial projects. As the non-NUST intake graduated from the program, NUST offered them positions in the new SAGE program. This is clearly the sign of a sustainable model of wide benefit, reaching outside the intended collaboration. Whereas the postgraduate group performed above expectation, there were challenges with the post-doctorate program – mostly for family reasons and difficulties associated with early childhood development and basic schooling systems. Looking back, such challenges are normal, predictable and should have been better provided for in the plan. Future collaborations should consider such matters in detail as part of the planning and recruitment phases of collaborative projects.

September 2017 marked the next important milestone, i.e. the establishment of SAGE at NUST Campus Risalpur, some 125 km away from the Main Campus at Islamabad. SAGE was mandated to commence postgraduate programs in mining with effect from the fall of 2018 and engage in academia-industry linkages to develop Pakistan-specific mining solutions through postgraduate studies and research. Identified research projects included mineral economics, predictive forecasting of mega Geohazards and sustainable development, starting with the CPEC economic corridor – an infrastructure project through challenging mountain ranges (Himalayas, Karakoram and Hindukush) and resource-rich areas. SAGE hosted an inaugural seminar in November 2017, again well attended by mining stakeholders, Wits Mining and other international delegates. After obtaining the approval from the Higher Education Commission (HEC) and Pakistan Engineering Council (PEC), SAGE announced its PhD program in April 2019. Eight candidates (a significant number for the newly established program) enrolled for the Fall-2019 intake (a year later than originally planned) to do research in areas of rock mechanics, mine health and safety, mineral processing, mechanized mining systems, bulk material handling systems, mineral resource management and ventilation engineering). On the academia-industry linkage front, SAGE reached out to the government mining departments of the provinces and was able to secure projects such as the development of mining cadaster systems, geological mapping and real-time monitoring of extraction at mines for KPK Province, mining studies (scoping and pre-feasibility level) for Mari Petroleum Pvt Limited, etc. These developments did not affect the WMI-SAGE collaboration, who which continued (and in fact expanded) its program of applied research areas on some world-first DigiMine projects. This work is in addition to the WMI appointing SAGE staff in visiting capacities to participate as equals in research projects, cross-supervision of postgraduate students and delivering courses in both Pakistan and South Africa. Fig. 8 gives an overview of the organizational outlook and wider NUST collaboration to deliver on the SAGE mandate.

### *4.4 Challenges and lessons*

In conversations with colleagues that were part of the NUST-WITS collaboration from the start, it is clear that the project was at risk at times. Conflicting phrases like - uphill, most challenging, frustrating, inflexible politics and policies, compelling, interesting and accomplishing - were used to describe the project.

The importance of leadership, friendship and goodwill. What pulled this collaboration through was the planning, goodwill, friendship and consistency in leadership. Successful university collaborations, therefore, require belief in the program, passion, discipline and character. These are more important than (inflexible) university standard procedures, charters and directives.

A conceived strength may be an actual weakness and vice versa. The language barrier and cross-cultural issues were not the leading challenges as was originally expected and typical of cross-cultural partnerships. Inflexible government policies, VISA restrictions allowing regular exchange and differences in university policies were bigger constraints. The partners achieved the objectives despite the frustrating processes and slow permissions. Unexpectedly, the approach that formed the basis of the agreement, and was considered a strength at the start of the collaboration, i.e. selecting the university staff with different first degrees, posed the most risk to the project. The innovative solution to broaden the capacity of participants through additional course work and taking non-NUST participants into the program solved the problem – and in fact, became a strength when SAGE recruited them as faculty members in the new school.

Financial Challenges. Because of their age, the NUST fac-

Tab. 3. Details of the NUST faculty, background qualifications, mining qualifications and repatriation
Tab. 3. Dane dotyczące wydziału NUST, wykształceni , kwalifikacji górniczych i repatriacji

