

A business model for the collaborative delivery of a master's degree in nuclear engineering by South African universities

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Abstract

The worldwide focus on energy security and the reduction of greenhouse gas emissions has brought on a renewed interest in nuclear power as an alternative energy source. Some two decades of low activity in the field of nuclear power has resulted in a global nuclear skills shortage, due to an aging worker corps and low levels of new entrants to the career. These factors have contributed to a new international trend for tertiary education institutions to collaborate in nuclear education in a number of regional and international networks.

The present research arises from a need stated by the Nuclear Industry Association of South Africa to develop the current skills base of nuclear engineers and to transfer and manage nuclear knowledge to upcoming engineers in South Africa.

The main goal of this research was to develop a business model for the collaboration between South African universities for the delivery of a Master's degree in nuclear engineering. The model proposes an equitable method of allocating government funding to the participating universities, as well as an external entity through which possible industry funding will be applied to the costs of delivering the programme. A unique aspect of the model is a common set of lectured modules, while the participating universities will be free to practise their own chosen research forte.

Opsomming

Die wêreldwye fokus op energiesekerheid en die vermindering van kweekhuisgasvrystellings het 'n nuwe belangstelling in kernkrag as alternatiewe energiebron na vore gebring. Die lae aktiwiteit op die gebied van kernkrag die afgelope ongeveer twee dekades het gelei tot 'n wêreldwye gebrek aan kernvaardighede vanweë 'n ouer wordende werkerskorps en lae vlakke van nuwe toetreders tot die beroep. Hierdie faktore het bygedra tot 'n nuwe internasionale neiging vir tersiêre instellings om saam te werk in kernopleiding in 'n aantal streek- en internasionale netwerke.

Die huidige navorsing het sy ontstaan te danke aan 'n behoefte uitgespreek deur die Nuclear Industry Association van Suid-Afrika om die huidige vaardigheidsbasis van kerningenieurs te ontwikkel en om kernkennis onder opkomende ingenieurs in Suid-Afrika oor te dra en te bestuur.

Die hoofdoel van hierdie navorsing was om 'n besigheidsmodel te ontwikkel vir die samewerking tussen Suid-Afrikaanse universiteite vir die lewering van 'n Meestersgraad in kerningenieurswese. Die model stel 'n onpartydige metode vir die toekenning van staatsbefondsing aan die deelnemende universiteite voor sowel as 'n eksterne entiteit waardeur moontlike nywerheidsbefondsing aangewend sal word vir die lewering van die model. 'n Unieke aspek van die model is die gemeenskaplike stel onderrigde modules, terwyl die deelnemende universiteite toegelaat sal word om dié navorsingsgebied waarin hulle uitblink, te beoefen.

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LIST OF ACRONYMS/ABBREVIATIONS

• ACRC	- Advanced courses and Research Committee
• ADMI	- Advanced Design and Manufacturing Institute
• ANENT	- Asian Network for Education in Nuclear Technology
• ANSN	- Asian School for Nuclear Medicine
• ARCCNM	- Asian Regional Cooperative Council for Nuclear Medicine
• ASNM	- Asian School for Nuclear Medicine
• CARST	- Centre for Applied Radiation Science and Technology
• CESM	- Classification of Education Subject Matter
• CF	- Carbon Fibre
• CHE	- Council for Higher Education
• CO ₂	- Carbon dioxide
• COED	- Concise Oxford English Dictionary
• CPD	- Continuing Professional Development
• CTA	- Collaborative Training account
• CVD	- Chemical Vapour Deposition
• DHET	- Department of Higher Education and Training
• DoE	- Department of Energy
• DST	- Department of Science and Technology
• EAC	- Education Advisory Committee
• EMSNE	- European Master of Science in Nuclear Engineering
• ENEN	- European Nuclear Education Nuclear
• ERC	- ENEN Review Committee
• EU	- European Union
• FNCA	- Forum for Nuclear Cooperation in Asia
• FTE	- Full-time enrolment
• HEQC	- Higher Education Quality Committee
• HR	- Human Resources
• HTR	- High Temperature Reactor
• IAEA	- International Atomic Energy Agency
• ICAS	- Institutional Committee for Academic Standards
• INIE	- Innovations in Nuclear Education and Infrastructure
• k	- Thousand
• KMC	- Knowledge Management Committee
• LABS	- Laboratory for Accelerator Based Sciences

• LMS	- Learner Management System
• m	- Million
• M.Eng.	- Master in Engineering
• M.Sc.	- Master's in Science
• MANuS	- Master's in Accelerator and Nuclear Science
• MatSci	- Master's in Materials Science
• MEPHI	- Moscow Engineering Physics Institute
• NASSP	- National Astrophysics and Space Science Programme
• NCC	- NTEC Co-ordination Centre
• NECSA	- Nuclear Energy Corporation of South Africa
• NIASA	- Nuclear Industry Association of South Africa
• NLRD	- National Learning Record Database
• NNR	- National Nuclear Regulator
• NPP	- Nuclear Power Plant
• NRC	- Nuclear Regulatory Commission
• NRF	- National Research Foundation
• NSERC	- Natural Sciences and Engineering Research Council of Canada
• NTEC	- Nuclear Technology Education Consortium
• NWU	- North-West University
• PBMR	- Pebble Bed Modular Reactor
• Ph.D.	- Doctor of Philosophy
• ppm	- Parts per million
• PQM	- Programme Qualification Mix
• PRA	- Probabilistic Risk Assessment
• PWR	- Pressurized Water Reactor
• QAC	- Quality Assurance Committee
• RAC	- Research Advisory Committee
• RCA-RO	- Regional Co-operative Agreement – Regional Office
• SA	- South Africa
• SANEC	- South African Nuclear Education Consortium
• SAPSE	- South African Post-Secondary Education
• SARCHI	- South African Research Chairs Initiative
• SAQA	- South African Qualifications Authority
• SC	- Steering Committee
• Si	- Silicon
• SiC	- Silicon Carbide

- TAAC - Teaching and Academic Affairs Committee
- TIPC - Training and Industrial Projects Committee
- TUT - Tshwane University of Technology
- UJ - University of Johannesburg
- UK - United Kingdom
- UNENE - University Network of Excellence in Nuclear Engineering
- UNISA - University of South Africa
- US - United States
- UWC - University of Western Cape
- WNSA - Western Nuclear Science Alliance

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Global climate change is a reality that is evidenced by the increase in greenhouse gasses in the atmosphere to a present level of about 380 ppm (Kintisch, 2009:1546) (WNA, 2008). Scientists predict that drastic, economy-changing cuts to greenhouse gas emissions will only spare the planet half the trauma expected over the next century (Fisher, 2009). Kate Chapple from the British Environment Agency (quoted by Govender, 2009) says: "If we stopped all our [greenhouse gas] emissions, if we stopped our carbon footprint tomorrow, we would still see effects for the next 30 years."

Electricity generation is one of the major causes of CO₂ emission, providing half of the expected increase from 2005-2030. As a result, 100 countries agreed that low-carbon energy technologies need to be adopted, acknowledging that nuclear power is a 'key mitigation technology' (Bernstein *et al.*, 2007:17).

Nuclear power is an essential element of the solution for the greenhouse gas emission dilemma and, since 1960 it has been the world's fastest growing major source of energy (Ritch, 2009). This nuclear revolution is experienced by many countries around the world. According to Haskins (2008), 35 new nuclear plants were under construction in fourteen countries in July 2008.

In South Africa, the government has embraced nuclear power as a future energy source. Haskins (2008) reports that the South African Minister of Energy, Dipuo Peters, has stressed the government's seriousness in deploying nuclear energy to lower the country's emissions of greenhouse gasses. The development of nuclear technology ensures that the nuclear industry of this country could be one of the most innovative in the world (Boureson & Lacey, 2007).

It is estimated that the further development of the nuclear industry in South Africa can create up to a hundred thousand jobs across the value chain (SAPA, 2009). The current lack of qualified nuclear personnel in the country poses a threat to the growing nuclear industry. Ms. B. Sonjica, previous Minister of Minerals and Energy, stated in February 2007 that the government would aggressively address nuclear skills development (Matube, 2009:2). Skills development in the nuclear environment will also help to preserve the current nuclear knowledge (Thugwaneta *et al.*, 2008).

Engineering skills are globally in short supply (Department of Labour, 2008:13), and the retirement of qualified and experienced nuclear personnel and lack of adequate replacement is creating a global problem of a lack of nuclear skills (Khan & Bock, 2008:1). This problem, together with the developing nuclear industry in South Africa, has created a need for a broad range of nuclear skills to be developed. Qualified nuclear engineers, as economic enablers, are of the utmost importance, although there is not a very high demand in numbers (NIASA, 2009:52). This provides the opportunity for a collaboration model to be developed for the education and training of high-quality nuclear engineers without one particular institution taking the full financial responsibility as well as full responsibility for the technical content to be transferred.

1.2 OBJECTIVE

The main objective of this research is the development of a business model for the collaboration between South African universities and South African nuclear industries for the delivery of a Master's degree in nuclear engineering. NIASA is driving the research to develop a collaboration business model for the country's current tertiary education environment.

The specific objectives of this research are as follows:

- The international trend for the collaboration between tertiary education institutions in nuclear education was studied as background for the development of a South African model;
- Existing South African collaboration models were researched as background;
- As nuclear engineering education should be a result of a proactive exercise of estimation of the industry needs (Ishino, 2002:1), the needs for nuclear engineers as expressed by the South African nuclear industry were obtained;
- The needs obtained of the nuclear industry were compared to the needs and drivers of the higher education environment for providing training at a Master's degree level. This will act as foundation for the objective to follow;
- A proposed model for collaboration between South African universities and nuclear industry for the delivery of a Master's degree in nuclear engineering was presented and discussed;
- The collaboration programme was modelled as a financial system and the financial implications of the proposed collaboration model was provided and discussed in the form of budgets;
- The collaborative programme courses could be presented by the delivery system as was presented. This delivery system, as implemented, was discussed and conclusions were drawn;
- Finally, conclusions and recommendations on the research were offered.

CHAPTER 2: BACKGROUND

2.1 EXISTING INTERNATIONAL NUCLEAR EDUCATION COLLABORATION MODELS

The present international nuclear human resource skills shortage has brought about an international trend for tertiary education institutions to collaborate in nuclear education. Five primary international collaboration models were researched and analysed. A summary of the characteristics of these models provided a foundation from where the South African model was developed.

2.1.1 ENEN (European Nuclear Education Network)¹

2.1.1.1 Introduction

European Nuclear Education Network (ENEN) is globally recognised as the representative European organisation that is functioning in networking activities in the field of nuclear education and training, as stated on their website. The project of establishing a “European Nuclear Engineering Network” was launched in January 2002. The ENEN Association was given legal status as a non-profit international organisation and a permanent character on 22 September 2003. In 2006, the ENEN-II project was launched, aiming at the developing of the ENEN Association in a sustainable way in the nuclear field and nuclear education (ENEN, 2006/7). Currently, the members of ENEN include 45 members, from 18 countries, consisting of 38 universities, six research centres and one multinational company.

The two types of members within ENEN are effective and associated members. Effective members provide high-level education in the nuclear field as a basis for doctoral studies. Associated members provide committed support to the ENEN Association and have firm relations with members that provide nuclear education (for example state members, regulatory bodies, governmental institutions, nuclear industries and academic institutions).

The statutes of ENEN show that the income received by the ENEN Association is obtained in the form of contributions by the members as well as grants. The contribution by members is determined every year by the General Assembly of ENEN.

¹ ENEN: <http://www.enen-assoc.org/en/home.html>

2.1.1.2 Objectives

The European Nuclear Education Network (ENEN) Association has as its main objective the “preservation and the further development of expertise in the nuclear fields by higher education and training. This objective should be realized through the co-operation between universities, research organisations, regulatory bodies, the industry and any other organisations involved in the application of nuclear science and ionising radiation”, according to their website.

ENEN has specific objectives, which include: the further development and promotion of the collaboration in nuclear training and education of students, researchers and professionals; to ensure the quality of nuclear training and education; to increase the attractiveness for students, researchers and professionals to engage in the nuclear fields; and to promote life-long learning and career development at postgraduate or equal level.

The other basic objectives of ENEN are: to harmonise the European Master of Science curricula and to promote Ph.D. studies; to promote exchange of students and lecturers within the ENEN network; to provide incentives to increase the number of students; to establish a framework for mutual recognition; and to strengthen the relationship between the academia (universities), end-users and any other organisations involved in the application of nuclear science by facilitating nuclear academic education and by offering continuous training.

As seen on their website, ENEN has certain goals with respect to the academia and to the end-users, which include nuclear industries, research centres, regulatory bodies and nuclear applications.

Goals with respect to the academia:

- To “develop a more harmonized approach for education in the nuclear sciences and nuclear engineering in Europe;
- to integrate European education and training in nuclear safety and radiation protection; and
- to achieve better co-operation and sharing of academic resources and capabilities at the national and international level.”

Goals with respect to end-users:

- To “create a secure basis of skills and knowledge of value to the European Union;
- to maintain an adequate supply of qualified human resources for design, construction, operation and maintenance of nuclear infrastructures, industries and power plants; and

- to maintain the necessary competence and expertise for the continued safe use of nuclear energy and applications of radiation and nuclear techniques in agriculture, industry and medicine" (ENEN, 2009).

2.1.1.3 Structure of association

The ENEN board is composed of eight ENEN members (six effective and two associated members) elected by the **General Assembly**, composed by representatives of all ENEN members. The work is organised by the **Management Committee**, comprising the chairs of the six ENEN working committees (ENEN Review Committee, Teaching and Academic Affairs Committee, Advanced Courses and Research Committee, Training and Industry Projects Committee, Quality Assurance Committee, Knowledge Management Committee), under the chairmanship of the secretary general.

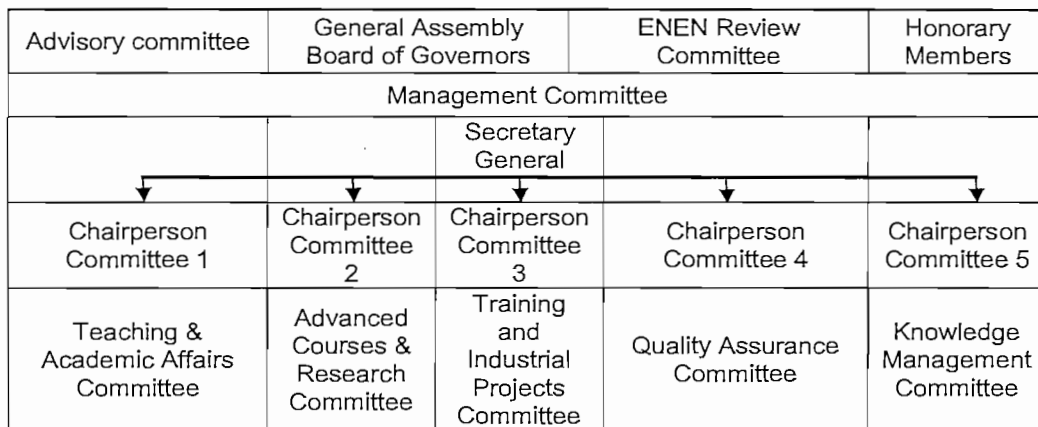


Figure 1: Structure of ENEN association (ENEN, 2009)

Honorary Members are individuals who are recognized for distinguished work in the field of nuclear education and training. These members are invited to participate in meetings as organised by the **Board of Governors**.

The **Advisory Committee** was created with the responsibility of guiding the Association in the implementation of ENEN-II project and selecting activities and products. This committee also acts as a communication channel to ascertain the needs of the end-users.

The **ERC** (ENEN Review Committee) was created to prepare a recommendation to the board on the structure for the ENEN Association for 2009.

The tasks of **TAAC** (Teaching and Academic Affairs Committee) comprise of: the evaluation of applications for European Master of Science degree in Nuclear Engineering (EMSNE) certificates; the promotion of student and lecturers exchange between ENEN members; the support for the establishment of high-level education by ENEN members; and the awarding of the International ENEN Course label.

The tasks of **ACRC** (Advanced Courses and Research Committee) include: the provision of specialised courses for postgraduate and Ph.D. students; support to research establishments; connecting universities for the aim of research; and the evaluation of ENEN advanced courses.

The tasks of **TIPS** (Training and Industrial Projects Committee) are: to identify the needs of the industry; to organise training sessions and to keep the training catalogue updated; to facilitate and raise funds for the exchange of students and lecturers; and to facilitate the integration of European and national industrial research projects.

The tasks of **QAC** (Quality Assurance Committee) consist of: serving as a working group on a variety of quality issues; to improve ENEN documentation; to evaluate new ENEN members; to support organisations for high-quality nuclear education; to evaluate exchange courses; and to support all quality assessment tasks.

The tasks of **KMC** (Knowledge Management Committee) include: to prepare, maintain and implement action plans to preserve important scientific knowledge; to ensure efficient use of ICT; and to provide access to specialised software and to publish books, CDs and DVDs.

2.1.1.4 Financial model

ENEN was established under the European Commission/EURATOM 5th framework programme. It was also supported by the 6th and 7th framework programme for some projects.

A membership fee of €1000 (for effective members) and €5000 (for associated members) according to each organisation has been fixed. Furthermore, each national network within ENEN has its own unique system of financial support. Some of the national networks as well as some other ENEN members receive financial support directly from the industry. Financial support is received from the European Union (EU) and other companies at the ENEN level, as stated by Radek Skoda (2009), lecturer at the Czech Technical University. According to a verbal meeting with Ryoko Kusumi (2009), secretary general of ENEN, efforts towards other funding methods are in process.

