Foundry Students' Experiences under Engineering Programme for Localization*

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Metal Casting Technology Station-University of Johannesburg (MCTS-UJ) is managed through The Technology Innovation Agency (TIA), and it works closely with the School of Mining and Metallurgy and Chemical Engineering, UJ. MCTS-UJ submitted a proposal for Research and Innovation in Foundry Technology (RIFT) programme to The Department of Science and Technology (DST) in 2011 to address government's localisation plan. The proposal addressed the Human Capital Development aspect in the advanced foundry technology for the South African foundry industry. As part of the RIFT programme, MCTS-UJ, an initiative of DST partnered with the Technische Universität Bergakademie Freiberg, Germany to develop a programme to train and retain Masters students from South Africa. We used qualitative interviews as part of the case study to explore how MCTS-UJ succeeded in retaining the female students and why some students decided to leave or stay back. The semi-structured interviews were conducted with four female students who participated in the RIFT programme to understand their experiences during their study in Germany. At the end of the RIFT programme the students completed an equivalent programme to our Masters in South Africa that is Dipl. Ing in Foundry Technology. We compared all interview data with archived information in many documents based on RIFT programme to determine if they draw the same conclusions. We felt that satisfactory progress of the students should be monitored throughout the Engineering programmes and adequate funding is necessary to attract and retain female students in Engineering We make recommendations for Foundry Engineering programme for localisation and explore the impact of RIFT programme on skills development. Interviews with MCTS staff helped to explore the impact of RIFT programme on technology localisation. We also developed a model for the retention of female students in foundry Engineering.

Keywords: engineering programme for technology localisation; foundry students' experiences; a model for retention of female students in engineering

1. Introduction

Research and Innovation in Foundry Technology (RIFT) programme is an initiative of Department of Science and Technology intending to develop human capacity to drive research and innovation in metal casting in South Africa. The programme was rolled out in two phases. As part of phase 1, the four students at MCTS-UJ were sent to the Technische Universität Bergakademie Freiberg (Technical University of Freiberg, Germany) and they completed the Dipl. Ing in Germany. Phase 2intends to disseminate the scientific and technical knowledge gained by RIFT programme and upon completion of the degree, the students were expected to share their knowledge with the broad local foundry through their involvement in research projects, consultancy, training, provision of technical skills and technical services to the industry.

This is an exploratory study that provides insights on the female students' experiences while participating in the Research and Innovation in Foundry Technology (RIFT) programme. In this paper we also explore how to train and retain foundry Engineering students. Four students embarked and finalised the Masters study in Germany at the Technische Universität Bergakademie Freiberg. The project was funded by DST and implemented by MCTS-UJ.

The Department of Science and Technology identified technology gaps during benchmarking and afforded the four South African students an opportunity to study internationally. The students faced various challenges while participating in the programme and it was very difficult for MCTS-UJ to retain these Engineering graduates in such programmes and thereafter at MCTS-UJ upon their return from Germany. MCTS is constantly striving to improve relations with Universities and companies to assist graduates to find work opportunities globally. Through the RIFT, MCTS has managed to assist two of the graduates to find placements, one in Germany and one in UK.

Many authors used pipeline theory [1, 4] to examine female students' experiences in higher education. Various authors suggested individual factors (such as poor performance, feeling unprepared for demands of the engineering program, difficulty fitting into engineering) and institutional factors (such as disappointment with engineering advising) as the common themes for non-persisting engineering undergraduates [2]. Watkins and Mazur [3, p. 39] discussed how to retain students in Science, Technology, Engineering, and Mathematics.

Mills and Treagust [5] opines engineering as a profession including engineering education is maledominated. Blumenthal et al. [14, p. 1] discussed strategies for attracting international students, as well as national and campus-based programs through which American and German engineering students can study abroad and gain international experience relevant to their future careers. Their research also indicates engineers' need for global competencies and multicultural skills and how this can be achieved through study abroad [14, p. 11]. These literature reviews have provided further insights to our methodology and clear direction for this research.