| | Faculty | Qualification | Start date | Broad area of study | Repatriation |
|---|---|---|---|---|---|
| | Professor Emeritus Asghar Qadir - Astute patron, Co-architect of the NUST-WITS collaboration and Advisor to Rector NUST on the program | | | | |
| 1 | Sarfraz Ali | MSc (Geotech Engg) | July 2012 | PhD in Rock Mechanics | Nov 2015 |
| 2 | Tariq Feroze | MSC (Mechatronic Engg) | Oct 2012 | PhD in Mine Ventilation Systems | Dec 2016 |
| 3 | Hamid Ashraf | MSc (GIS & RS) | Aug 2013 | PhD in Mineral Resource Management | Aug 2017 |
| 4 | Zeeshan Asghar | MBA | Aug 2013 | MSc (Mineral Marketing) | Oct 2015 |
| 5 | Mohsin Ali Syed | BE (Mechanical Engg) | Aug 2013 | MSc in Bulk Material Handling systems | Jul 2015 |
| 6 | Muhammad Rizwan | PhD (Structural Engg) | Aug 2013 | Post-Doc in Underground Support Systems | Nov 2014 |
| 7 | Samia Gormani | PhD (Geology) | Jun 2014 | Post-Doc in Exploration and Economic Geology | Aug 2014 |
| 8 | Intikhab Hussain | BE (Information and Communication System Engineering) | Jan 2015 | MSc in Underground Wireless Communication | Dec 2016 |
| 9 | Faiq Javaid | BE (Mechanical Engg) | Feb 2016 | MSc in Mine Planning and Optimization | Mar 2019 |
| 10 | Sarmad Javaid | BE (Materials Engineering) | Feb 2017 | MSc in Metal Accounting / Mineral Processing | Feb 2019 |
| 11 | Srosh Bashir | Bachelors Computer Sciences | May 2018 | Underground Object Recognition in Mining | MSc in Progress |
| 12 | Muhammad Ashraf | MS Computer Engineering | June 2018 | Signal Absorption Rates for PPE | MSc in Progress |
| 13 | M Ahsan Mahboob | MS in GIS & RS | Feb 2019 | Data Science, Machine Learning and Artificial Intelligence Approach to Mineral Exploration and Evaluation | PhD in Progress |

ulty initially selected for this program were married with families. Their stipends were the same as for younger, unmarried "bachelor" students, but the expenses much more. NUST and WITS policies compounded the problem by having limits to support. The NUST administration expects its scholars while studying at foreign universities, to do academic duties and sustain themselves in the last year of their study leave. Furthermore, the NUST stipend for African countries is less than that for European countries. This is despite Johannesburg being as expensive as some European cities when it comes to living expenses. WITS also posed a distinct challenge in its lack of fully funded scholarships for international students and restrictions on stipend and support maximums. The NUST scholars expected to take advantage of additional earning opportunities (for doing academic duties), which opportunities were limited for non-Africans. The first intake found life in Johannesburg particularly difficult, but their dedication to the collaboration and pride prevented them from leaving.

Academic challenges and choice of research area and supervisor. None of the NUST faculty had first degrees in mining engineering. The little preparation time given to them before coming to WITS compounded the problem. Despite this additional pressure, it still worked out because of the planning to match first degrees with specializations, personal research interests and supervisors. Identifying supervisors up-front turned out to be a good idea in one way because it allowed 'twinning' early on. A disadvantage was limited knowledge about their research areas and other available study areas on offer at WITS, causing some NUST faculty to feel that they made wrong choices. Looking back, lessons include first, allowing more time to do core subjects and courses while still in Pakistan and second, allowing NUST Faculty more choice of research area and supervisors.

Lack of Follow-up from NUST and WITS attitude of 'What is in it for us' at times. The number of scholars required for the program, research areas, deadlines and other objectives were part of the planning process. Importantly, a champion was appointed, who had the responsibility to lead NUST Faculty and represent the NUST interest at WITS. Over time, because of bureaucratic policies, financial constraints and a change in University leadership, NUST lost track of the initial objectives and stopped sending more faculty, resulting in some domains of mining not being covered. This development put more pressure on the champion at WITS to meet the objectives of the collaboration. Because of many other commitments, the collaboration was never a top-of-the-list priority for WITS too, and participants of the collaboration felt that they were just 'a means to meet an end'. The change in the Headship at Wits Mining also happened during this time, but new momentum was established after the creation of the WMI, which institute prioritized the NUST-WITS collaboration again. Fundamentally, the collaboration survived the typical ups-and-downs of university collaborations. Today, the NUST-WITS collaboration stands out as one of the most successful university collaborations ever in the long history of Wits Mining. The postgraduate and research capacity at SAGE demonstrates the hallmark of sustainable mining engineering capacity in Pakistan. That is the ability to deliver