2.1.1.5 Programme offered

A European Master of Science degree in Nuclear Engineering (EMSNE) can be obtained from the ENEN Association (Moons *et al.*, 2004:3).

Students participating in the programme register at an ENEN “home” institution and obtain the required credits at institutions of their choice. The “home” institution grants the official degree of Master of Science in Nuclear Engineering, where after the ENEN Association will grant the quality label *European Master of Science in Nuclear Engineering*.

A full-time load of 10 semesters beyond secondary level will have to be completed before obtaining this degree. This is equal to 300 credits at academic-level in engineering studies. At least 60 credits should be purely nuclear engineering-oriented and at least 30 credits should be obtained from another ENEN institution than the “home” institution. One credit amounts to 30 hours of work and one semester typically contains 30 credits or 900 hours of work. A summary is provided in Figure 2 (Knebel, 2003:19).

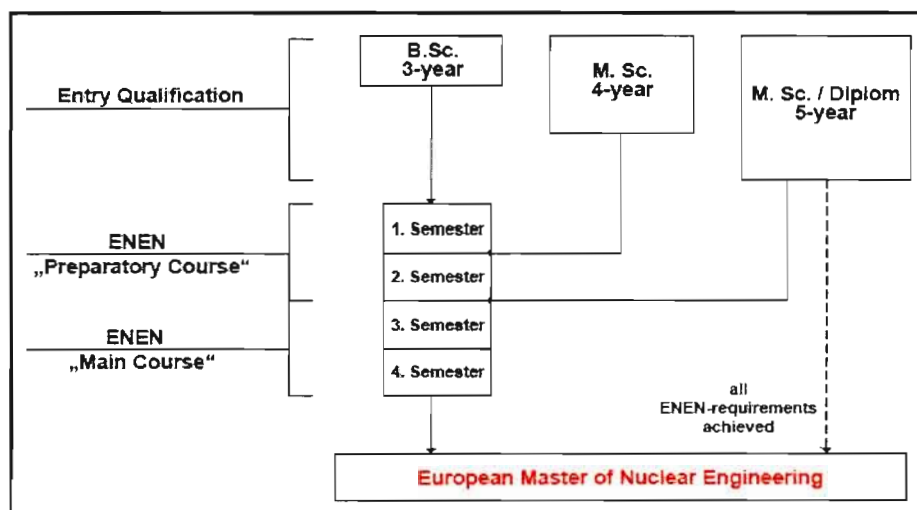


Figure 2: Summary of EMSNE (Knebel, 2003: 19)

The ENEN Association provides the opportunity for Ph.D. students to acquire topics for research. Courses and seminars in various nuclear fields are also offered as a continuous training programme.

2.1.2 NTEC (Nuclear Technology Education Consortium)²

2.1.2.1 Introduction

A consortium of United Kingdom (UK) universities and higher-education institutions, called NTEC, has developed a postgraduate level training concept. The training programme was designed to meet the UK's projected nuclear skills requirements in various nuclear fields. The programme has been approved by the Institution of Mechanical Engineers.

According to their website, NTEC provides an unparalleled programme in the UK for postgraduate level training in the field of nuclear science and technology. The consortium consists of more than 90% of the nuclear teaching expertise existing in the UK, including the following institutions: Universities of Birmingham; Lancaster; Leeds; Liverpool; Manchester and Sheffield; City University; London; HMS Sultan; Imperial College London; UHI Millennium Institute and Westlake Research Institute.

2.1.2.2 Objectives

The purpose of NTEC is to develop and deliver a nationally co-ordinated programme of postgraduate and CPD training in support of the nuclear energy, fusion, legacy clean-up, nuclear medicine and naval propulsion sectors.

2.1.2.3 Structure

A **Steering Committee**, comprising of the programme directors of each party institute, the CTA manager and up to three co-opted members, is responsible for the policy, strategy, risk management, financial oversight and operation of the programme.

An **External Advisory Board**, whose structure is governed by the Steering Committee, is responsible for external advice on the educational programme and delivery thereof.

The **Advisory Committee of Examiners** is responsible for the management of academic processes associated with the programme.

The **NTEC Co-ordination Centre** (NCC), within the co-ordinating institution, currently the Dalton Nuclear Institute at the University of Manchester, carries out the day-to-day management of the programme, as provided by the NTEC consortium agreement (NTEC, 2006).

² NTEC: <http://www.ntec.ac.uk/>

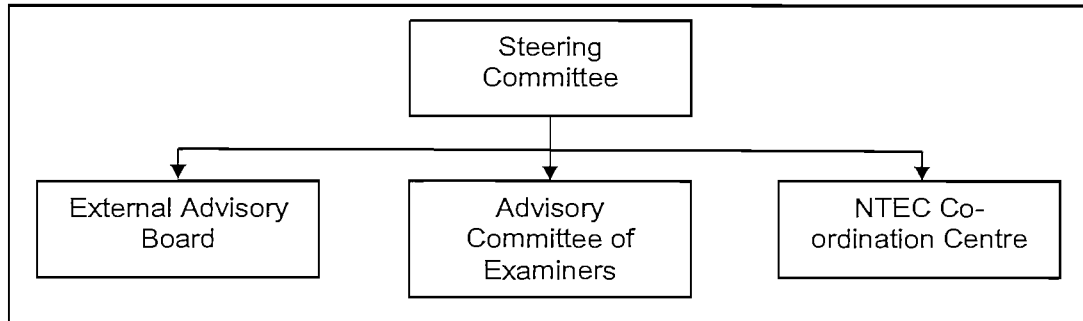


Figure 3: Structure of NTEC

2.1.2.4 Financial model

The following financial model was established in 2006 at the start of the formation of the consortium. The Steering Committee reviews the fees annually (NTEC, 2006:1).

NTEC money flow:

NTEC operates two accounts, Collaborative Training account (CTA), managed by the STA manager, and suspense account (managed by the NCC manager on authority from the SC). The suspense account receives all fees paid by students, bursaries or sponsorships and pays the following expenses:

- £1,500 per M.Sc. student to the registering university (for administration, supervision and dissertation costs);
- for each course delivered by the institution, fee paid = £4,500 + £100 per student (first 10 students) + £50 per student (max of 26 students);
- £94,000 p.a. (approved annually by the SC) for running costs of co-ordinating centre;
- new module developing costs;
- discretionary bursaries to students;
- discretionary funds for module providers, project supervisors or students; and
- £60,000 for an exit strategy reserve.

Partner institutions money flow:

A partner institution receives £1,500 per M.Sc. student and £500 per certificate or diploma student for administration, arrangements and supervision of the student's dissertation.

When delivering a course (minimum of four students required to run a module), the institution receives a fee = £4,500 + £100 per student (first 10 students) + £50 per student (max of 26 students).

CTA funds:

The CTA account covers travel and accommodation expenses of lecturers delivering modules outside their home institutions. Other funds are among others used for developing courses, distance-learning elements of courses, and the NTEC website. The total CTA cost is £350,000 p.a.

Start-up plans:

Year a: (Start of CTA grant) NCC staff is recruited, core modules and eight elective modules are prepared, IT facilities and website are prepared as well as marketing, and advertising of NTEC programmes take place.

Year a + 1: Courses run and programme is presented to 10 CTA students.

Year a + 2: Modules are prepared in distance-learning format.

Year a + 3, 4: (End of CTA grant) NTEC financially self-sustaining.

Exit strategy:

The consortium can be wound up over a period of three years if the NTEC programme does not materialise.

Year z – 2: Decision is made to terminate consortium. All core modules and eight elective modules run with module development stop.

Year z – 1: Registrations on M.Sc. and diploma students have stopped and NTEC suspense account is closed.

Year z: No modules running. Only activity is supervision of dissertations (responsibility lies with registering universities).

2.1.2.5 Programme offered

The structure and content of the programme leads to postgraduate qualifications up to Master's level in nuclear science and technology. According to their brochure published in September 2005, the programme was established after thorough research and consultations with the UK nuclear sector, including industry, regulators, government departments and the postgraduate teaching expertise within UK universities and research institutes.

The programme allows students to undertake an M.Sc. degree over a one-year period on a full-time basis, as well as on a part-time basis over three years. Part-time students complete four core modules in year one (obtaining a postgraduate certificate), four elective modules in year two (obtaining a postgraduate diploma) and project and dissertation in year three (obtaining an M.Sc.). Full-time students take the modules before concluding with the dissertation.

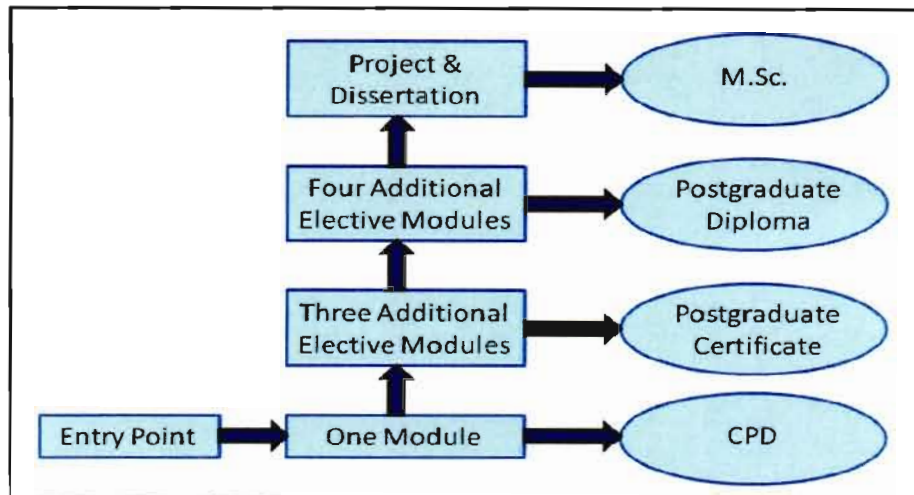


Figure 4: NTEC programme structure (NTEC, 2009)

Within the framework of the programme students can also complete a postgraduate diploma or postgraduate certificate. The individual modules are presented in individual short course format, which is ideal for employees within the industry for CPD purposes. These individual modules could contribute towards obtaining a Post-graduate qualification.

Table 1: Fees for 2009/2010 (NTEC, 2009)

M.Sc.	£13,520
Postgraduate Diploma	£11,230
Postgraduate Certificate	£6,760
Single Module (CPD)	£2,270

The curriculum offered by NTEC, as can be seen on their website, is as follows:

Core modules - Decommissioning Stream:

- Decommissioning/Waste/Environmental Management
- Decommissioning Technology and Robotics
- Management of the Decommissioning Process
- Processing, Storage and Disposal of Nuclear Wastes

Core modules - Nuclear Technology Stream:

- Reactor Physics, Criticality and Design
- Nuclear Fuel Cycle
- Radiation and Radiological Protection
- Criticality Safety Management

Elective modules (available 2005):

- Risk Management
- Policy, Regulation and Licensing
- Design of Safety-critical Systems
- Environmental Impact Assessment
- Reactor Thermal Hydraulics
- Reactor Materials and Lifetime Behaviour
- Environmental Decision Making Applied to Decommissioning
- Experimental Reactor Physics
- Geotechnical Aspects of Radioactive Waste Disposal
- Particle and Colloid Engineering in the nuclear industry
- Reactor Physics, Criticality and Design
- Public and Political Aspects of Nuclear Decommissioning
- Safety Case Development
- Water Reactor Performance & Safety

The core of each module is one week of direct teaching at the relevant institution, minimising the time away from the workplace for an employee whilst maximising the effectiveness of delivering the module. Prior to this week, students must complete approximately 20 hours of pre-reading. After the direct teaching week, students should complete about 70 hours worth of post-module assignments before a potential final examination. See annexure A for the module delivery schedule.

Eight of the course core modules are offered in distance learning format. The contents of these modules include the same syllabus and outcomes as their direct teaching counterpart. They are presented at a fixed time once per annum, in order to facilitate the concept of a 'virtual classroom'. The web-based virtual learning environment, BlackBoard, is accessible anywhere, any time and includes module content, timetables, course news, handbooks, discussion groups and video clips.

The distance learning concept is implemented by using:

- Content (selective release/timed release)
- Multimedia (animation/audio/video)
- Communication Tools (discussion/e-mail/chat)
- Assessment (quizzes/self-tests/online assignment submission)
- Course Management (student tracking/online grade book)

Pre-requisites for the programme (M.Sc., postgraduate diploma and postgraduate certificate students) are at least a 2:2 degree (second-class honours degree) in a relevant discipline. Applicants who have industry experience will be considered individually. Students can apply at the NTEC co-ordination centre at the University of Manchester, University of Liverpool or University of Sheffield.

Students seeking a postgraduate qualification will register with the university of their choice and visit other members of the consortium to attend their selected modules. Guidance with respect to the dissertation is obtained from the university where the student is registered.

2.1.3 UNENE (University Network of Excellence in Nuclear Engineering)³

2.1.3.1 Introduction

According to their website, UNENE was established by the government of Canada as a not-for-profit corporation with letters patent issued July 22, 2002. This network is an alliance of universities, nuclear power utilities, research and regulatory agencies for the support and development of nuclear education, research and development capability in Canadian universities.

2.1.3.2 Objectives

The main purpose of UNENE is to meet the current and future needs of the Canadian nuclear industry by providing a sustainable supply of qualified nuclear engineers and scientists through university education, university-based training and by encouraging young people to choose nuclear careers. The primary means of achieving this are to establish new nuclear professorships at six Ontario universities and to enhance funding for nuclear research at selected universities in order to retain and sustain nuclear capability in the universities. Educational programmes are organised by the network and delivered through its universities (Garland, 2007:11).

The three main objectives of UNENE are thus to enhance the supply of highly qualified graduates in nuclear engineering and technology; to revitalise university-based research and development in nuclear engineering and technology and to create a group of respected, university-based nuclear experts for public and industry consultation (Garland, 2007:4).

2.1.3.3 Structure

Membership to UNENE consists of two categories: Voting members (pay annual membership fee and host research chairs) and non-voting members (pay annual membership fee and participate in research and teaching).

From the UNENE annual report of 2004 it is clear that the **Board of Directors**, with each voting member represented by one director, manages the property and business of UNENE and sets policies and procedures. For administration purposes, the **Board of Directors** appoints the president and CEO, secretary/treasurer and programme co-ordinator. (Elbestawi, 2004)

³ UNENE: <http://www.unene.ca/>

It functions through two standing committees, the membership of which is drawn from organisations of members of UNENE: **Education Advisory Committee** (EAC) and **Research Advisory Committee** (RAC).

According to the annual report of 2005/6, the function of the EAC is to advise the board on education-related issues, to set up the Master's degree in Nuclear Engineering, admission standards, accreditation, course selection and delivery effectiveness and soliciting students for the programme. The main objective of the RAC is to encourage research and train personnel in CANDU technology through establishing industrial research chairs and funding research at universities.

The members of UNENE include Federal Government (Natural Sciences and Engineering Research Council of Canada), industrial partners (Atomic Energy of Canada Limited, Bruce Power, Ontario Power Generation, Canadian Nuclear Safety Commission, CANDU Owners Group, Nuclear Safety Solutions) and university partners (McMaster University, Queen's University, University of Ontario Institute of Technology, University of Toronto, University of Waterloo, University of Western Ontario, University of Ontario Institute of Technology, Ecole Polytechnique, University of New Brunswick, Royal Military College and University of Guelph).

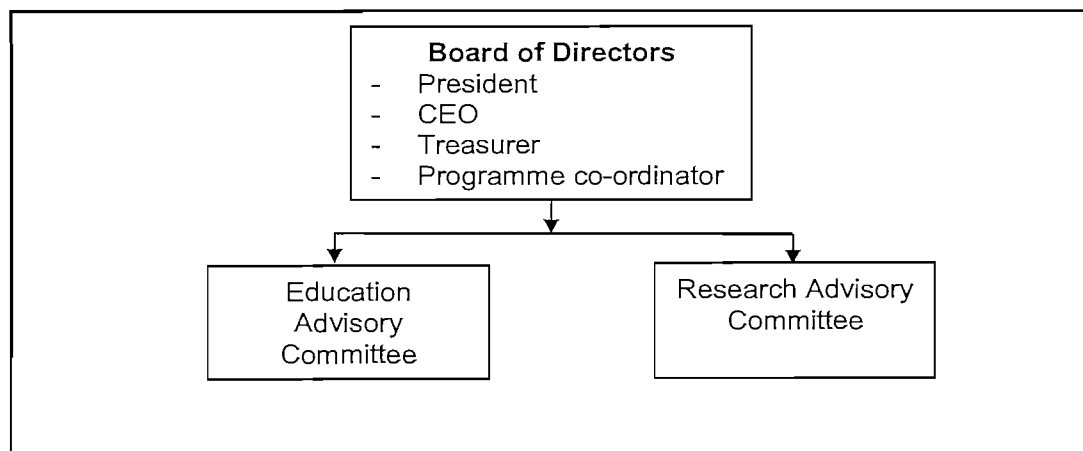


Figure 5: Structure of UNENE

2.1.3.4 Financial model

According to Radek Skoda (2009), lecturer at the Czech Technical University, it was agreed that funding would be handled on the following principle:

All funding obtained from external (industry) sources will be matched by the Federal Government and the Government of the Province of Ontario. In this way, if \$1 is received from industry, the network will have funding of \$3 in total.