The European Union has vigorously promoted academic mobility within Europe, through which many thousands of students spend a semester or more in another European country on programs like European Region Action Scheme for the Mobility of University Students (ERASMUS) [15]. Personal development and other values of the programme also included development of key skills by the participants such as, socio-communicative skills, intercultural awareness, adaptability, endurance, problem-solving abilities and being able to work productively in a team [15]. Similarly, RIFT programme was initiated to address international mobility of South African students, to develop key skills in foundry technology to address local foundry needs and it helped them to understand intercultural issues and socio-economic aspects of the two countries.

2. Objectives

The main objective is to explore female foundry Engineering students' experiences under RIFT programme for localisation. The sub-objectives are to determine how MCTS-UJ partnered with the Technische Universität Bergakademie Freiberg (Technical University of Freiberg, Germany) to develop a programme to train students from South Africa and ways to retain the students during their study in Germany. We explore ways that the programme used in phase 2, to retain the foundry students in Engineering at the MCTS-UJ itself, upon completion of the Masters degree as well. Other subobjectives are to discuss the impact of the RIFT programme on technology localization and to see the impact of RIFT on skills development. We developed a model for foundry Engineering programme student retention.

3. Research design and methodology

We used qualitative research methods to get the subject's opinions and beliefs on RIFT programme. We identified underlying significance of the programme using case study method. We use a single case study research [7, p. 49] method and as part of that we conducted semi-structured interviews [9, 10, p. 40] with RIFT programme students during early 2015 to understand how the students enrolled for the RIFT programme, their experiences and why it was necessary for MCTS-UJ to decide to send students to Germany and to retain them on return. An interview protocol was followed [9]. We used purposive sampling [10, p. 169] to select those students who participated in the RIFT programme. Respondents were selected on the ground that the RIFT students who participated can provide the most accurate information.

We posed open-ended questions during the interviews. The open ended does not limit the respondents or interviewees choice of answers [11, 12]. The questions focused on benefits in participating in the programme, why the students decided to stay on in the RIFT programme, why they decided to leave. We also posed questions on attempts by MCTS-UJ to retain the students. We had to conduct further semi-structured interviews with MCTS staff in August 2015 to understand the impact of RIFT programme on localisation and to see their current roles in the industry.

A content analysis [8] of all documents provided by the RIFT programme interim committee gave further insights on the student experiences, impact on skills development, outcomes and impact of the programme on localisation. Some of the documents that were used for content analysis are: Report on review of the implementation of Masters programme in Advanced foundry technologies—UJ (February 2014) and the Minutes of 4th MCTS-RIFT programme Steering Committee, UJ (12 Nov 2014). We checked if the interviews and the archived documents analysed drew the same conclusions.

4. Data analysis and results

Case study—*RIFT programme:* MCTS-UJ partnered with Technische Universität Bergakademie Freiberg (TU Freiberg), Germany for the Research and Innovation in Foundry Technology (RIFT) programme to exchange research staff between institutions and to train Engineering students in casting technology from South Africa. This programme was funded by the Department of Science and Technology (DST), South Africa.UJ staff took three research expedition trips to establish which European Universities in Germany and Poland had compatible metallurgical programmes with those offered by UJ and for the meetings in preparation of the candidates' placement at TU Freiberg with Dr H Polzin and Dr-Ing Dommaschk.

As advertised in June 2011, all candidates participating should be South African citizen, must hold Bachelor Degree in Metallurgy or equivalent with focus in Physical Metallurgy and Metal Casting and an average of at least 70% in the final year. The candidates should be between 22 and 28 years of age. During the RIFT call both male and female candidates were accepted, but just before departure the male candidate withdrew and the female candidates continued. Although 5 candidates were approved initially, one of them, a male candidate withdrew even before departure due to commitments at home. Out of the four female candidates left three were not sure about the benefits of the programme.