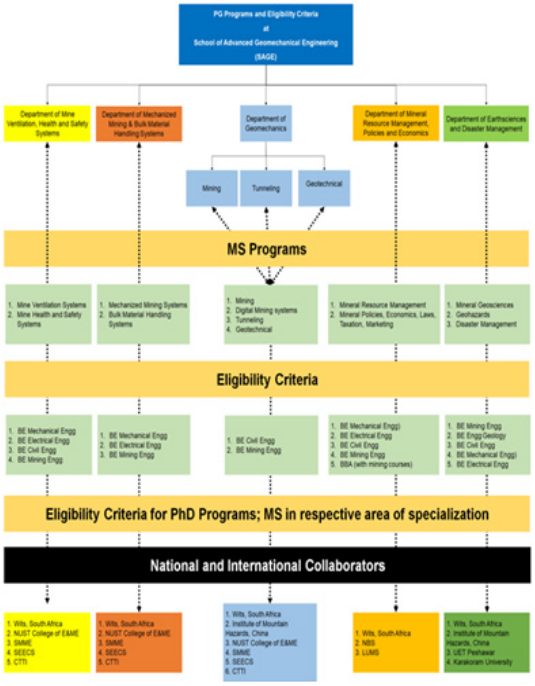


Fig. 8. SAGE organization and collaboration outlook

Rys. 8. Struktura organizacyjna SAGE i perspektywy współpracy

quality courses, do supervision and engage in projects serving the country and influencing national policy.

## 5. Conclusion and Recommendation

A well-orchestrated international partnership, friendship and dedication are vital ingredients for successful university collaboration. Both NUST and WITS see this particular collaboration as a success - in fact, a model for other collaborations. The overall objective was achieved, namely to develop the faculty who must teach mining engineering education and do research for the benefit of Pakistan. Faculty development is the most important investment in sustainable programs with infrastructure coming second. The twinning of staff helped NUST staff to become familiar with teaching content and laboratory use (and equipment). Although NUST already has laboratories, SAGE started an expensive (mining) laboratory equipment program to do more laboratory testing and analysis. While this is happening, the collaboration still relies on exchange programs, sharing of facilities and data transfer for research purposes. The collaboration has matured over the years, and it continues. Going forward, the partners will seek more and new opportunities to participate in educational, research and consulting that are mutually beneficial and allowing for additional income streams. One way of achieving this is to continue sharing strengths, while the two partners continue to grow. The lessons from this collaboration have significant implications for other countries because the model is transportable. It is recommended that such collaborations heed the lessons learned while seeking their own mutually beneficial projects. The authors will do the following differently should another opportunity arises:

– As part of the initial planning phase, do a survey on both sides to decide on the qualifications and levels of the programs. This information must inform a pre-learning phase before enrolling as postgraduate students;

– Explore more exchange opportunities for respective faculty members for lecturing scarce specializations in mining. This includes the possibility of joint Chairs;

– Actively pursue the possibility of dual qualifications on the back of exchange programs and using technology;

– Plan for a commercialization phase at the end, where services, research outcomes and technologies can go to market; and

– Extend support to government staff in order to also build inspectorate capacity in mine health and safety, mine and exploration licensing, mineral and tax policy frameworks, mining policy, cadaster design and national resource and reserve statements.

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*Budowanie międzynarodowego potencjału w inżynierii górniczej: współpraca edukacyjna NUST-WITS w dziedzinie górnictwa*

*Pakistan nie rozwinął w pełni swojego sektora wydobywczego. Dzieje się tak pomimo wysokiej jakości zasobów mineralnych. Górnictwo w Pakistanie jest głównie „rzemieślnicze" i „na małą skalę", a aby to się zmieniło, kraj ten musi rozwinąć umiejętności, aby wspierać kwitnący sektor formalny o znaczeniu w XXI wieku. Pakistan ma wysokiej jakości uniwersytety, a niektóre z nich już oferują kursy górnicze. Opierając się na tej platformie, NUST University zwrócił się w 2011 roku do School of Mining Engineering na University of the Witwatersrand (Wits Mining), aby rozpocząć współpracę, która przyniesie większe korzyści sektorowe dla Pakistanu. Wynikiem dyskusji było budowanie potencjału specjalistów górnictwa w Pakistanie na poziomie studiów podyplomowych i podyplomowych. Zastosowano podejście, które polegało na zidentyfikowaniu wymagań personelu uniwersyteckiego w zakresie wspierania programu nauczania, uczenia się i badań dla sektora górniczego XXI wieku, a następnie powiązaniu ich z kwalifikacjami wykładowców, którzy zostali wyznaczeni do realizacji programu na NUST. Współpraca okazała się udana dzięki przywództwu, energii i starannie dobranym „czempionom" po obu stronach. Jedną z wielu atrakcji współpracy było utworzenie doskonałego laboratorium prowadzącego badania nad wpływem czwartej rewolucji przemysłowej na sektor górniczy. Projekt Digital Mining stanowił rdzeń badań i nadal umożliwia regularną wymianę studentów, pracowników i doktorantów w ramach spójnego tematu badawczego.*

**Słowa kluczowe:** *współpraca międzyuczelniana, górnictwo w Pakistanie, górnictwo w RPA, budowanie zdolności, górnictwo XXI wieku*