The first-phase funding that was required included:

- From industry: \$7.5 m
- Universities: \$0.81 m
- NSERC: \$7.12 m (estimated)

Other funding support includes:

- Industry and universities: \$4.97 m

2.1.3.5 Programme offered

The UNENE educational programme is a graduate programme that has been accredited by the Ontario Council of Graduate Studies. This course-based Master's of Nuclear Engineering is jointly offered by the universities of McMaster, Waterloo, Western Ontario, Queen's and Toronto. Other universities in Canada provide additional instructional support. The programme provides an overview of the fundamentals in many nuclear topic areas. A further variety of fields can be studied by completing courses in nuclear power plant design, operation and safety as well as the technologies of many industries that use nuclear techniques.

In order to complete the programme, a student must be registered as a graduate student at one of the UNENE universities. These universities present the UNENE programme and other Ontario and Canadian universities participate by providing courses and instructors. The registered student is eligible to take all the courses in the UNENE programme and will be credited for them at the university where the student is registered. It is possible to take one or more courses for a certificate of attendance but it is still necessary to be registered at a UNENE university.

A student will be granted a Master's degree in Engineering from the university of registration upon the completion of 10 half-term UNENE courses or eight half-term courses and an industrial project (project equivalent to two half-term courses) with a minimum passing grade of B- or 70% for each course/project. The courses must be selected from the curriculum, which includes technical courses and business courses from the Advanced Design and Manufacturing Institute (ADMI) programme. Once the student has started with the programme, there is a five-year period in which to complete the courses.

The fee per course is \$2,500 + incidentals payable to the university where he is registered. Small additional fees may also be payable.

The curriculum offered is as follows:

Presented by the University of Western Ontario:

- UN 0600 - Industrial Research Project
- UN 0601 - Control, Instrumentation and Electrical Systems in CANDU-based Nuclear Power Plants
- UN 0602 - Nuclear Fuel Waste Management
- UN 0603 - Project Management for Nuclear Engineers

Presented by the University of Waterloo:

- UN 0700 - Industrial Research Project
- UN 0701 - Engineering Risk and Reliability
- UN 0702 - Power Plant Thermodynamics

Presented by McMaster University:

- UN 0800 - Industrial Research Project
- UN 0801 - Nuclear Plant Systems and Operations
- UN 0802 - Nuclear Reactor Analysis
- UN 0803 - Nuclear Reactor Safety Design
- UN 0804 - Nuclear Reactor Heat Transport Systems Design
- UN 0805 - Radiation Health Risks and Benefits

Presented by Queen's University:

- UN 0900 - Industrial Research Project
- UN 0901 - Nuclear Materials
- UN 0902 - Fuel Management

Presented by the University of Toronto:

- UN 1000 - Industrial Research Project
- UN 1001 - Reactor Chemistry and Corrosion Lister

The courses are presented conveniently for part-time students and are presented in two or more extended weekend intense instruction sessions with a multi-week interval between them. The courses are brought to the students and therefore presented at various suitable locations. Assessment may be based on assignments, projects, papers and exams.

Research areas include the following:

- Nuclear Safety Analyses and Thermal Hydraulics (McMaster)
- Advanced Nuclear Materials (Queen's)

- Nano-Engineering of Alloys (Toronto)
- Risk-based Life Cycle Management (Waterloo Ontario)
- Control, Instrumentations and Electrical Systems (Western Ontario)
- Nuclear Chemistry (Western Ontario)
- Health Physics and Environmental Safety (Ontario Institute of Technology)
- Chemistry and Corrosion (Ecole Polytechnique, Montreal, Québec, Canada)
- Nuclear Fuels (Royal Military College)

Pre-requisites for the programme are a baccalaureate in the field of engineering, science or mathematics with an acceptable grade point average (typically 75% minimum). Work experience will be taken into consideration.

2.1.4 ANENT (Asian Network for Education in Nuclear Technology)⁴

2.1.4.1 Introduction

According to their website, ANENT was set up in February 2004 to promote, manage and preserve nuclear knowledge; to enhance the quality of the resources for the sustainability of nuclear technology; and to ensure the continued availability of qualified human resources in the nuclear field in the Asian region. ANENT operates on a basis of co-operation for the mutual benefit of its members (Amin *et al.*, 2006:3).

2.1.4.2 Objectives

The objective of ANENT is to facilitate co-operation in education, related research and training in nuclear technology in the Asian region through exchange of students, teachers and researcher establishment, sharing of information and materials for nuclear education and training and facilitating communication between ANENT member organisations and other regional and global networks.

The prime function of ANENT is to integrate available resources for education and training in synergy with existing International Atomic Energy Agency (IAEA) and other mechanisms, to attract talented youth in view of alternate competing career options, to create public awareness about the benefits of nuclear technology and its applications, to encourage senior nuclear professionals to share their experience and knowledge with the young generation and to use information technology, in particular web-based education and training to the maximum possible extent.

2.1.4.3 Structure

ANENT is guided by a **Co-ordination Committee** whose meetings are held once a year. The chair of the Co-ordination Committee is also spokesperson of ANENT as a whole. An ANENT scientific secretary serves as a focal point to convene Co-ordination Committee meetings and to report on activities. The activities are divided into work packages that are completed by teams of participating institutions under guidance of a co-ordinator, reporting back to the Co-ordination Committee.

An individual institution may become a member of ANENT by confirmation by a representative who has attended the Co-ordination Committee meeting. The members of ANENT include:

- IAEA;

⁴ ANENT: <http://www.anent-iaea.org/anent/index.jsp>

- Organisations from Australia (Australian Nuclear Science and Technology Organisation);
- Organisations from China (Tshinghua University);
- Organisations from India (Bhabha Atomic Research Centre);
- Organisations from Indonesia (Centre of Education and Training, National Nuclear Energy Agency);
- Organisations from Malaysia (Malaysia Institute for Nuclear Technology, University Kebangsaan Malaysia, University Putra Malaysia);
- Organisations from Mongolia (Nuclear Research Centre, National University of Mongolia);
- Organisations from Pakistan (KANUPP Institute of Nuclear Power Engineering, Pakistan Institute of Engineering and Applied Sciences, Centre for Non-destructive Testing);
- Organisations from Korea (Cheju National University, Chosun University, Korean Advanced Institute of Science and Technology, Kyung Hee University, Seoul National University, Hanyang University, Nuclear Training Centre, Korea Atomic Energy Research Institute, Nuclear Safety School, Korea Institute of Nuclear Safety, Nuclear Power Education Institute, Korea Hydro and Nuclear Power Company, National Radiation Emergency Medical Centre, Korea Institute of Radiological and Medical Sciences, Department of Nuclear Medicine, Seoul National University);
- Organisations from Sri Lanka (Atomic Energy Authority, University of Colombo);
- Organisations from Thailand (Office of Atoms for Peace);
- Organisations from the Philippines (Philippine Nuclear Research Institute); and
- Organisations from Vietnam (Hanoi University of Technology).

The collaboration members include ENEN, World Nuclear University (WNU), Asian Regional Cooperative Council for Nuclear Medicine (ARCCNM), Asian School for Nuclear Medicine (ASNM), UNENE, CANTEAH (The most comprehensive educational and reference library on CANDU technology), and Ontario Power Generation. Potential collaborating members include Regional Co-operative Agreement - Regional Office (RCA-RO), Asian Nuclear Safety Network (ANSN), Forum for Nuclear Cooperation in Asia (FNCA) and Moscow Engineering Physics Institute (MEPHI).

2.1.4.4 Financial model

According to Keiko Hanamitsu (2009), technical officer of IAEA, ANENT members do not pay a membership fee but are encouraged to provide in-kind contributions to ANENT. Funds are provided by the IAEA through a regular budget and the Technical Co-operation Fund. Operation and maintenance of the ANENT website is handled by the Republic of Korea (Korea Atomic Energy Research Institute) where the original server is located.

2.1.4.5 Activities

The activities within ANENT include:

- Activity 1: Exchange of information and materials for education and training. This is the highlight of ANENT. Currently, the focus lies on the development and utilisation of e-learning through the cyber platform.
- Activity 2: Exchange of students, teachers and researchers through the regional TC project.
- Activity 3: Distance learning that has been implemented in two e-training courses on energy planning. The multimedia course on nuclear reactor physics will be disseminated after online registration and agreement on licence has been finalised.
- Activity 4: Establishment of reference curricula at NKM-related meetings for curriculum development and facilitating credit transfer and mutual recognition of degrees (through ENEN).
- Activity 5: Liaison with other networks and organisations.

Education and training within ANENT is implemented by the use of a cyber platform (Learning Management System: LMS) that serves as a web-based learning management tool. It is set up on the ANENT web portal for the promotion of education and training in nuclear technology, primarily for ANENT members, but also for non-members (ANENT, 2006:9).

This cyber platform provides functions to cover the learning management process cycle as well as the following cases:

- Learning case: academic courses, training courses, seminars/workshops/meetings and self-learning;
- learning management process cycle: course establishment, registration, learning and post-learning;
- learning delivery type: on-line, off-line and blended;
- learning contents type: VOD, multimedia and voice;
- learning management type: open, approved and closed; and
- learning recognition type: self-learning, pass-fail and credit-based.

The learning management process cycle consists of four major stages, namely:

S1: course establishment

S2: registration

S3: learning

S4: post-learning

This learning management process involves the learner, lecturer, course manager, general manager and web-system administrator. Each has its own respective roles/ activities as indicated in Figure 6.

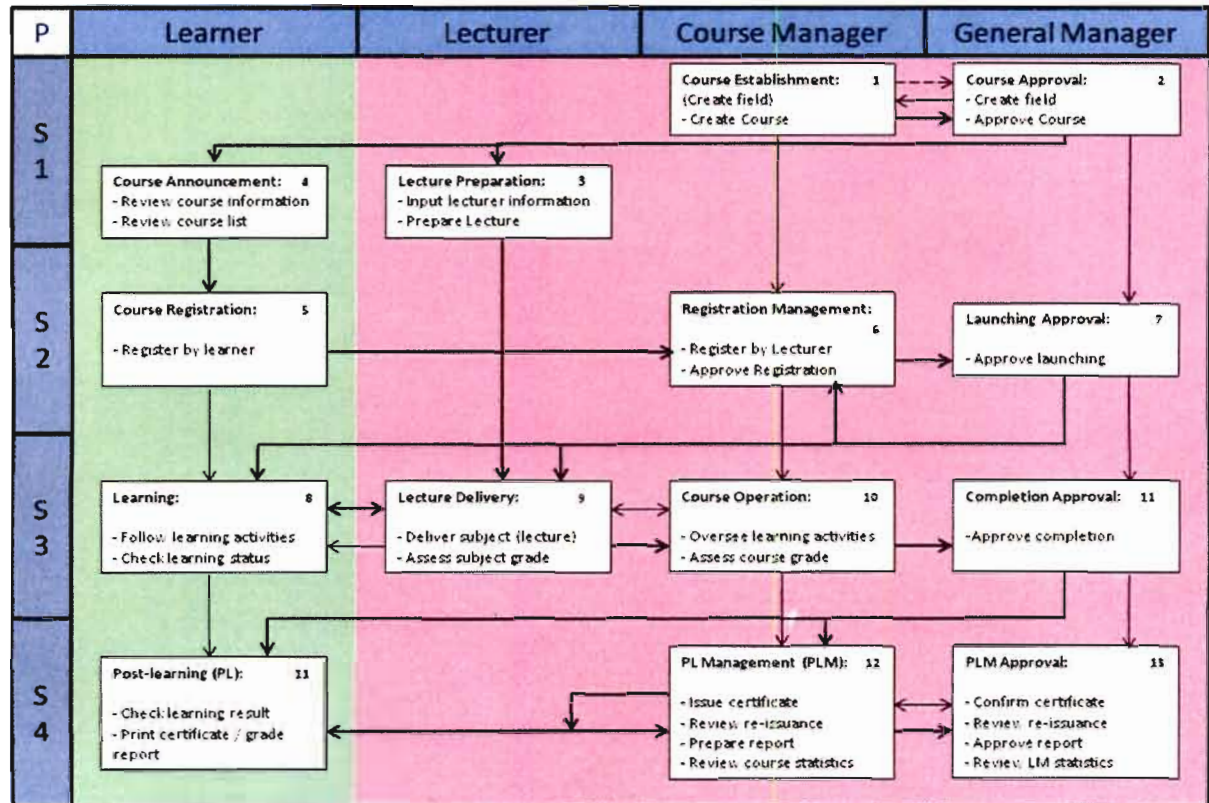


Figure 6: Learning management process (ANENT, 2009)

The following courses have already been presented by ANENT:

1. Test Approval Course
2. Test Open Course
3. 2007 IAEA e-training on Evaluating External Cost of Health and Environmental Impacts of Nuclear Power and other Energy Options
4. HRD Management
5. Material Collection
6. Radioactive Waste Management
7. Regional Training Course to Train the Trainers on the Cyber Platform Development and Course Operation
8. Regional Workshop on Managing Nuclear Knowledge
9. e-training on MESSAGE Model for Elaborating Sustainable Energy Strategy

2.1.5 Consortiums under INIE (Innovations in Nuclear Education and Infrastructure) programme⁵

2.1.5.1 Introduction

The INIE programme was established to strengthen the US university nuclear engineering education programme. According to the website, this is done by the inventive use of university research and training reactors as well as partnerships between universities, Department of Energy (DoE), national laboratories and the US industry. The programme was established in 2001 by the DoE as a reaction to the drastic lack of supply in nuclear engineers.

In 2007, six consortia existed within INIE, comprising of 32 US universities and colleges. These consortia address issues that capitalise on their participants' collective strengths. When the US budget for 2007 was announced, the funds towards the INIE programme were cut. Because of the lack of funding, the consortia came to an end together with the DoE's university programmes (Michal, 2007:1).

2.1.5.2 Objectives

As mentioned above, the primary objective of INIE was to strengthen university nuclear engineering education programmes in the US through the innovative use of the university research and training reactors and to encouraging strategic partnerships between the universities, the DoE national laboratories, and U.S. industry (Fjeld *et al.*, 2004:11).

The INIE programme was established to provide quality universities and reactor facilities; to establish programmes that fully integrate the use of university research reactors with nuclear engineering education programmes; to sustain highly qualified research reactor staff; and to establish internal and external user programmes.

2.1.5.3 Structure

INIE was divided into six consortia and each consortium had plans for educational innovations, infrastructure enhancements and research initiatives.

The consortia were as follows:

Western Nuclear Science Alliance (WNSA)

- Oregon State University
- University of California - Davis

⁵ INIE: <http://www.ces.clemson.edu/inie/>

- Washington State
- University of California - Berkeley
- Idaho State University
- Reed College
- University of California - Irvine
- University of Utah
- University of Nevada - Las Vegas

The WNSA website stated that all members had equal voting rights and responsibilities and were directed by the WNSA **Management Council**. The chair appointed **subcommittees** at times, comprising of members to evaluate specific items. An **Advisory Committee** was formed to provide advice and expert opinion to the Management Council (WNSA, 2001).

Midwest Nuclear Science and Engineering Consortium

- University of Missouri - Columbia
- University of Missouri - Rolla
- University of Missouri - Kansas City
- Linn State Technical College
- Polytechnic University of Puerto Rico
- Kansas State University

Consortium of Big-10 University Research and Training Reactors

- Pennsylvania State University
- Ohio State University
- University of Wisconsin at Madison
- University of Illinois at Urbana - Champaign
- Purdue University
- University of Michigan
- University of Cincinnati

New England Consortium

- Massachusetts Institute of Technology
- Rhode Island Nuclear Science Centre
- University of Massachusetts – Lowell
- Rensselaer Polytechnic Institute

Southwest Consortium of Research Reactors

- Texas A & M University
- University of Texas
- University of New Mexico

Multi-university Southeast INIE Consortium

- North Carolina State University
- University of Maryland
- Georgia Institute of Technology
- University of Tennessee
- University of Florida
- University of South Carolina
- South Carolina State University

2.1.5.4 Financial model

The consortiums received grants from the INIE programme. The amounts from 2002-2005 are summarised in Table 2.

Table 2: Funding for INIE consortiums (Fjeld *et al.*, 2004:7)

Consortium	2002 - 2003	2003 - 2004	2004 - 2005
Big-10	\$1.97 M	\$1.97 M	\$2.17 M
New England	\$1.1 M	\$1.1 M	\$1.15 M
Southwest	\$1.05 M	\$1.05 M	\$1.15 M
West	\$1.3 M	\$1.3 M	\$1.4 M
Midwest	-	\$0.6 M	\$1.4 M
Southeast	-	\$0.4 M	\$1.46 M
TOTAL	\$5.5 M	\$6.5 M	\$8.8 M

A total of \$39 million was supplied to the consortia up to 2006.

2.1.5.5 Programme offered

The following education activities were conducted by all the INIE consortiums:

- Distance learning, making use of Web-based presentations, modules, videos, animations and real-time delivery of experiments via the Internet (Landsberger *et al.*, 2006:1)
- Graduate assistantships
- Inter-consortium collaboration

Other activities included:

- Outreach (by Big-10, Midwest, West)
- New Nuclear Degrees (Midwest)
- Intra-consortium collaboration (Midwest, Southeast, Southwest, West)

Research activities and initiatives from the consortiums included:

- Research Seed Money (Big-10, Midwest, Southwest, West)
- Neutron Science (Big-10, New England, Southeast)
- Neutron Scattering (Midwest, Southeast)
- Virtual Research and Training Reactor (Big-10)
- Mini-grant Programme (Big-10)

Multi-university Southeast INIE Consortium:

The consortium conducted the following education initiatives:

- Establishing an Internet-based nuclear reactor laboratory course;
- developing a minority education outreach programme; and
- creating web-based, distance learning nuclear engineering education modules.