The students had to study and pass their German proficiency course which was a prerequisite. They started formal academic programme started on 1st April 2013 and they did some of the courses related to casting materials, joining, mouldings and moulding process. Throughout the programme the students reported on social integration difficulties.

The four women candidates Miss Mashila Rachel Motadi, Ms. Seithuti Given Lesejane, Ms. Nthambeleni Beaurothy Singo and Ms. Mampai Lereto Raganya departed for Germany from South Africa on 28 February 2012and completed the Masters programme implemented by the Metal Casting Technology Station, Faculty of Engineering and the Built Environment and returned on the 17th December 2014. The RIFT interim committee concluded that it is important to ensure that the students become involved in meaningful projects when they return to South Africa.

We conducted interviews in early 2015 and posed the following interview questions to the above four candidates. The specific interview questions that focussed on benefits, decision to stay or leave and student retention that were posed and the responses of the candidates are provided here.

1. How did you benefit from RIFT?

The responses as provided by the four candidates were as follows:

- I gained a reputable Masters degree accompanied by world class foundry experience.
- I managed to obtain my master's degree from one of the best Universities in Germany and got international exposure of the foundry industry. Learning the German language was also a great benefit for me.
- By getting financial support to do my masters in Germany

• Through the RIFT programme I was able to experience life in a different part of the world. This broadened my view, not only on the technical expertise that I went there to gather, but also on socio-economic and cultural issues. I got to see first-hand how the dynamics of a society influence the corporate and industrial environments, and hence a country's productivity.

2. Why did you decide to leave and what made you stav on?

Responses from three candidates below:

- I decided to leave because I was eager to learn new things from the German perspective and to bring back the acquired knowledge in order to improve the standard and working conditions of South African foundries. I decided to stay on just to make sure that I successfully complete what I started. Quitting is/was not an option for me.
- During the early months of the RIFT programme, presumably because of the major change in diet and stress, I experienced health issues that led to my having to have surgery. Having never had to deal with any significant health issues previously, dealing with such a health scare was quite traumatising. Even after my health condition was under control, psychologically I was still panicked. As long as I remained in the same environment, still on the RIFT programme as it was being run at the time, the same sources of stress continued to exist. I decided it would be best for me, for the sake of my physical and mental health, to be back in a familiar environment where I had more control of my own life and access to the support of my family. Once I was back in South Africa I got to meet with the RIFT Committee.

This was the first time since inception of the programme that any one of us RIFT students had been allowed direct access to the committee upon which our entire existence in Germany depended. I was surprised to find out that they were unaware of our many struggles out there, and they were surprised by my "sudden withdrawal" from the programme. I felt for the first time a genuine sense of concern from most of the committee members, and they raised the question that if I was given a clean bill of health and the sources of stress ceased to exist would I be able to complete the programme? I consulted my family doctor, and with a clean bill of health, a promise of a stipend increases and better communication and administration of the RIFT programme and an appreciation for the great opportunity that the programme is, I decided to head back to Germany.

• Because I was unable to get a better job with my SA qualification therefore I thought a degree from overseas could make a difference

3. What attracted you to the programme?

The responses from the four candidates were as follows:

- The International experience that came with it, and taking that to integrate it in SA so that we could one day globally-competitive.
- I was attracted by the fact that the studies would take place in a foreign country.
- The possibility to get a degree from overseas.
- Germany is synonymous with engineering excellence. An opportunity to invest only 18 months in a foreign country (plus 6 months practical work in South Africa) (Phase 1 of the programme ended up running for 34 months in Germany), learn a new language, develop my technical expertise and obtain two masters degrees for my efforts (it was implied that upon completion of the programme we would obtain a double degree from Technische Universität Bergakademie Freibergand UJ) seemed like a good deal.