The following research areas were also explored by the consortium:

- Radiation dosimetry; and
- boron-neutron capture therapy for the treatment of cancer and research reactor modelling and simulations.

2.1.6 Comparison between international nuclear education collaboration models

Model	ENEN	NTEC	UNENE	ANENT	INIE
	European Nuclear Education Network Association	Nuclear Technology Education Consortium	University Network of Excellence in Nuclear Engineering	Asian Network for Education in Nuclear Technology	Innovations in Nuclear Infrastructure and Education
Objectives of the network	Preservation and the further development of expertise in the nuclear fields by higher education and training.	To develop a new concept in postgraduate-level training for the nuclear sector in order to meet the UK's projected nuclear skills requirements in decommissioning and clean-up, reactor technology, fusion and nuclear medicine. The programme has been approved by the Institution of Mechanical Engineers.	Ensure a sustainable supply of qualified nuclear engineers and scientists to meet the current and future needs of the Canadian nuclear industry through university education, university-based training and by encouraging young people to choose nuclear careers.	Facilitate co-operation in education, related research and training in nuclear technology in the Asian region through exchange of students, teachers and researcher establishment, sharing of information and materials of nuclear education and training and serving as a facilitator for communication between ANENT member organisations and other regional and global networks.	The primary objective of INIE is to strengthen university nuclear engineering education programmes in the US through the innovative use of the university research and training reactors and encouraging strategic partnerships between the universities, the DOE national laboratories, and U.S. industry, etc.

Members of the Network	45 members, from 18 countries, consisting of 38 universities, six research centres and one multinational company.	Universities of Birmingham, Lancaster, Leeds, Liverpool, Manchester and Sheffield, City University, London, HMS Sultan, Imperial College London, UHI Millennium Institute & Westlake Research Institute.	The members include the Federal Government, industrial partners and university partners (Canada).	Members include Universities from Australia, China, India, Indonesia, Malaysia, Mongolia, Pakistan, Korea, Sri Lanka, Thailand, the Philippines, and Vietnam.	Southwest Consortium of Research Reactors, Western Nuclear Science Alliance, Consortium of Big-10 University Research and Training Reactors, New England Consortium, Midwest Nuclear Science and Engineering Consortium Multi-university Southeast INIE Consortium
Organisation of the Network	The ENEN board is composed of eight ENEN members elected by the General Assembly. The Management Committee is composed of the Chairs of the five ENEN Working Committees (ERC, TAAC, ACRC,	A Board of Directors will govern the Consortium. A Steering Committee is responsible for oversight and operation. NTEC Co-ordination Centre (Dalton Nuclear Institute) carries out day to day management. External	Board of directors manages property and business, sets policies and procedures. Standing committees: Education Advisory Committee Research Advisory	The network is guided by a Co-ordination Committee.	INIE was divided into six consortia, each with their own Management Committee.

	TIPC, QAC, KMC).	Advisory Board is responsible for external advice and Advisory Committee is responsible for management of academic processes.	Committee. Established by the Government of Canada.		
Funding	Fixed membership fee: Full members = €1000 Associated members = €5000. Each national network within ENEN has its own system for financial support. Some national networks and other ENEN members receive financial support from industry.	Total CTA cost = £350,000. Suspense account: • £1,500 per student • Fee per course = £4,500 + £100 per student (first 10) + £50 per student (max of 26) • £94,000 p.a. • New module development costs • Bursaries to students • Other discretionary funds • £60,000 for exit strategy	Funding received from industry, is met by the Federal Government and Ontario Government. <u>The first-phase funding:</u> • From industry: \$7.5 M • Universities: \$0.81M • NSERC: \$7.12M (estimated) <u>Other funding support:</u> • Industry and universities: \$4.97M	ANENT members do not pay a membership fee, but encouraged to provide in-kind contributions. Funds are provided by the IAEA (Technical Co-operation Fund). The ANENT website is handled by the Republic of Korea (Korea Atomic Energy Research Institute) where the original server is located.	A total of \$39 million was distributed to six consortia.

Courses and programme	ENEN provides a European Master of Science degree in Nuclear Engineering (EMSNE) to students who have obtained a Master's degree in Nuclear Engineering, or equivalent, from an ENEN member, The ENEN member networks and universities provides Master degrees in Nuclear Science and Engineering. ENEN offers a list of Ph.D. topics that can be researched and courses and seminars are offered.	Master of Science degree in Nuclear Science & Technology A total of 21 modules are currently available for students wishing to gain this M.Sc. either full-time (over one year) or part-time (over three years). The courses are also available as short courses for continuing professional development. A broad portfolio of subjects is covered, from reactor theory through decommissioning to waste disposal & storage. Further topics covering advanced	UNENE joint M.Eng. programme in Nuclear Engineering. This joint course-based Master's of engineering is offered by McMaster, Waterloo and Western and Queens. A student registered at e UNENE University, can take all the courses in the UNENE programme and obtain credits where he is registered. A Master's degree is obtained with 10 UNENE half-term courses or eight courses + Industrial project with a minimum passing grade of 70%.	The activities within ANENT include: •Activity 1: Exchange of information and materials for education & training, currently focusing on the development and utilisation of e-learning through the Cyber Platform. •Activity 2: Exchange of students, teachers and researchers through the regional TC project (RAS/0/047) •Activity 3: Distance learning that has been implemented in two e-Training Courses on Energy Planning. The multimedia course on Nuclear Reactor Physics will be disseminated after	Education activities: • Distance Learning • Graduate assistantships •Inter-consortium collaboration Other activities: • Outreach (by Big-10, Midwest, West) •New Nuclear Degrees (Midwest) •Intra-consortium Collaboration (Midwest, Southeast, Southwest, West) Research activities and initiatives: • Research Seed Money (Big-10, Midwest, Southwest, West) •Neutron Science (Big-
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		reactor physics, nuclear fusion, nuclear medicine and radiochemistry are being considered for future years. From September 2008, eight of the core modules will be offered in distance learning format. Students may also undertake a Postgraduate Diploma or Postgraduate Certificate within the framework of the programme.		online registration and agreement on licence has been finalised. •Activity 4: Establishment of reference curricula at NKM-related meetings for curriculum development and facilitating credit transfer and mutual recognition of degrees (through ENEN). •Activity 5: Liaison with other networks and organisations.	10, New England, Southeast) •Neutron Scattering (Midwest, Southeast) • Virtual Research and Training Reactor (Big-10) •Mini-grant Programme (Big-10)
Organi- sation of the courses and programme	ENEN-co-ordinated EMSNE and Ph.D. topics. ENEN networks and universities co-ordinate separate Master's degrees.	The programme is co-ordinated by the Dalton Nuclear Institute at the University of Manchester. Individual modules are organised jointly between the teaching institutes delivering those modules	Programme is co-ordinated by UNENE with students registered at McMaster, Western Ontario Waterloo and Queen's University	Students, teachers and researchers are exchanged between the institutions,	Not available

Pre-requisites	Applicants must have completed a Master's degree in Nuclear Engineering, or equivalent, from an ENEN member. Certain subjects must have been covered by the student in courses, as well as a master thesis project must have been successfully defended.	Applicants straight from university will be required to have at least a 2.2 degree in a relevant discipline. For applicants with some years' industrial experience, a lesser qualification may be acceptable. Entry requirements for the M.Sc., PG Diploma and PG Certificate are the same. Each applicant is considered individually.	Applicants must hold an honours baccalaureate degree in the fields of engineering, science or mathematics with an acceptable grade point average, set by the university where admission is sought, for entry into a Master's degree programme in engineering. Consideration may be given to relevant work experience In addition, applicants must be deemed to have satisfactory preparation, as a result of university education and work experience, to succeed in the programme. The application process takes at least a month.	Not Applicable	Not Available
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Distance learning	Not Applicable	Eight of the course modules are offered in distance learning format. The course is presented in the following phases: • 20 hours of pre-module preparation and pre-reading • one week direct teaching • 70 hours post-module assignments following the taught week • an examination may be incorporated	Not Applicable	Cyber-learning: This cyber platform (i.e. Learning Management System: LMS) serves as a web-based basic learning management tool on the ANENT web portal for the promotion of education and training in nuclear technology primarily for ANENT members and non-members.	Distance learning was developed within the consortia
Links with other networks	NTEC, BNEN, CNEN, REFIN, CIRTEN, FINNEN, KINT, ETH, EPEL, NTEC, EC, SNETP, IAEA, WNU, ANENT	ENEN II, IAEA, FORUM, NEA, NEI, ENTRAC, NEPTUNO, WNU	CNA, CNS, WIN, WNU, INIS, IAEA, ANENT, NTEC, INLN, NSERC	IAEA, RCA, ENEN, WNU, ARCCNM, ASNM, UNENE, CANTEAH, RCA-RO, ANSN, FNCA and MEPHI.	SCR, WNSA, Consortium big-10, URTR, NEC, MNSEC, MUSIC

2.1.7 Analysis of international nuclear education collaboration models

Model	ENEN	NTEC	UNENE	ANENT	INIE
Does the network succeed in its objectives?	Yes, the objective of preserving and further developing expertise in the nuclear field by higher education and training is accomplished by co-operation between universities, research organisations, regulatory bodies and the industry. The objective is realized by the working committees, each with a specific aim.	Yes, the objective of developing a new concept in postgraduate-level training for the nuclear sector in order to meet the UK's projected nuclear skills requirements is accomplished by offering an unparallel programme in the UK for postgraduate level training in the field of nuclear science and technology.	The objective of ensuring a sustainable supply of qualified nuclear engineers and scientists to meet the current and future needs of the Canadian nuclear industry is partly accomplished by offering a joint Master's degree programme in Nuclear Engineering, and not Nuclear Science.	Yes, the objective of facilitating co-operation in education, research and training in nuclear technology in the Asian region is accomplished through the exchange of students, teachers and researches, sharing of information and materials for nuclear education and training and facilitating communication between ANENT member organisations and other networks. The objectives are clearly realized by the ANENT activities.	The objective of strengthening university nuclear engineering education programmes in the US was partly accomplished by the establishment of six regional consortia. Furthermore, research, education and collaboration activities and initiatives were introduced.

Is the organisation of the network effective?	Yes, the network is effectively organized and structured with the use of a Board (highest governing authority), Management Committee (managing projects) and active Working Committees.	Yes, the network is effectively structured with the use of a Board of Directors (governing the Consortium), Steering Committee (oversight and operation), Co-ordination Centre (carrying out the day-to-day management), External Advisory Board (providing external advice) and Advisory Committee (managing academic processes).	Yes, the network organization includes the Board of directors (managing property and business, sets policies and procedures) and Standing committees (Education Advisory Committee Research Advisory Committee) which effectively accomplishes the objectives of UNENE.	Considering the activities of ANENT, the Co-ordination Committee is sufficient.	The structures of the management committees of the six consortia are unknown.
Is the funding sufficient?	Yes, the membership fees provide ENEN with financial resources to offer the necessary support. Furthermore, each national network within	Yes, the detail start-up plan and exit-strategy ensures that funding can be dispensed effectively. Furthermore, external funding also contributes	Yes, funding received from the nuclear industry, universities and government guarantees a successful network programme and activities.	Because of the funding provided by IAEA, ANENT is able to succeed in the operation of its activities.	No, the INIE programme terminated in 2006 because of a lack of funding.

	ENEN has its own system for financial support.	to activities of the network.			
Is the organization of the courses and programme effective?	ENEN networks and universities co-ordinate their own separate Master's degrees. ENEN only co-ordinates the EMSNE programme and Ph.D. topics.	The programme is effectively co-ordinated by a Co-ordination Centre, offering a broad portfolio of 21 modules and CPD courses. Furthermore, individual modules are organised jointly between the teaching institutes delivering those modules.	The programme is co-ordinated by UNENE. Students register at specific Universities and can take all the courses in the UNENE programme and obtain credits where he is registered. In theory, this acknowledgment of credits from other institutions should be an easily organized system.	The ANENT activities are co-ordinated by a Co-ordination Committee. Furthermore: students, teachers and researchers are exchanged between the institutions. Not enough information is available to comment on the effectiveness that the activities are organized.	The organization of the programmes are unavailable,

2.1.8 Summary

In comparing the existing international nuclear education collaboration models, the following conclusions were made:

1. The primary objective of the networks is collaboration in the education of skilled nuclear scientists or engineers according to the needs of the industry.
2. Each network and its participants are governed by an external governing body/steering committee.
3. Quality assurance is of the utmost importance and is handled by a committee or an identified participant.
4. External industry and/or government funding was required to establish and sustain the workings of the networks.
5. Post-graduate programmes in nuclear education are offered.
6. Students and or lecturers are exchanged between institutions or CPD courses are presented.
7. Distance learning is a trend and not an exception.
8. All networks are linked with other networks to create a nuclear education network of networks.

2.2 EXISTING SOUTH AFRICAN EDUCATION COLLABORATION MODELS

Five primary South African education collaboration models of different structures were researched and analysed. A summarisation of the characteristics of these models contributes to the foundation from where the South African collaboration model for nuclear engineering education was developed.

2.2.1 MatSci (Master's in Materials Science) and MANuS (Master's in Accelerator and Nuclear Science)⁶

2.2.1.1 Introduction

These programmes have been introduced at the University of the Western Cape (UWC) as a collaboration initiative between the University of the Western Cape, University of Zululand and iThemba LABS, as mentioned on the website of UWC.

2.2.1.2 Objectives

The primary objective of the MatSci and MANuS programmes is to enable graduates from a wide range of undergraduate science and related degrees to enter industry or government with appropriate skills or to progress to a doctoral qualification (Ph.D.) by offering an academic and practical course at M.Sc. level.

2.2.1.3 Structure

As mentioned above, the MANuS and MatSci programmes are conducted by a consortium consisting of the University of Zululand, iThemba LABS and UWC.

2.2.1.4 Financial model

In 2008, 16 Honours students and 13 Master's degree students were enrolled in the MANuS and MatSci programmes. The programmes need R200,000 per year for experimental equipment. According to Professor Robert Lindsay from UWC, the programme has been running at a loss, which has been absorbed by the parties concerned.

⁶ MaSci & MANuS:

http://www.uwc.ac.za/index.php?module=cms&action=showfulltext&id=gen11Srv7Nme54_7777_1220022247&parent=gen11Srv7Nme54_6513_1210050427&menustate=physics_menu

2.2.1.5 Programme offered

The MANuS and MatSci offers two-year courses, which includes lectures and practical work in the first year and a research project in the second year.

In the first year, a student attends lectures at the University of Western Cape (UWC) Campus, Cape Town. Practical work and projects are completed at the neighbouring iThemba LABS and after a written examination, a student can obtain an Honours degree.

In the second year, the student completes a research project and a dissertation at iThemba LABS, UWC, University of Zululand and other participating organisations such as NECSA and the Council for Scientific and Industrial Research (CSIR).

The courses offered by MatSci and MANuS are provided in Table 3.

Table 3: Courses offered by MatSci and MANuS

	First Year	Second Year
MatSci	• Modern Physics: Space/Time/Matter • Electromagnetism: Theory and applications • Mathematical Methods • Communication and Presentation Skills • Introduction to Solid State and Semiconductor Physics • Introduction to Quantum Physics • Statistical Physics • Electron Microscopy • Polymer Science • Metals • Computational and Information Technology • Advanced Analytical Techniques • X-ray Diffraction • Practical and (optional) Project	Research projects for dissertations are available in a wide range of disciplines: • Nano Science • X-ray Diffraction • Materials Characterisation

MANuS	• Modern Physics: Space/Time/Matter • Electromagnetism: Theory and Applications • Mathematical Methods • Communication and Presentation Skills • Nuclear Physics: Introduction, Structure & Reactions • Quantum Mechanics: Introduction and Applications • Thermal and Statistical Physics • Accelerator Physics: Introduction and Technologies • Environmental Radioactivity: An Introduction • Nuclear Power Reactors • Detectors, Electronics and Instrumentation • Computational and Information Technology Practical work and (optional) Project	Research projects for dissertations are available in a wide range of disciplines: • Nuclear Structure • Nuclear Reactions • Environmental Radioactivity • Accelerator Mass Spectrometry • Accelerator Development and Technologies
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The IThemba LABS website provides the entry requirements for the programmes: first degrees in Computer Science, Physics, Engineering, Chemistry or Mathematics. Students can register for the programmes at Universities of Zululand or Western Cape. Generous funding by the NRF is available to successful applicants.

2.2.2 NASSP (National Astrophysics and Space Science Programme) Consortium⁷

2.2.2.1 Introduction

The NASSP Consortium offers postgraduate programmes in the field of Astrophysics and Space Science. The programme started after a meeting held in 2001/2002 to discuss the future of astronomy in South Africa.

2.2.2.2 Objectives

Prof Peter Dunsby, programme director of NASSP, alleges that the primary objective of NASSP is to address the need to grow human capacity in South Africa in the field of astronomy. The development of skilled employees by offering education is a national driver that is being addressed by NASSP.

2.2.2.3 Structure

NASSP consortium consists of a co-ordinator, Steering Committee (with chair), Extended Programme co-ordinator, administrator and IT system administrator. The Steering Committee meets once or twice a year to discuss the NASSP and no formal MOU (Memorandum of Understanding) has been drawn up between the members. The following facilities are partners of the NASSP consortium:

Research facilities:

- South African Astronomical Observatory
- Hartebeesthoek Radio Astronomy Observatory
- High Energy Stereoscopic System
- Hermanus Magnetic Observatory

NASSP Consortium:

- University of Cape Town
- University of KwaZulu-Natal, Durban Campus
- University of KwaZulu-Natal, Pietermaritzburg Campus
- University of the Free State
- North-West University, Potchefstroom Campus
- University of Zululand
- Rhodes University

⁷ NASSP: <http://www.star.ac.za/>

- University of the North-West, Mmabatu Campus
- University of South Africa
- University of the Western Cape
- University of the Witwatersrand, Johannesburg
- South African Astronomical Observatory
- Hartebeesthoek Radio Astronomy Observatory
- Hermanus Magnetic Observatory

NASSP sponsors:

- Ford Foundation
- National Research Foundation
- Department of Science and Technology
- University of Cape Town
- Canon Collins Educational Trust for Southern Africa
- The Andrew W. Mellon Foundation

2.2.2.4 Financial model

NASSP was allocated US\$175 000 from the Ford Foundation for the programme operation in the first two years (Anon, 2002). The Allen Foundation has supported the programme for the next three years. Annual funding is obtained from DST and since 2008 the annual funding has increased to a three-year funding allocation.

Professor Peter Dunsby (2009) commented that NRF funding supports the bursaries allocated to the enrolled students, salaries of the lecturers are supported by DST and UCT receives funding in the form of subsidy allocations.

2.2.2.5 Programme offered

The website shows that the NASSP consortium offers three programmes: Honours, Master's and Ph.D. degrees in Astrophysics and Space Science. Within the programmes students need to complete courses, lectures given by the NASSP consortium staff, and take a substantial practical component, including field trips (NASSP, 2002).

Honours in Astrophysics and Space Science

This programme is hosted at the University of Cape Town and started in February 2003. The entry requirements for the programme are a B.Sc. degree in Physics, Mathematics, Astronomy

or Engineering. In order to complete the programme, students are required to take a total of 12 units, registered at UCT (one unit = 24 lectures and six tutorials).

The programme comprises of three components:

1. Theory (courses):

- Electrodynamics
- General Astrophysics
- Spectroscopy
- Astrophysical Fluid Dynamics
- General Relativity
- Computational Methods in Astronomy

2. Observation and research techniques (courses):

- Observational Techniques: Optical and Infrared Astronomy
- Observational Techniques: Radio Astronomy

3. A project and seminar component

Master's in Astrophysics and Space Science

A student can register for an M.Sc. at participating NASSP institutions. Entry requirements for the Master's degree are an Honours degree in Physics, Mathematics, Astronomy or Engineering.

In the first semester, students complete the taught component of the Master's at the hosting University of Cape Town. Five NASSP courses are taught by South African researchers from NASSP institutions.

After the first semester, students work on a research topic at the registered institution under supervision of scientists.

The following courses are offered:

- Plasma Physics
- Magneto hydrodynamics
- Geomagnetism and Aeronomy
- Hot Topics in Cosmology
- Cataclysmic Variables
- Extragalactic Astronomy

- Advances General Relativity
- High Energy Astrophysics and Pulsars
- General Astrophysics
- Stellar Structure and Evolution
- Observational Cosmology
- Observational Techniques
- Space Technology
- Computational Astrophysics

Ph.D. in Astrophysics and Space Science

Students can register for and complete their Ph.D. studies at any NASSP partner institution. Entry requirements are a Master's degree in Astrophysics and Space Science.

2.2.3 CARST (Centre for Applied Radiation Science and Technology)⁸

2.2.3.1 Introduction

CARST was established as the Centre for Applied Radiation Science and Technology in the Faculty of Agriculture, Science and Technology of the University of the North-West, now known as the North-West University (Mafikeng Campus) on 1 January 2004 with the Potchefstroom University for Christian Higher Education in South Africa.

The Centre is a collaborative effort between the North-West University (NWU): Mafikeng Campus and South African industrial and research stakeholders: South African electricity-generating and supply utility (Eskom); the National Nuclear Regulator (NNR); the Nuclear Energy Corporation of South Africa (NECSA); the iThemba Laboratory for Accelerator Based Sciences (iThemba LABS); the Pebble Bed Modular Reactor Group (PBMR); and the National Research Foundation (NRF). This centre was established in 1998.

2.2.3.2 Objectives

One of the key objectives of CARST is to conduct research and training in the area of applied nuclear and radiation sciences and technologies. This is done in order to stabilise the nett skills attrition in this area and to contribute to the economy of South Africa by contributing towards human skills development.

2.2.3.3 Structure

CARST is driven by the following staff:

- Manager
- Senior lecturer
- Administrative officer
- Safety officer
- Assistant PA

Stakeholders participate in an advisory committee on policy regarding national and international developments and trends. The stakeholders include the North-West University (Mafikeng Campus) and industry and research stakeholders (Van der Linde, 2009:2).

⁸ CARST: <http://www4.tlabs.ac.za/carst/welcome.html>

2.2.3.4 Financial model

Funding within CARST is required for:

- Staff salaries
- Laboratory and instrumentation
- Honours Degree, Master's degree, Doctoral and post Doctoral students
- Curriculum development and writing of study guides
- Marketing
- Operational costs

Bursaries offered to students are covered by funding received by industry partners. Funding in the form of tuition fees are received from stakeholders and the North-West University to cover capital purchases, lecturing, personnel and other staff and operational costs.

2.2.3.5 Programme offered

The Centre offers a two-year Master's degree course in Applied Radiation Science and Technology (MSc-ARST). Before 2006, a student could exit with a diploma in Applied Radiation Science and Technology (PGD-ARST) after only one year on the Master's programme. Fifty-one degrees and four postgraduate diplomas have been conferred in this programme.

After 2006, a 120 credit Honours degree is being awarded. One credit represents 10 hours of work to be done by the student. The Master's degree has been extended to 180 credits with a full year of research and coursework of an applied nature after the Honours degree had been obtained (See Figure 7). The courses are presented by university lecturers and by the industry, national and international recognised experts.

The following topics are focused on during basic training:

- Nuclear Physics
- Nuclear Chemistry
- Radiation and Environment
- Radioactive Waste Management

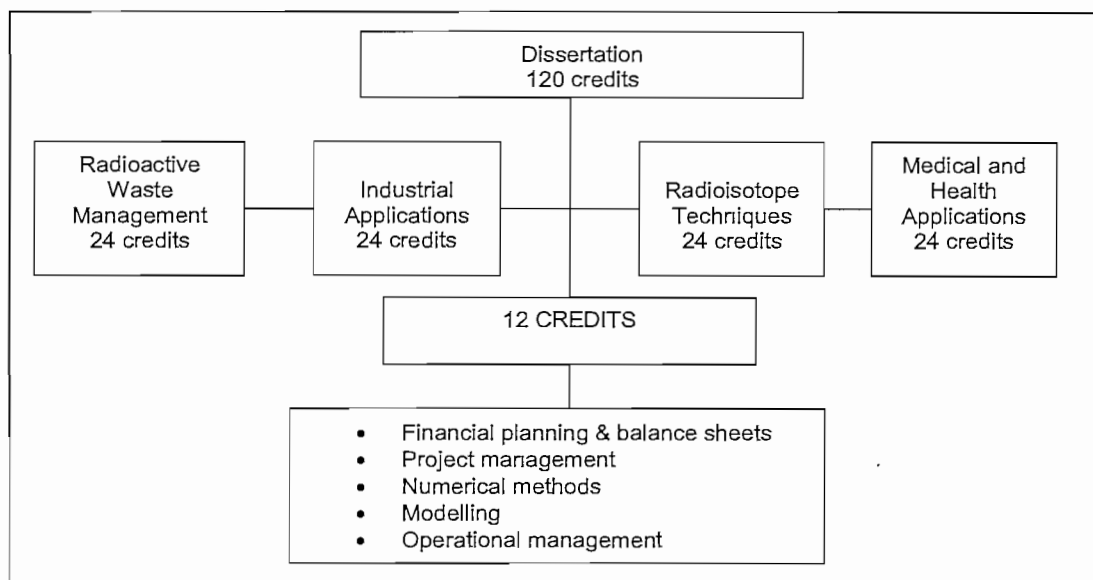


Figure 7: Master's degree in Applied Radiation Science (Van der Linde, 2009:9)

The total credits completed by students when a Master's degree in applied radiation sciences is obtained, amounts to a total of 668 credits shown in Table 4.

Table 4: Credits (Van der Linde, 2009:11)

Degree	Credits
3-Year BSc Degree	360
BSc Honours Degree	128
MSc Degree	180
TOTAL	668

The pre-requisite for the honours degree in Radiation Science and Technology is a Bachelor's degree in Science. After this Honours degree in Radiation Science and Technology, a Master's degree in Radiation Science and Technology can be obtained. For any student wishing to enter the programme with a background of any other Bachelor's degree in Science, CARST requires the student to take a set of prescribed bridging modules.

2.2.4 SANHARP (South African Nuclear Human Asset and Research Programme)⁹

2.2.4.1 Introduction

To support the South African vision of including nuclear energy in the country's energy mix, the Department of Science and Technology (DST) has established SANHARP within PBMR. According to the SANHARP website, this programme was initiated in 2005, but since then it has been decided that the broader range of nuclear skills should be developed, not limiting the PBMR. Therefore, the chair was moved from PBMR (Pty.) Ltd. to NECSA.

The vision of SANHARP is "to facilitate a broad-based national program that will deliver on capacity building and research and development initiatives for and in partnership with the nuclear sector in South Africa" (NIASA, 2008:43).

The mission of SANHARP is "To initiate, facilitate and support education, learning, knowledge transfer and research programs that will provide solutions to the current and future human as well as intellectual capital requirements of the South African nuclear sector" (NIASA, 2008:43).

2.2.4.2 Objectives

SANHARP has the following strategic objectives:

- To position the development of human and intellectual capital for the nuclear sector in South Africa on local and international platforms;
- promote innovation, teaching and research capacity for the nuclear sector in South African secondary and tertiary institutions in areas of science, engineering and technology;
- facilitate nuclear skills development through knowledge transfer programmes, collaboration and co-operation as part of technology acquisition from local and international educational and research institutions;
- develop a critical research and skills base to support the nuclear sector in South Africa; and
- promote and ensure comprehensive public awareness and understanding of nuclear-related issues.

2.2.4.3 Structure

The SANHARP programme was initiated by the DST and consists of a central **Steering Committee**, **sub-committees** and a **secretariat** (See Figure 8). The Secretariat consists of the programme manager, personal assistant, project officer, bursaries manager and schools outreach manager.

⁹ SANHARP: <http://www.sanharp.tlabs.ac.za/sanharp/default.htm>

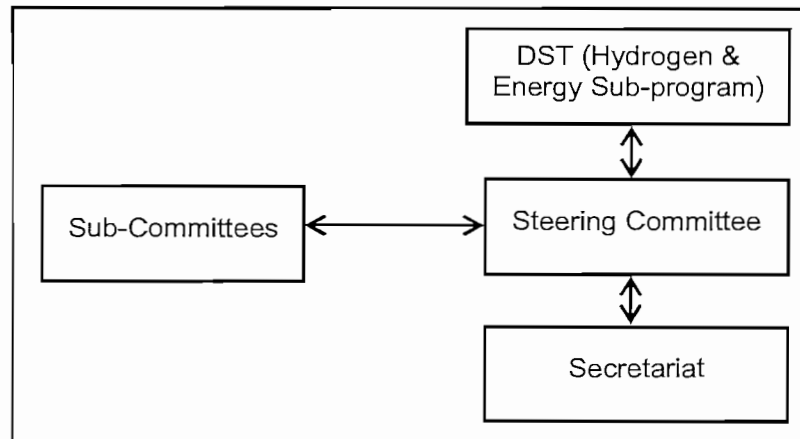


Figure 8: Governance structure (Sanharp, 2009)

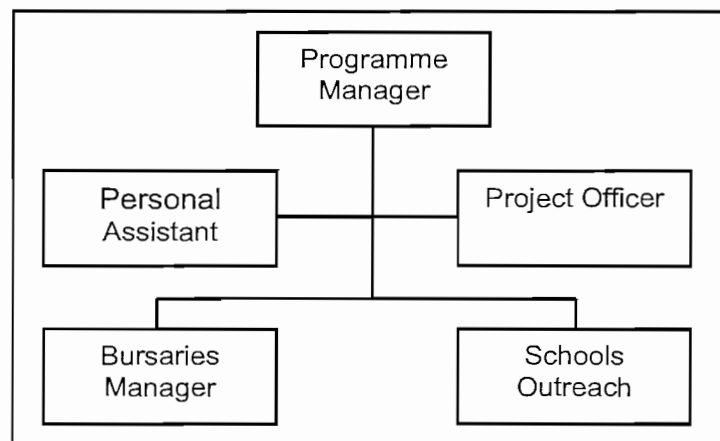


Figure 9: Secretariat structure (Sanharp, 2009)

2.2.4.4 Financial model

SANHARP is an initiative of the Department of Science and Technology (DST) to advance skills in the entire nuclear industry. Programmes running within SANHARP are therefore funded by the DST.

2.2.4.5 Programme offered

The following programmes are currently running within SANHARP

- The Bursaries Scheme, offering full sponsorships to students in selected areas of science and engineering from undergraduate level to postgraduate level. Currently there are more than 160 bursary holders in the scheme. This number is expected to reach 500 in the next five years.
- The Schools' Outreach Project seeks to ensure a pipeline of learners with a strong foundation in mathematics and science to take up undergraduate bursaries that are offered

by the programme. The project also offers bursaries to students from grade 10 to grade 12 across the country in 32 so-called Dinaledi schools. Students who matriculate satisfactorily are then taken up in the Bursaries Scheme.

- The Nuclear Hub Website provides awareness on the nuclear industry and serves as a hub for different stakeholder users.
- The Research Chairs management is under the National Research Foundation's (NRF's) South African Research Chairs Initiative (SARCHi). The SARCHi programme seeks to create chairs with regard to defined research themes pertinent to nuclear technology.
- Communities of Practice aim to support stakeholder groups and associations in the nuclear industry.

2.2.5 M'Soné (Master's in the Science and Organisation of Nuclear Energy)¹⁰

2.2.5.1 Introduction

The idea for a new Master's degree in Nuclear Engineering arose from the need to support the South African nuclear renaissance. It was decided to initiate a collaborative effort between several universities so that complimentary skills could be gained to the multidisciplinary course. A collaboration between the University of Johannesburg (UJ) the Tshwane University of Technology (TUT), UNISA, University of Kwa-Zulu Natal, iThemba LABS and industry partners including Eskom, NNR, NECSA and PBMR was established to present the programme: M'Soné (M'Soné, 2008:1). This programme has not yet been accredited and approved by DHET and HEQC.

2.2.5.2 Objectives

The primary objective of the partner institutions is to present a Master's degree in Science and Organisation of nuclear energy.

2.2.5.3 Structure

A full-time **Programme Manager** co-ordinates the course, manages student logistics and provides the link between universities and the industry.

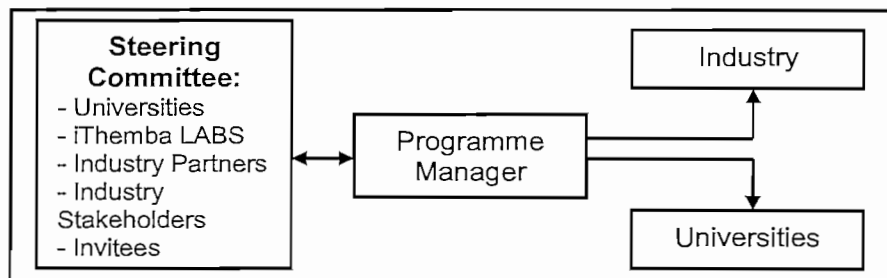


Figure 10: Structure of M'Soné

A proposal for the establishment of a **Steering Committee** is under way (M'Soné, 2009:1). This Steering Committee will concern itself with decisions affecting the M'Soné programme as a whole. This committee will be represented by:

- An official representative from each participating university;
- one or more iThemba LABS representatives;
- an official representative from each of the industry partners (providing guidance and advice);

¹⁰ M'Soné: No available website

- a representative from each industry stake-holder (providing e.g. financial sponsorship and lecturers); and
- invitees as determined by the Steering Committee.

2.2.5.4 Financial model

It is envisaged that funding for the programme will be resourced by government agencies and industry partners. The gross annual budget is estimated at R4 m. The proposed budget for running the M'Soné programme is shown in Table 5. Year 1 is based on 20 enrolled students and Year 2 onwards on 40 students. All costs shown are to be multiplied by 1000.