4. Were attempts made by MCTS—UJ to retain you?

The responses from the four candidates were as follows:

- We are obliged to stay with MCTS.
- No attempts were made to retain me in Germany, as I was really looking forward to coming back home.
- Yes, I got numerous metallurgical job opportunities.
- When I withdrew from the programme in 2013 most of the committee members expressed an eagerness to have me continue on the programme. Dr Nyembwe, who I have always looked up to and whose opinion and advice I respect, was particularly instrumental in helping me consider the pros of continuing on the programme. Now upon completion of Phase 1 of the RIFT programme there has been no targeted "attempts" made to retain us for Phase 2. We are obliged to stay at the MCTS for a period of three years.

5. Did RIFT programme benefit you?

The responses from the four candidates were as follows:

- It helped achieve my primary goal, which was completing my Masters, as to utilizing my knowledge, that is another case.
- Yes, the RIFT program benefited me (as mentioned in question 1. above).

- Yes, because I could get a masters certificate from the best mining University in the world.
- Yes.

Content analysis of the documents: The content analysis of the documents validated the costs for the projects and the skills that the students developed when they participated in the program. The RIFT programme was funded by the Department of Science and Technology and they requested MCTS-UJ to implement the programme. As part of the RIFT programme for the studies in Germany the minimum total cost or expenses for each student that was calculated by MCTS-UJ was R600000 over 3 years. This was evident in the Minutes of 4th MCTS-RIFT programme Steering Committee, UJ (12 Nov 2014) that indicated the project expenditure of R2158841.02.

The minutes of the meeting also explains that the RIFT programme expenses for the students included accommodation, health insurance, stipends, air tickets, visa costs, language course costs, electricity, gas, Internet, registration, bursaries, computers and books, exam fees air insurance, booking fees furniture costs, other travel expenses, and bank transfer fees. The "Report on the review of implementation of Masters programme in Advanced foundry technologies—UJ also clarifies that laptops with special key functions that accommodate the special lettering used in German writing were subsequently purchased for the students for an amount of R41,210.

The Minutes of 4th MCTS-RIFT programme Steering Committee, UJ also indicate a second addendum amounting to additional R290000 that was signed by Department of Science and Technology and UJ in 2014 that was utilized for some of the additional expenses. It was evident from the report on the Review of implementation of Masters programme in Advanced foundry technologies—UJ, that there was no indication whether cost factors such as other living costs in Germany and currency fluctuations were considered. It was also clear from the report that all funds were spent for the purposes of the Project, which is also evident in the minutes of the meeting.

It is evident from the report on the Review of implementation of Masters programme in Advanced foundry technologies—UJ that additional costs of R12,000 were incurred when one of the students, resigned and returned to SA. Upon further negotiations with the committee she subsequently returned to Germany at her own costs. Both documents clarified the expenses were the same amount.

The report on the review of implementation of Masters programme in Advanced foundry technol-

ogies—UJ revealed that UJ deviated from the contract when they could not reach an agreement regarding the course syllabus of UJ and the Technische Universität Bergakademie, Freiberg, Germany, and hence the students were therefore not registered for a Masters degree at UJ as well. This was agreed by both institutions. Initially both parties agreed that a dual qualification (Masters degree from Germany as well as UJ) would be obtained by the students that enrolled for the program.

The Minutes of 4th MCTS-RIFT programme Steering Committee, UJ (12 Nov 2014) indicate that the students passed the first German language proficiency course (A2/B1) and second six months German language proficiency course (B2/C1) from October 2012. The minutes indicate the students completed Dipl.—Ing in Foundry Technology on 17th December 2014 and the four candidates brought back expertise in casting simulation, grey and ductile iron casting production and sand casting technology.

It is also evident from the minutes that phase 2 of the RIFT programme intends to disseminate the scientific and technical knowledge gained by the four candidates and will share their knowledge with the broad local foundry through their involvement in research projects, consultancy and offering training, technical skills and technical services to the industry. In the next section we will discuss the impact of RIFT programme on skills development and impact of the programme on technology localisation.