Table 5: Proposed Budget (M'Soné, 2008:4)

Budget Item	Year 1 Annual	Year 2 & on Annual	Comment
Course co-ordinator	350	350	Person at senior lecturer level.
Administrator	-	160	Full-time person required.
Stipend to students for accommodation and subsistence @ R3 500 p.m. x 12 (first year) x 14 (second year)	840	1 820	Total of 40 students (20 first year, 20 second year) from 2010.
Travel and subsistence for module lecturers in South Africa	150	150	For travel and teaching the courses.
Travel and subsistence for module lecturers international (4 x 3 weeks)	250	250	Air ticket + accommodation (three weeks) and fee (R30k) – 4 x (10k + R1k/day x 21 + R30k)

Transport: Shuttle for UJ ↔ iThemba LABS (10km/day x 250 days) Shuttle for Necsa (100km/day x 20 days) Shuttle for site visits to stakeholders (50km/day x 5 days)	50	50	Running costs only – 4 750 km @ R3/km = R14 250.
Setting up student space, IT infrastructure such as Wifi, software, etc.	250 (once off)	-	Includes systems administration.
Tutors	75	75	4 tutorials per week x 30 teaching weeks x 3 tutors x R200/1 hour (marking tutorials included)
Demonstrators: 18	40	40	15 Labs repeated twice, needing three demonstrators to have 3 or 4 of 20 students accommodated R360/3 hours (marking lab report included).
Student registration & tuition fees	336	515	20 @ R16k tuition, R800 registration (first year) 20 @ R8k tuition, R800 registration (second year)
Laboratory equipment for practicals	500 (once off)	-	
Attendance of conferences	125	250	Conference fees, accommodation for 40, including air travel @ R2k
Marketing	100	100	Course will require brochures, posters and advertising
(Annual equipment maintenance)	-	240	
Annual gross costs (excluding lecturers' costs)	1 476	4 000	
Once off	750	-	

Lecturers' cost	-	875	
*1 DoE Master's subsidy	-	(800)	
*2 Net annual cost	1 476	4 075	

Comments on the proposed budget:

***1 DoE Master's subsidy:**

As will be discussed in Chapter 3, the subsidy received by higher-education institutions are only received two years after it has been earned by students enrolled in the programme. Therefore, the R800,000 received in the second year that the programme will be presented is not a valid income in Year 2, as it will only be received by the institution in years 3 and 4.

***2 Costs per student:**

The running cost per student in the programme is as follows:

Year 1:

- 20 enrolled students
- The total costs of the programme are equal to R1,4 m.
- The cost per student amounts to R73k.

Year 2:

- 40 enrolled students
- The total costs of the programme are R4 m + the unsound subsidy (R800, 000) which is equal to R4,8 m.
- The cost per student amounts to R121k.

The cost per student of the proposed collaborative programme will be discussed in Chapter 5.

2.2.5.6 Programme offered

Students completing the Master's degree in nuclear energy will devote the first year to course work and the second year to a research project. Topics that will be covered include physics and mathematics behind nuclear reactions, statistical risk analysis, environmental impact and safety (UJ, 2008:1). Lectures and tutorials will mostly take place at UJ.

The M'Soné programme will in the future primarily focus on the following:

- Safety (Statistical Modelling for Divisions);

- Nuclear Materials ((Radiation Damage, Ageing, Fuel Studies, other nuclear materials studies); and
- Advanced Reactor Analysis and Development (Physics, Applied Mathematics, Computational Modelling).

As a start, students will only register at UJ, with an ultimate plan to allow students to register at any one of the collaborating universities. Practical work will be completed at iThemba LABS and NECSA. Research will be carried out using facilities at NECSA, iThemba LABS, Jefferson Lab (in the USA) and CERN-ATLAS experiment in Europe. Specialisation in the Master's degree will come from the elective courses taken and the topic of the research project.

The prerequisites for the Master's degree in the Science and Organisation of Nuclear Energy are an Honour's degree in science or engineering with at least one year physics and mathematics. Students may receive recognition for prior learning coupled with industry experience. After completing the Master's degree, students can enrol for a Ph.D. in a relevant topic.

2.2.6 Comparison between South African education collaboration models

Model	MANuS and MatSci	NASSP	CARST	SANHARP	M'Soné
	Master's in Materials Science and Master's in Accelerator and Nuclear Science	National Astrophysics and Space Science Programme	Centre for Applied Radiation Science and Technology	South African Nuclear Human and Research Programme	Master's in Science and Organisation of Nuclear Energy
Objectives of the network	The primary objective is to enable graduates from a wide range of undergraduate science and related degrees to enter industry or government with appropriate skills or to progress to a doctorate qualification (Ph.D.) by offering an academic and practical course at M.Sc. level.	The primary objective of NASSP is to address the need to grow human capacity in South Africa in the field of astronomy. The increase of skilled people in the workplace by offering education is a national driver that is being addressed by NASSP	One of the key objectives of CARST is to conduct research and training in the area of applied nuclear and radiation sciences and technologies. This is done in order to stabilise the skills attrition in this area and to contribute to the economy of South Africa.	Strategic objectives: •To position the development of human and intellectual capital for the SA nuclear sector. •To promote teaching, research and innovation capacity in SA and tertiary institutions in areas of nuclear science, engineering and technology. •To facilitate nuclear skills development through skills transfer programmes, collaboration and co-	The primary objective of the partner institutions is to present a Master's degree in Science and Organisation of Nuclear Energy.

				operation •To develop a critical research and skills base to support the SA nuclear sector. •To promote and ensure public awareness and understanding of nuclear-related issues	
Members of the network	University of Zululand, IThemba LABS and UWC.	<u>Research facilities:</u> South African Astronomical Observatory, Hartebeesthoek Radio Astronomy Observatory, High Energy Stereoscopic System, Hermanus Magnetic Observatory <u>NASSP Consortium:</u> University of Cape Town, University of KwaZulu-	The centre is a collaboration between: • North-West University (Mafikeng Campus) • ESKOM • NNR • NECSA • iThemba Laboratory for Accelerator Based Sciences • iThemba LABS • PBMR • NRF	Department of Science and Technology (DST) established the SANHARP programme within PBMR, later moving to NECSA.	<u>University members:</u> • UJ • Tswane University of Technology • UNISA • University of Kwa-Zulu-Natal <u>Other members:</u> • iThemba LABS <u>Industry participants showing interest:</u> • Eskom

		Natal, Durban Campus, University of KwaZulu- Natal, Pietermaritzburg Campus, University of the Free State, North- West University, Potchefstroom Campus, University of Zululand, Rhodes University, University of the North- West, Mmabatu Campus, University of South Africa, University of the Western Cape, University of the Witwatersrand, South African Astronomical Observatory, Hartebeesthoek Radio Astronomy Observatory, Hermanus Magnetic Observatory <u>NASSP sponsors:</u>			• NNR • NECSA • PBMR
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		Ford Foundation, National Research Foundation, Department of Science and Technology, University of Cape Town, Canon Collins Educational Trust for Southern Africa, the Andrew W. Mellon Foundation			
Organi- sation of the network	Not available	NASSP consortium consists of • Co-ordinator • Steering Committee (with chair) • Extended programme co-ordinator • Administrator • IT system administrator	Virtual Centre driven by: • Manager • Senior lecturer • Administrative officer • Safety officer • Assistant PA Stakeholders participate in an advisory committee on policy regarding national and international developments and trends. The stakeholders include	<pre> graph TD DST[DST (Hydrogen & Energy Sub-program)] <--> SC[Steering Committee] SC <--> Secretariat[Secretariat] SC <--> SubComm[Sub-Committees] PM[Program Manager] --- PA[Personal Assistant] PM --- PO[Project Officer] PA --- BM[Bursaries Manager] PO --- SO[Schools Outreach] </pre>	A full-time programme manager co-ordinates the programme. A proposal for the establishment of a Steering Committee is under way. This Steering Committee (SC) will concern itself with decisions affecting the M'Soné programme as a whole. The SC will be represented by: An

			the University of North-West and industry and research stakeholders		official representative from each participating university, one or more iThemba LABS representative, an official representative from each of the industry partners, representative from each industry stakeholder, and invitees
Funding	The cost for operating the programme is covered by the participating universities (including the subsidy received).	NASSP was allocated US \$175 000 from the Ford Foundation for the programme operation in the first two years. The Allen Foundation supported the programme for the next three years. Annual funding is obtained from DST and since 2008, the annual funding has increased to a three-year	<u>Funding is required for:</u> • Staff salaries • Laboratory and instrumentation • Honours, Master's, Doctoral students & Postdoctoral students • Curriculum development and writing of study guides • Marketing • Operational costs Bursaries offered to	SANHARP is an initiative by the Department of Science and Technology (DST) to advance skills in the entire nuclear industry. Programmes running within SANHARP are therefore funded by the DST.	It is envisaged that funding for the programme will be resourced by Government agencies and industry partners. The gross annual budget is estimated at R4 m.

		funding allocation. NRF funding supports the bursaries allocated to the enrolled students, salaries of the lecturers are supported by DST and UCT provides funding in the form of subsidy allocations.	students are covered by funding received by industry partners. Funding in the form of tuition fees are received from stakeholders and the North-West University to cover capital purchases, lecturing, personnel and other staff and operational costs.		
Courses and programme	Two-year courses are offered, including lectures and practical work in the first year and a research project in the second year. <u>Year 1:</u> Students attend lectures at the UWC. Practical work and projects are completed at iThemba	<u>Honours:</u> Includes the following components: 1. Theory (courses): • Electrodynamics • General Astrophysics • Spectroscopy • Astrophysical Fluid Dynamics • General Relativity • Computational Methods in Astronomy	Two-year Master's degree course in Applied Radiation Science and Technology (M.Sc.-ARST). After one year, a 120 credit Honours degree is awarded. The Master's degree is extended to 180 credits with a full year of research and coursework of applied nature after the honours degree had been	<u>Programmes within SANHARP:</u> • Bursaries Scheme • Schools Outreach Project • The project currently offers • Nuclear Hub Website • Research Chairs • Communities of Practice supporting stakeholder groups and	The Master's degree in nuclear energy will include a first year of course work and second year research project. Lectures and tutorials will mostly take place at UJ. The M'Soné programme will in the future primarily focus on the following: • Safety (Statistical

	LABS. After a written examination, an Honours degree is obtained. <u>Year 2:</u> Students complete a research project and dissertation at iThemba LABS, UWC, University of Zululand and other organisations such as NECSA and the CSIR.	2. Observation and research techniques (courses): • Observational Techniques: Optical and Infrared Astronomy • Observational Techniques: Radio Astronomy 3. A project and seminar component <u>Master's:</u> In the first semester, students complete the taught component of the Master's degree at the hosting UWC. From the second semester, students work on a research topic. <u>Ph.D.:</u> Students register and carry out Ph.D. studies at	obtained. <u>The following topics are focused on during basic training:</u> • Nuclear Physics • Nuclear Chemistry • Radiation and Environment • Radioactive Waste Management	associations in the nuclear industry	modelling for divisions) • Nuclear Materials ((Radiation damage, ageing, fuel studies, other nuclear materials studies) • Advanced Reactor Analysis and Development (Physics, Applied Mathematics, Computational Modelling) An ultimate plan to allow students to register at any one of the collaborating universities. Practical work will be completed at iThemba LABS and NECSA. Research will be carried out using facilities at
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		any NASSP partner institution.			NECS, iThemba LABS, Jefferson Lab (in the USA) and CERN-ATLAS experiment in Europe. Specialisation in the Master's degree will come from the elective courses taken and the topic of the research project.
Prerequi- sites	First degrees in Computer Science, Physics, Engineering, Chemistry or Mathematics.	<u>Honours:</u> B.Sc. degree in Physics, Mathematics, Astronomy or Engineering. <u>Master's:</u> B.Sc. in Physics, Mathematics, Astronomy or Engineering. <u>Ph.D.:</u> Master's degree in Astrophysics and Space	The pre-requisite for the honours degree in Radiation Science and Technology is a Bachelor's degree in Science. After this, an Honours degree in Radiation Science and Technology, a Master's degree in Radiation Science and Technology can be obtained. Bridging modules will have to be completed with a	Not applicable	The pre-requisites for the Master's degree in nuclear science are a three year Bachelor's degree in Science or Engineering with at least one year of physics and mathematics. Students may receive recognition for prior learning coupled with industry experience

		Science.	background of any other Bachelor's degree in Science.		
Links with other networks	NIASA	Astronomy partner institutions	IAEA, AFRA, NTEC, IUSS, WNU networks, ANENT	NECSA	NIASA

2.2.7 Analysis of South African education collaboration models

Model	MANuS and MatSci	NASSP	CARST	SANHARP	M'Soné
Does the network succeed in its objectives?	The primary objective is to enable graduates to enter industry or government with appropriate skills or to progress to a doctorate qualification (Ph.D.) by offering an academic and practical course at M.Sc. level. This objective is put into practise, as 16 Honours students and 13 Master's degree students were enrolled in 2008.	The primary objective of NASSP is to address the need to grow human capacity in South Africa in the field of astronomy by offering education. The objective is successfully addressed by offering Honours, Master's and Doctoral degrees in Astrophysics and Space Science.	One of the key objectives of CARST, to conduct research and training in the area of applied nuclear and radiation sciences and technologies, is addressed by the Honours and Master's degree (including research and training) in Applied Radiation Science and Technology that is offered.	The objectives are partly addresses in the programmes currently active in SANHARP: •To position the development of human capital, bursaries are offered. •To promote teaching, research and innovation capacity in tertiary institutions, the chairs initiative is active. •To facilitate collaboration and co-operation, communities were established. •To promote and ensure public awareness, the schools outreach programme was initiated.	The success of the primary objective, to present a Master's degree in Science and Organisation of Nuclear Energy, is yet to be determined as the programme is still in concept phase.

Is the organisation of the network effective?	The organization of the network is unavailable,	The NASSP consortium consists of a thorough structure of a Co-ordinator; Steering Committee; Extended programme co-ordinator; Administrator; and IT system administrator.	The personnel employed by CARST include a Manager, Senior lecturer, Administrative officer, Safety officer and Assistant PA. These personnel as management structure is adequate as NWU is the only participating higher education institution. Furthermore, stakeholders can participate in an advisory committee.	The structure in which SANHARP programmes are operated (Steering Committee and Sub-committees) provides a potential effective management structure. Within the Sub-committees, the personnel should provide adequate support in the management of the projects.	A full-time programme manager (co-ordinating the programme) and Steering Committee (making strategic decisions) could, in theory, be an adequate organisational structure.
Is the funding sufficient?	The cost for operating the programme has been covered by the participating universities. Even so, the programme has been running at a	Ford Foundation, the Allen Foundation, DST and NRF support the programme with funding. Furthermore, UCT receives funding in the	Funding is received by industry partners in the form of bursaries for students. Other expenses seem to be covered by stakeholders and NWU.	The funding provided by the DST has been sufficient to drive the SANHARP programmes.	It is envisaged that funding for the programme will be resourced by the Government and industry partners. Funding has not yet been obtained.

	loss because of the lack of external funding.	form of Government subsidy allocations. These external sources provide the programme with sufficient financial input.			
Is the organisation of the courses and programme effective?	The programme is organized so that course-work is completed at UWC and research is conducted at iThemba LABS, industry partners, UWC or University of Zululand. This suggests effective co-operation between the partnering institutions.	Students can register for the Master's degree at any NASSP institution and complete the taught component at UCT (five courses are taught by researchers from NASSP institutions). The research component is completed at the registered institution under supervision of scientists. The effective collaboration between institutions is apparent.	The programme is presented by NWU and organisation of the programme is managed internally by NWU (with input from the Advisory committee).	The SANHARP programmes are organized by programme managers and supporting personnel.	In concept, the programme includes lectures and tutorials completed at UJ, practical work completed at iThemba LABS and NECSA and research conducted at participating institutions. This programme has not yet been presented and the effectiveness of the delivery of the programme could not yet be determined.

2.2.8 Summary

The following can be concluded from the existing South African education collaboration networks:

1. The primary objective of the networks is to facilitate or fund education according to the skills needs in South Africa.
2. The networks are managed by a programme manager.
3. External grants are received as income to establish and sustain the programmes offered.
4. Post-graduate programmes in nuclear and other education are offered or funded.
5. Networks are linked with other networks for aid or input.

2.3 CONCLUSION

In this chapter, five primary international nuclear education collaboration models and five primary South African education collaboration models of different structures were researched. The characteristics of these models were analysed and summarised to provide a foundation from where a South African collaboration model for nuclear engineering education could be developed. This collaboration model, as will be explained in Chapter 4, should include the following attributes:

1. The primary objective of the collaboration effort in South Africa should be to educate nuclear engineers according to the needs of the nuclear industry.
2. The network should be managed by an external governing body.
3. Government or industry funding should have to be obtained to establish and sustain the network and programmes offered.
4. The network should be linked with other nuclear education networks.

CHAPTER 3: ACADEMIC VS NUCLEAR INDUSTRY NEEDS

3.1 INTRODUCTION

In this chapter the needs and expectations of the nuclear industry for nuclear engineers trained at Master's degree level will be investigated. This will be compared to the needs and drivers of the higher education environment for providing training at a Master's degree level. At the end of the chapter, a summary will sketch the reconciliation of the industry and academic environments. This information will act as a foundation for the next chapter, where a suggested collaboration curriculum for a Master's degree in nuclear engineering will be introduced.

3.2 INDUSTRY NEEDS

The future of nuclear energy in South Africa is certain but not yet defined, therefore Yashin Brijmohan, Technical Capacity Development Manager at Eskom (2009) stated that developing a postgraduate programme in nuclear engineering (with important bridging modules) would be more successful than educating students towards a Bachelor's degree in nuclear engineering. If engineers therefore obtain general Bachelor's degrees in engineering (for example mechanical or electrical), and post-graduate degrees in nuclear engineering, they will have a broad choice of career paths without limiting their options to only within the nuclear field.

Brijmohan also mentioned that at the start of a programme the presentation of a Master's degree in nuclear engineering should primarily be course-based. This will create a broad knowledge base among employees. At a later stage, this knowledge can be applied and contribute towards research in specific areas. Brijmohan provided a possible suggestion for the distribution of students within a Master's degree in a nuclear engineering programme. This suggestion includes 70% of the students completing primarily course work, 20% of the students completing equal course work and research, and 10% of the students completing primarily research.

Clive le Roux, general manager of Nuclear Programs at Eskom (2009), stated that at an early stage of the nuclear energy production, a broad field of nuclear knowledge should be developed in South Africa, and that students should therefore focus on course based Master's degrees and only at a later stage will large research topics be better defined. According to le Roux, if a fleet of nuclear power stations were to be commissioned in South Africa, the need of Eskom for nuclear engineers (with a broader engineering background) will be enormous and the education and training of these engineers is therefore of the utmost importance.

Jeff Victor, Manager of National Capacity Building at PBMR (2009), said that the combination of knowledge transfer with modules, industry-based research and experience within the industry is the most effective method of training nuclear engineers. He believes that the South African nuclear industry as a whole will require a large number of nuclear engineers in the near future. At the time that this dissertation was written, Jeff Victor was busy compiling a skills guideline document, on behalf of NIASA (Moodie, 2009). This document will provide detail information on the exact number of nuclear engineers that will be needed in South Africa.

Nuclear industry leaders therefore agree that nuclear education at Master's degree level is of the utmost importance for the foundation of nuclear knowledge in South Africa. A suggestion is that nuclear engineers are trained by emphasising course-based work at Master's degree level. The specific needs for the training of nuclear engineers will be reported on in the following paragraphs.

3.2.1 Specific needs of the nuclear industry

From the above paragraphs it is clear that there is a definite need to investigate the specific needs of the nuclear industry for the knowledge, skills and competencies that their employed nuclear engineers should be trained towards. The following questions were posed to industry leaders in South Africa to obtain detail information on what a course-based Master's degree in 'nuclear engineering should include:

1. What **knowledge** is required of a nuclear engineer in the industry?
2. What **skills** are required of a nuclear engineer in the industry?
3. What **competencies** are required of a nuclear engineer in the industry?
4. What **research** is required in the industry to be done by nuclear engineering students?

The Concise Oxford English Dictionary (COED, 2004) defines the following:

- **Knowledge** as (i) information and skills acquired through experience or education, (ii) the sum of what is known, (iii) awareness or familiarity gained by experience;
- **Skill** as (i) the ability to do something well; expertise or dexterity, (ii) (skilling) to train a worker to do a particular task;
- **Competency** as (i) the quality or extent of being competent, and
- **Competent** as (i) having the necessary ability or knowledge to do something successfully (ii) acceptable and satisfactory); and
- **Research** as (i) the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions, (ii) use research to discover or verify information

The answers to the questions were gathered from the industry leaders and are provided in Annexure B. The information from the South African nuclear industry was gathered by the following employees:

- Eskom (John Gosling, chief learning officer)
- PBMR (Jeff Victor, national capacity-building manager)
- Necsa (Dr. Pamela Dube, senior manager for Learning and People Development)
- NNR (Puleng Maseko, talent Manager and Dr Jean Joubert, co-ordinator of the PBMR assessment in the assessment group)

Table 6 provides a summary of the core knowledge, skills, competencies and research topics required by the South African nuclear industry. From this summary, conclusions can be drawn about the knowledge, skills and competencies that could be taught and the research that could be included in a Master's degree programme in nuclear engineering. This information will be interpreted in the following chapter, where a suggested collaboration curriculum for a Master's degree in nuclear engineering will be introduced.

Table 6: Summary of South African nuclear industry needs for nuclear engineers

	Knowledge	Skills	Competencies	Research
Nuclear materials, physics and chemistry	- Nuclear Materials - Chemistry in general - Uranium and fluoride chemistry - Water chemistry - Core physics (neutronics) - Core kinetics analysis - Thermal-hydraulics - System core thermo hydraulics - System thermo hydraulics	- Participate in the material specifications and material testing programmes	- Reactor kinetics	- Diffusion study - Femtochemistry (SiC Improvement) - Application of nuclear physics - Ag migration - SiC nanotubes study - Si Isotopes study - Impact of CVD conditions on SiC layer - Graphite dust study - Graphite life extension - Graphite characterisation - Graphite feedstock (coke) - Heat-resistant concrete - High temperature materials - Passive cooling - Ag plate out study
Fuel and waste	- Design and Handling - Transport and Storage - Waste handling	- Understanding of fuel management philosophies and related safety demonstrations	- Waste management - Transport of fuel - Fuel Temperature	- Fuel modelling - Nuclear fuel cycle - Waste management

	- Fission product transport and plate-out analysis - In-core behaviour and depletion effects - Fuel management analysis - Fuel performance analysis - Radioactive waste characterisation	- Ability should be obtained to establish facilities for the testing of processes relating to the PWR fuel fabrication for uranium conversion processes through powder metallurgy processes and mechanical engineering assembly components.	Measurement	- Waste heat recovery and use
Analysis, design and engineering	- Life cycle of nuclear plant (birth, maintenance, operation, decommissioning) - Plant engineering analysis - Computer codes, methodologies applied, assumptions made and interpretation of results - Nuclear facility behaviour under design, transient and accident conditions - Conducting of relevant analysis - Chemical and Mechanical Engineering Principles - PWR - Ensure the technical quality and correctness of analysis performed	- Nuclear lifecycle - All phases of design, manufacturing, production and quality assurance - Conduct designs according to specifications and requirements - Ensure designs and physical drawings meets requirements and specifications - Specify, conduct, plan, manage and control analyses - Compile design reports - Meticulous skills in Reactor accuracy - Analytical skills are required in reactor accuracy	- Decommissioning and decontamination - PRA - Specialised nuclear technology - Facility operations - Computer literacy and information technology - Arithmetic and mathematical reasoning and numeracy	- Improvements in the manufacturing process and the related efficiencies - Reactor design and analysis - Understanding of adjacent fields of product design - Control and instrumentation - CF control rods - Limitations for NPP utilisation

	by team members - Code-to-code and code-to-experiment V & V analysis -Mathematical model development - Analysis understanding - Methods and algorithm	- Verification and validation of computer codes		
Regulatory aspects	- Nuclear regulatory requirements - International regulatory practices - Licensing - Siting of nuclear installations	- Licensing	- Regulatory requirements and guidance - Authorisation - Inspection, investigation and auditing techniques	
Health, safety and radiation	-International codes and standards on safety - Safety principles - Criticality safety - Accident scenario definition	- Health and Safety - Radiation Protection - Application of the knowledge base to evaluate safety cases in those areas - Understanding of deterministic accident analysis - Application of conservatism in criticality safety demonstration	- Nuclear security - Deterministic safety analysis or assessment - Radiation protection - Emergency planning, preparedness, and response -Safety and protection-focused analytic techniques	
Project management	- Problem identification - Defining and planning of work - Contractual conditions - Environmental issues	- Contract expert consultants as and when required and to manage the contractual relationship	- Legal operations - Leadership and Planning - Negotiation - Conflict management	

	- Financial aspects in SA framework	- Identify possible suppliers for components and build relationships with the suppliers - Building and maintaining stakeholder relationships - Report progress to management or stakeholders	- Performance, project, quality, knowledge management - Organisational understanding - Building and maintaining stakeholder relationships - Stakeholder management - Information technology and HR management - Finance management - Corporate governance - Engineering and configuration management - Facility quality management systems - Compliance assurance and enforcement	
Systems, processes and procedures	- Procedures and concepts within technical /subject area - Record keeping and enterprise processes	- Develop, execute and maintain all the relevant and necessary processes and procedures - Monitoring systems -Obtain and discuss requirements with system engineers - Assist and advise systems engineers in compiling		

		specifications - Negotiate requirements with system engineers - Provide technical feedback to other parts of company within the appropriate process - Manage the processes for area of responsibility		
Other	- Report writing and formulating of recommendation - Technical reviews - Training and mentoring - Treatment of uncertainty and use of conservatism	- Communication skills (excellent demand of the spoken and written English language) - Participating in component qualification programmes - Facilitating and managing performance	- Communication competencies - Report writing, presentations - Interpersonal competencies - Nuclear Plant Operation - Training and development - Articulating and cascading the vision and values - Facilitating and managing performance - Business understanding - Teamwork and co-operation - Conceptual, analytical, innovative thinking - Problem solving and decision-making	-Actual case studies from Koeberg (Eskom)

3.3 ACADEMIC ENVIRONMENT

Globally, universities are ranked according to the institution's research productivity. In 2003, South Africa's higher-education institutions transformed from 36 universities and technikons to a total of 23 institutions (De Villiers & Steyn, 2007:3). The DoE has stated that one of the purposes of restructuring is to establish institutions that address current national skills needs (Inglesi & Pouris, 2008:1).

3.3.1 Subsidy formula

Before 2003, the governmental subsidy was allocated to universities and technikons through the South African Post-Secondary Education (SAPSE) funding formula, which was largely full-time enrolment- (FTE) driven (Ishengoma, 2002:5). This formula was in place for more than 20 years but did not address institutional inequalities or motivate institutions to increase the intake of disadvantaged students (Moja & Hayward, 2005:32). After the transformation of higher education institutions, a new funding framework (NFF) was introduced (Van Harte *et al.*, 2006:3). It was formally approved by the Ministers of Education and Finance respectively and was published in a Government Gazette in December 2003. (South Africa, 2003)

Subsidy allocations are separated into block grants (87% of the total subsidy amount) to cover operational costs of higher educations and earmarked grants designed for specific purposes.

The block funds are divided into:

- Teaching inputs;
- teaching outputs;
- research outputs; and
- institutional factor allocations.

Earmarked grants will be used for the following purposes (SA, 2003:13):

- The National Student Financial Aid Scheme;
- teaching, researching and community development;
- interest and redemption payments on loans approved and guaranteed before 1991;
- institutional restructuring, including mergers and the recapitalisation of institutions; and
- the higher-education quality assurance framework.

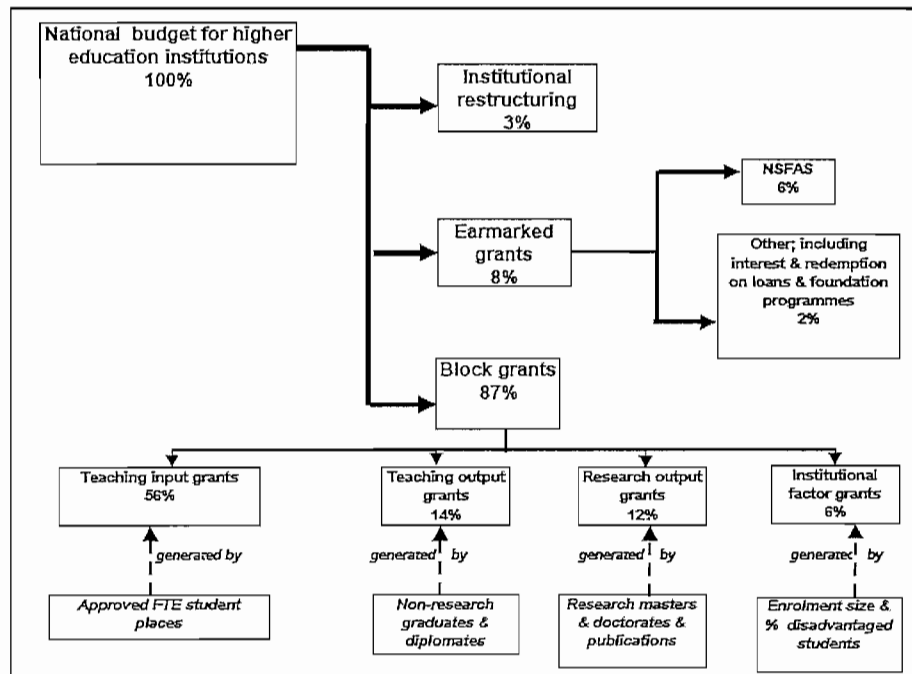


Figure 11: Division of government budget grant categories 2004/5 to 2006/7 (Department of Higher Education, 2004:5)

The **teaching input** allocation (64% of total block grants) is determined according to a funding grid. This funding grid includes Table 7, showing the Classification of Education Subject Matter (CESM) categories (Department of Higher Education, 2004:7). Students in the same CESM group will receive the same weight in teaching input subsidy as shown in Table 8.

Table 7: Allocation of academic disciplines to funding groups (Department of Higher Education, 2004:7)

Funding group	Classification of Education Subject Matter categories included in funding group
1	Education, law, librarianship, psychology, social services/public administration
2	Business/commerce, communication, computer sciences, languages, philosophy/religion, social sciences
3	Architecture/planning, engineering, home economics, industrial arts, mathematical sciences, physical education
4	Agriculture, fine and performing arts, health sciences, life and physical sciences

Table 8: Weighting factors for teaching inputs: 2004/05-2006/07 (Department of Higher Education, 2004:7)

Funding group (See Table 3-2)	Undergraduate & equivalent		Honours & equivalent		Master's	Doctoral
	Contact	Distance	Contact	Distance		
1	1.0	0.5	2.0	1.0	3.0	4.0
2	1.5	0.75	3.0	1.5	4.5	6.0
3	2.5	1.25	5.0	2.5	7.5	10.0
4	3.5	1.75	7.0	3.5	10.5	14.0

A student obtaining a Master's degree in nuclear engineering would fall within Funding group 3 and would therefore obtain the participating institution with a weighting factor of 7.5. All the students within an institution multiplied by their weighting factors contribute towards the total teaching input subsidy received by the higher education institution from the government.

The funding received by universities for **teaching outputs** is estimated by two separate funding calculations. The first formula combines different weightings for different types of degrees (see Table 9) multiplied by headcount of enrolled students. This determines the normative total. The second formula uses the same weighting as the normative total, but multiplied with graduates actually produced. This computes the actual teaching output (lower than the normative teaching output) for funding year n-2. Institutions may be eligible for a teaching development grant based on the difference between the normative and actual output totals (SA, 2003:13).

Table 9: Weighting factors for teaching outputs: 2004/05 to 2006/07 (Department of Higher Education, 2004:9)

1st certificates and diplomas of 2 years or less	0.5
1st diplomas and bachelors degrees: 3 years	1.0
Professional 1st bachelor's degree: 4 years and more	1.5
Postgraduate and postdiploma diplomas	0.5
Postgraduate bachelors degrees	1.0
Honours degrees/higher diplomas	0.5
Non-research masters degrees and diplomas	0.5

A student in a Master's degree in nuclear engineering programme primarily research- oriented, would obtain a weighting factor of 1.0. On the other hand, a student following a course-based Master's degree in nuclear engineering would obtain a weighting factor of only 0.5.

Universities receive an annual subsidy from the government, based on their **research outputs**, which include journal publications as well as Master's degree and Ph.D. graduates. Each university has a set target for research outputs (normative total). This is based on the number of

permanent academic staff, multiplied by a weighting factor (see tables 10 and 11) (Gower, 2009). Academic staff has a primary function of training Master's degree and Ph.D. students to conduct research. This will lead to publications for which the DoE will provide the institution with a research output subsidy, which serves as an extremely important source of income (NMMU, 2005:2). For the institutions that do not produce the normative total, but a lower actual research output, research development funding is available (Moja & Hayward, 2005:47).

Table 10: Weightings for research outputs: 2004/05 to 2006/07 (Department of Higher Education, 2009:13)

Publication units	1
Research masters graduates	1
Doctoral graduates	3

Table 11: Ratios of weighted publication units to permanently appointed instruction/research staff requirements: 2004/05 to 2006/07 (Department of Higher Education, 2009:13)

Universities	1.25
Technikons	0.5

A student obtaining a research-based Master's degree in nuclear engineering would obtain a weighting factor of 1.0. Publications will increase the total weighting factor, therefore increasing the total subsidy amount received by an institution.

Grants in the form of *institutional factor allocations* are also allocated to institutions with a large proportion of disadvantaged students, with social or economic deprived circumstances (COED, 2004). Institutions may therefore receive up to 10% subsidy added to their teaching input allocation based on the proportion of disadvantaged contact students. Table 12 shows the percentage added to teaching input grants based on the proportion of African and coloured contact students enrolled at an institution. The factor is calculated linearly.

**Table 12: Institutional factor grants for disadvantaged students: 2004/05 to 2006/07
(Department of Higher Education, 2009:16)**

Proportion of African + coloured students in relevant FTE student enrolment (SA citizens)	Additional amount added to relevant teaching input grant
80% and above	10.00%
75%	8.75%
70%	7.50%
65%	6.25%
60%	5.00%
55%	3.75%
50%	2.50%
45%	1.25%
40% and below	0.00%

It is important to note that all subsidy grants have a lag period of 2 years. Subsidy allocated for year n-2 is calculated in year n-1 and paid to the respective institutions in year n. Subsidy allocated to higher education institutions have been decreasing as universities only received 68% state subsidy entitlement of the expected subsidy income in 1996-1997 and only 53% of the expected income for 2002-2003 (Koen, 2003). This has put mounting financial pressure on institutions for higher education (Kriek, 2009).

3.3.2 Summary of the academic environment

Professor Arnold Schoonwinkel, dean of Engineering, Stellenbosch University, says: "The current state subsidy formula for coursework Master's is so low compared to research based Master's that most tertiary institutions are discouraged from offering coursework Master's degrees, unless they can make up the costs by charging fairly high class fees." (2009)

The subsidy allocation formula, explained in paragraph 3.3.1, indicates that higher education institutions will be driven by the need for research outputs in the form of publications and conference contributions in order to receive the maximum Governmental funding. Unless external funding was received or high class fees were charged, tertiary institutions are discouraged from offering course-based Master's degrees.

3.4 CONCLUSION

As stated by industry leaders, nuclear engineers should be educated by completing courses or modules at Master's degree level at higher education institutions to have a broad field of knowledge in the nuclear field.

When considering the subsidy allocation formula of a primarily course-based Master's degree in nuclear engineering, it is clear that it is not financially viable for any higher education institution and thus conflicts with the needs of the nuclear industry. A resolution therefore is that if academic institutions should educate engineers based on the needs of the industry, external funding to academic institutions will be required to uphold the programme. External funding required by higher education institutions to present nuclear education will be discussed in Chapter 5.