5. Findings and discussions

The impact of RIFT programme on skills development: As evident from the interviews with four students (Question 5) and the archival documents, the RIFT students completed Dipl.-Ing in Foundry Technology. As one student responded for question 1 she was able to "see first-hand how the dynamics of a society influence the corporate and industrial environments, and hence a country's productivity". MCTS's expectation was for the students to work for the station at UJ for another 3 years upon completion of their studies. The skills and knowledge that they got in Germany is commendable. All students agreed they benefited from the RIFT programme.

Other main skills that the students gained as part of the RIFT programme which is evident from the interviews and the documents analysed were:

- The ability to work in a team
- Communication skills in German
- A broader perspective of the Foundry profession and technical expertise
- · Awareness of economic and social issues

The reports submitted by student as in the Minutes of 4th MCTS-RIFT programme Steering Committee, UJ (12 Nov 2014) indicate:

- One of the students stated that having exposed to a foundry environment, gave her the opportunity to fully interact with professionals, to learn foundry processes, improve teamwork and communication skills. Another student states that her objectives during the study were: customer liaison, melting practices, understanding simulation, role of design and failure analysis. Yet another student said she was allowed to assess casting after cutting to determine the type of defect formed after solidification. One student stated she gained valuable experience both technically and personally and gained experience in time management and communication.
- One of the students mentioned in the interview that she tried to resign later on, but with further assistance from the RIFT interim committee she was persuaded to return to Germany to complete her Masters programme. This had some impact on funding, but the School of Mining and Metallurgy and Chemical Engineering, FEBE contributed to these expenses.
- The RIFT students brought back four candidates with expertise in casting simulation, grey and ductile iron casting production and sand casting technology as evident in the minutes of the meeting. The minutes of the meeting indicate the students received solid theoretical background in the modules of cast alloys and moulding materials respectively taught by Dr H. Polzin and Dr-Ing C. Dommaschk in the Foundry Institute in Technische Universität Bergakademie Freiberg.

It is evident from the report one student resigned and returned to SA but some of the pending Masters papers were written by the student in Feb 2014 that brought her in line with other students. This is evident from the interview where one of the responses for Question 4 indicate a candidate withdrew from the programme in 2013 and the encouragement of the committee member was particularly needed in helping her consider the pros of continuing on the programme.

The impact of RIFT programme on technology localization: Interviews were conducted with MCTS staff to explore the student's role in the industry upon their return from Germany and to see the impact of the programme on technology localisation. The students developed the foundry skills that they could use upon return to South Africa.

The students completed a degree equivalent to our Masters in South Africa or Dipl. Ing in Germany. The interviews revealed that on return from Germany there was resistance from South African industry partners to acknowledge them as consultants and as experts in the foundry field. So MCTS found ways to employ or place them in various institutions and foundry industries for less 6 months for them to gain industry exposure. MCTS assumed when they impart and share their knowledge they gained in Germany, the South African foundries will begin to recognise them and this will also have some effect on technology transfer. The students with assistance from MCTS identified the shortcomings and held meetings with industry partners to present their findings.

One student currently works as a part-time lecturer at the Department of Engineering Metallurgy, University of Johannesburg. As of year 2015, two students are involved in industry training and gives short courses as suggested by MCTS in collaboration with the South African foundries. The two students are also part of National Youth Foundry Generation program.

They currently go the South African foundry industries, identify the technical problems and then suggest possible solutions and ensures organizations use the six sigma approach. MCTS-UJ has also used the six sigma approach to reduce defects and improve the products. The six sigma strategies, tools and principles used in many organizations improve business profitability and the effectiveness and efficiency of all operations to meet or exceed customer's needs and expectations [6].

In a way MCTS-UJ develops them to become future foundry consultants. One of the students was given a one year contract for internship in Germany in the year 2015. MCTS /RIFT provided her a one year gap period and upon her return in early 2016 she will them complete her 3 years here in South Africa. MCTS will assist all four female students to improve their qualifications further MCTS-UJ uses a model where monies spent as part of RIFT programme will be recovered through projects that these students now do for the foundry industry. The graduate engineers are now employed by MCTS/UJ itself. MCTS places them into the foundry industry based on various projects suggested by the industry. MCTS invoices the industry and the monies are paid back to MCTS. A part of the monies generated will go back as salary to the RIFT students involved in the foundry projects, but they get market-related remuneration. In a way MCTS staff are mentoring them to become future foundry industry consultants. In the next section we discuss a model for retention of foundry Engineering students.

A model for retention of students in foundry Engineering: Cohoon [13] made some recommendations to retain women in undergraduate programme, such as build institutional support so that program will have adequate resources, mentor undergraduates and use local job markets to provide students with work experience. We developed our model for foundry Engineering student retention taking into account such recommendations. Fig. 1 illustrates a model for Engineering student retention. This model is based on the responses with the students and based on the document analysis. This model mainly focuses on skills development, government's localisation plan and ways to retain foundry Engineering students.

South African government's localisation plan initiated ideas for such a project and funds were provided to the station to implement, from the Department of Science and Technology (DST). The funds from DST and collaboration with world class German foundry institution such as Technische Universität Bergakademie Freiberg, helped the students achieve the goals and they completed the Masters degree.

The RIFT programme was itself part of govern-



Fig. 1. A model for Engineering student retention programme.

ment's localisation plan. It helped the students get more international exposure in the world class mining/foundry institutions in Germany. The students completed the Masters degree and there is scope for higher studies at the station itself.

It also created scope for better job opportunities after they returned to South Africa. The graduates are now involved in various local projects identified by MCTS and the foundry industry. MCTS ensures they get market related remuneration for the work they do at the station. Some are involved in training and lecturing similar subjects at UJ.

MCTS will assist them to further their studies if they need to get their doctorate. There is enough scope for further technical training and research activities at the Metal Casting Technology Station at UJ. The funds and the international exposure played a significant role in their retention. After graduating, one of the students went back to work for a German company for one year to get more technical expertise. She will return by June 2016.

6. Conclusion

In this research we investigated foundry student's experiences in an Engineering programme for localisation. We explore how the RIFT programme members managed to retain female foundry students who participated in the MCTS-UJ's engineering programme. We have argued that satisfactory progress of the students should be monitored throughout the Engineering programmes and adequate funding was necessary to attract and retain the female students in Engineering. It was very clear from the foundry students' experiences that the students were unprepared for the Engineering programme and they found it difficult initially to fit into the programme. The RIFT interim committee ensured that all students who participated and completed the programme were involved in meaningful local projects when they returned back to South Africa after their studies in Germany. This ensured government's technology localisation plan. We have also noticed that the knowledge they gained in Germany must be acceptable to the South African foundry industry.

Upon their return to South Africa on the completion of studies, MCTS involved them in various local projects identified by the technology station at UJ and the foundry industry. We make recommendations for Foundry Engineering programme for technology localization and discuss the impact of RIFT programme on technology localisation and the impact of RIFT programme on skills development. It is evident that the students shared their knowledge with the broad local foundry through their involvement in research projects, consultancy and offering training, technical skills and technical services to the local foundry industry.

MCTS-UJ in collaboration with the Department of Engineering Metallurgy has appointed a Research Associate from Technische Universität Bergakademie Freiberg, Germanyas an initial initiative to foster closer links with SA Universities and to pave the way for long term sustainability. The funders are currently in the process of setting up a steering committee to monitor the program and assess the impact of the programme. Based on the success of RIFT programme, MCTS-UJ has now initiated a new Masters degree programme and it is anticipated that this will lead to more international mobility. Two German students will now be coming to South Africa to join MCTS-UJ this year to do their six month practical work for a similar Masters qualification.

In this paper we developed a model for foundry Engineering student retention. This model is useful to other foundry industries to develop such Engineering programmes that focus on student retention and skills development. Our future research will focus on how similar Engineering programmes such as Masters and even doctoral level degree can be developed at UJ with specific outcomes that is in line with South African foundry skills development and localisation.

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