CHAPTER 4: COLLABORATION MODEL

4.1 INTRODUCTION

From the previous chapter it is clear that if higher-education institutions were to train nuclear engineers according to the needs of the industry, external funding would have to be provided towards this education in order to compensate for the smaller subsidy received by higher education institutions for course-based Master's degrees. The industry is reluctant to provide funding to one particular institution to train nuclear engineers. This is because one institution may not have all the resources at its disposal for training as desired by the industry.

A collaboration of South African higher-education institutions to present nuclear training provides the solution of centralising funding appeals to the nuclear industry for training nuclear engineers. It is also an answer to the much needed increase of nuclear skills in South Africa by providing training to nuclear engineers at Master's degree level. This collaboration for nuclear education initiative is being driven by the NIASA Sub-committee for Education.

In this chapter a concept for a collaboration effort between South African universities to present nuclear education at Master's degree level will be explained. From the literature study contained in the previous chapters, suggestions will be made towards the development and implementation of this collaboration effort. These suggestions will only be in concept form and can be finalised and decided on by the yet to be established consortium for collaboration.

4.2 CONCEPT

The model for collaboration between South African universities to present nuclear education at Master's degree level rests on the fact that all the participating universities register exactly the same programme on their PQM (Programme Qualification Mix). This programme is a Master's degree in nuclear engineering, which includes modules (core and electives) and a research component.

Students studying for this Master's degree in nuclear engineering have a choice of three streams of modules to research components (see Figure 12):

- **Option A** includes a 100% research component of 172 credits and one 8-credit Research Methodology module.

- **Option B** includes 50% course work (four core modules and one elective module, each worth 16 credits) and 50% research component of 92 credits with a Research Methodology module of 8 credits.
- **Option C** includes 70% course work (four core modules and four elective modules, each worth 16 credits) and 30% research component. The research component includes a 44-credits research project and a Research Methodology module of 8 credits.

One credit represents 10 hours of work to be done by the average student.

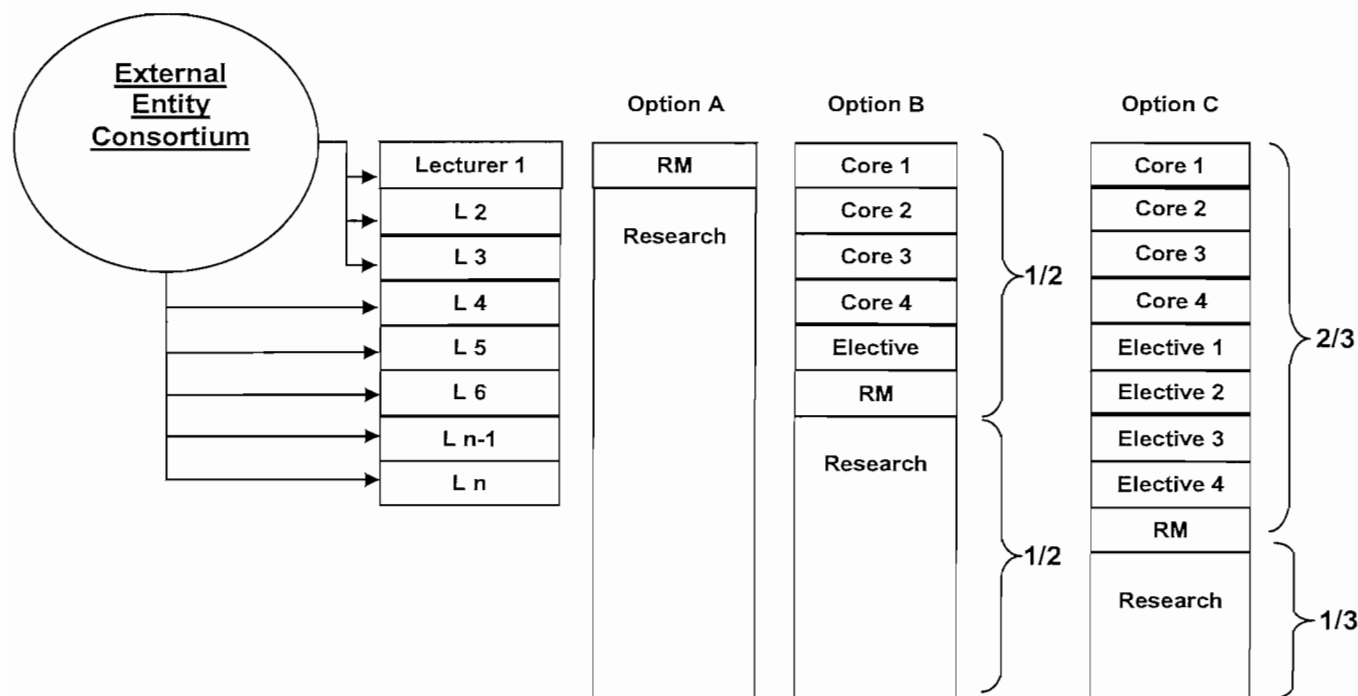


Figure 12: Explanation of model

Each student will be free to register for part-time, while employed or full-time studies at a specific participating university that specialises in the research field that interests him or her. The university where a student is registered will provide him with a supervisor and the necessary mentorship to complete research at that institution. A national curriculum of modules will be presented with the aid of a national schedule to all the students registered at participating universities in the national programme. Lecturers of modules that are nuclear field experts will teach the course work to all students registered at all participating universities according to the national schedule. The delivery of the modules can be achieved through an e-learning platform and partial contact sessions as will be explained in Chapter 6. After a student has completed his Master's degree in nuclear engineering, he will be able to apply to register for a Doctor of Philosophy (Ph.D.) at any of the participating universities.

As explained in Chapter 2, higher-education institutions receive subsidy grants from the government for every module completed and research outputs and publications by students registered at that institution. The process of carrying over subsidy allocations from university to university and recognising modules from other universities is time- consuming and complicated. This concept model for collaboration ensures that a student registers at a specific university. In this way, although modules are taught simultaneously to all students at all participating universities by the same lecturer, all subsidy allocations for a specific student will be received by the university where the student is registered. This university will also confer the Master's degree in nuclear engineering.

An external entity with representatives from each participating university and nuclear industry leader will manage the programme as well as the quality assurance thereof. This external entity, independent from any of the participating universities, will attain lecturers to present modules and handle funding from the nuclear industry and government agencies for this training of nuclear engineers. A suggestion for the governance structure will be provided in paragraph 4.4.

4.3 OBJECTIVE OF THE CONSORTIUM

The primary objective of the consortium is to ensure a sustainable supply of qualified nuclear engineers to meet the current and future needs of the South African nuclear industry through university education, university-based training and by encouraging young people to choose nuclear careers.

4.4 GOVERNANCE STRUCTURE (EXTERNAL CONSORTIUM AND COMMITTEES)

The collaboration effort between South African universities requires an effective governance structure. Three possible governance structures, including their advantages and disadvantages, are tabled as follows:

Table 13: Possible governance structures of collaboration effort

Governance structure	Advantages	Disadvantages
1. Each university manages own programme	- Academic freedom	- Duplication of organisational and academic work and administration - No common objective - Increase in number of personnel needed - High costs because of

		duplication
2. Nominated university manages unified programme	- No duplication of work - Short decision making process - Cost effective	- Participating universities' academic, quality and other standards may clash from - Academic freedom in all participating universities is compromised
3. External consortium manages unified programme	- No duplication of work - Cost effective - Academic & quality standards include minimum from all participating universities, therefore, minimizes potential clash - Minimize work-load and responsibility of participating universities - Single entry point for industry - External consortium would receive input from all participating universities on management structures and processes	- Academic freedom in all participating universities may be compromised

Weighing the advantages and disadvantages in Table 13, the collaboration would most probably require an external legal entity independent of any one of the participating universities. This external legal entity will relieve the participating universities from administrative responsibilities and will act as a single entry point for industry input. The legal entity can be established in the form of a consortium. A consortium, as per definition, is a partnership or by articles of association, specifically a temporary alliance of two or more business firms in a common venture (Webster, 1990).

The objective of this consortium, as provided in paragraph 4.3, is a combination of the objectives of NTEC and UNENE, as discussed in paragraph 2.1. The governance structure of this consortium should therefore be a combination of the organizational structure of UNENE and NTEC, as analysed in paragraph 2.1.7. The consortium will include the following committees:

4.4.1 Board of Directors

The **Board of Directors** will include representatives from each of the participating universities and representatives from the nuclear industry. This Board will determine the members of the consortium and the structure of the committees.

4.4.2 Advisory Committee

The **Advisory Committee** will comprise leaders in the nuclear industry and other role players in the education of nuclear engineers. The main objective of this committee will be to guide the association towards the needs of the end-users or nuclear industry. This will be achieved by providing input into the education and curriculum of the programme presented to nuclear engineers.

4.4.3 Steering Committee

The **Steering Committee** will develop, establish and maintain policies, procedures and strategies towards the operation of the programme. This committee will comprise of senior academics from the participating universities. Special attention will be paid to the quality assurance procedures that will have to be put in place as will be explained in paragraph 4.8. The input and recommendations received from the **Advisory committee** will be implemented in developing the details of the programme, curriculum, administration and other processes.

4.4.4 Programme director

The **programme director** will handle all day to day activities of the consortium. These activities include the operation of the programme as well as the implementation and management of processes as was established by the Steering Committee. The programme director will therefore report to the Steering Committee. A **programme administrator** will assist the programme director by managing *inter alia* administration, scheduling, courses and students.

4.5 ADMINISTRATION PROCESSES

The Steering Committee of the consortium will have to put certain procedures and processes in place to simplify and aid the operation of the programme and the communication between the participants of the consortium.

Keeping academic freedom of universities in mind, the following aspects will have to be considered when establishing the processes:

4.5.1 Accounts and fees

A membership fee payable by the consortium members should be decided on. The fees and financial implications are discussed in Chapter 5.

4.5.2 Programme validation and approval and review procedures

The Steering Committee, with input from the Advisory Committee, will develop the programme curriculum to be registered and approved. The programme will be registered at each university and be approved by the Department of Higher Education (DHET) in South Africa. This process will be described in paragraph 4.8. Students will therefore be able to register at any of the participating universities. The programme will be organised by the programme director, using procedure manuals to be set up by the Steering Committee.

4.5.3 Promotional material and courseware

The programme director will be responsible for the co-ordination of marketing material. Each participating university will be responsible for promoting the programme within their institution. Participating institutions will only be able to refer to the programme or consortium in any publicity as will be set out in guidelines by the Steering Committee. No participating institution may use the consortium logo without the consent of the Steering Committee.

4.5.4 Registration at universities

Students wishing to register for the programme can apply at the programme director with a special indication of the university where he wishes to be registered. The approval processes will be handled by the programme director with assistance from the Steering Committee.

4.5.5 Admissions policy and procedure

Student admissions to the programme will be handled by the programme director according to the admission criteria put in place by the Steering Committee using the minimum requirements as set by the participating universities. Exceptions will be handled by the Steering Committee.

4.5.6 Examination

The Steering Committee will compile a list of external examiners with input and approval from the Advisory Committee. These external examiners will then be appointed by the programme director.

4.5.7 Quality assurance and control

The Steering Committee will establish quality assurance processes and standards at the start of the programme by including all the minimum standards set by the participating universities. These processes and standards will be reviewed by the Steering Committee on an annual basis. The Advisory Committee will review and approve the quality assurance processes and standards before being implemented by the programme director. Participating universities will conduct a review of the programme every four years according to their own internal procedures.

4.5.8 Provision of facilities

All participating universities will provide facilities for full-time students registered at their institution to carry out the self-study parts of the modules offered. Universities will also offer research facilities to all students registered at that institution. The programme director, with assistance from the programme administrator, will organise lecture-room facilities and practical laboratories for the modules offered.

4.5.9 Awards

The marks for modules will be awarded by the lecturers and external moderators who will be appointed by the programme director. External examiners will also be approved by the participating universities. The marks for dissertations (the research component) and overall marks will be awarded by the university that the student is registered at. This university will also confer the Master's degree in nuclear engineering.

4.6 CURRICULUM OF PROGRAMME

The programme that will be presented by the collaboration of South African universities is a Master's degree in nuclear engineering. This programme will consist of a curriculum of modules offered to students and research to be done by the students in this programme. It is important that the curriculum that will be presented should be developed with input from the South African nuclear industry. In this paragraph, the only currently approved and available Master's degree in nuclear engineering in South Africa will be discussed and compared to the needs of the nuclear industry as was obtained in paragraph 3.2.1. A recommendation will be made towards the development of a detailed curriculum for a Master's degree in nuclear engineering.

4.6.1 Modules

The Postgraduate School for Nuclear Science and Engineering at the North-West University (NWU) currently offers the only approved Master's degree in nuclear engineering in South

Africa. The modules are offered as part of four possible study tracks: Pressurized Water Reactor (PWR) Systems Analysis, High Temperature Reactor (HTR) Systems Analysis, HTR Reactor Design and Nuclear Engineering Management (see Figure 13). The modules comprise of four compulsory and 10 elective modules, separating the students into the different specialised groups.

POSSIBLE STUDY TRACKS				
	PWR Systems Analysis	HTR Systems Analysis	HTR Reactor Design	Nuclear Engineering Management
1	Nuclear Engineering I	Nuclear Engineering I	Nuclear Engineering I	Nuclear Engineering I
2	Nuclear Engineering II	Nuclear Engineering II	Nuclear Engineering II	Nuclear Engineering II
3	Reactor Analysis	Reactor Analysis	Reactor Analysis	Reactor Analysis
4	Reactor Safety	Reactor Safety	Reactor Safety	Reactor Safety
5	PWR Technology	HTR Technology	HTR Technology	HTR Technology
6	Thermal Fluid Systems Modelling I	Thermal Fluid Systems Modelling I	HTR Fuels and Materials	PWR Technology
7	Computational Fluid Mechanics I	Computational Fluid Mechanics I	Advanced Reactor Analysis I	Nuclear Project Management I
8	LWR Thermal-Hydraulics	HTR Thermal-Fluid Analysis	PBMR Design	Nuclear Project Management II

Figure 13: Modules currently presented by the NWU (PGSNE, 2008)

A brief description of each of the modules offered by the NWU is provided in Annexure C. It can be noted that this curriculum contains detail content to cater for students with no background or prior studies in nuclear engineering.

4.6.1.1 Comparison with nuclear industry needs

The nuclear industry needs for nuclear engineers obtained were summarised in paragraph 3.2.1. This was compared to the Master's degree in nuclear engineering programme offered by the NWU. As can be seen in Table 14, Table 15 and Table 16, the outcomes required by the nuclear industry are largely covered by the modules in the programme.

Table 14: Knowledge outcomes covered by modules offered by NWU (not in any particular order)

	Knowledge outcomes	Covered by NWU modules
Nuclear Materials, Physics and Chemistry	- Nuclear materials - Chemistry in general - Uranium and fluoride chemistry - Water chemistry - Core physics (neutronics) - Core kinetics analysis - Thermal-hydraulics - System core thermal-hydraulics - System thermal-hydraulics	- Nuclear Engineering 1 - Nuclear Engineering 2 - Thermal-fluid Systems Modelling 1 - HTR Fuels and materials - Reactor analysis - Advanced reactor analysis 1 - HTR technology - LWR thermal-hydraulics - Computational Fluid Mechanics 1 - Covered in undergraduate studies and pre-requirement for enrolling for the Master's degree
Fuel and Waste	- Design and handling - Storage - Transport - Waste handling - Fission product transport and plate-out analysis - In-core behaviour and depletion effects - Fuel management and performance analysis - Radioactive waste characterisation	- Nuclear Engineering 2 - Reactor analysis - Reactor safety - PWR technology - HTR technology - PBMR design
Analysis, Design and Engineering	- Life cycle of nuclear plant (birth, maintenance operation, decommissioning) - Plant engineering and relevant analysis - Computer codes, methodologies applied, assumptions made and interpretation of results - Nuclear facility behaviour under design, transient and accident conditions - Chemical and mechanical engineering principles - PWR	- Nuclear Engineering 1 - Nuclear Engineering 2 - Reactor analysis - Advanced Reactor Analysis 1 - Reactor safety - Computational Fluid Mechanics 1 - PWR technology - HTR technology - PBMR design - Nuclear project management - Mathematics for nuclear engineers

	-Ensure the technical quality and correctness of analysis performed by team members - Code to code and code to experiment V & V analysis - Mathematical model development - Analysis understanding - Methods and algorithm	- Covered in undergraduate studies and a pre-requirement for enrolling for the Master's degree
Regulatory aspects	- Nuclear regulatory requirements - International regulatory practices - Licensing - Siting of nuclear installations	- Nuclear Engineering 1 - Nuclear Engineering 2 - Reactor safety - PWR technology
Health, Safety and Radiation	- International codes and standards on safety - Safety principles - Criticality safety - Accident scenario definition	- Nuclear Engineering 1 - Nuclear Engineering 2 - Reactor safety - HTR technology
Project Management	- Problem identification - Defining and planning of work - Contractual conditions - Environmental issues - Financial aspects	- Nuclear project management 1 - Nuclear project management 2 - Reactor Safety
Systems, Processes and Procedures	- Procedures and concepts within technical /subject area - Record keeping and enterprise processes	- Nuclear project management - Research project
Other	- Report writing and formulating recommendation - Technical reviews - Training and mentoring	- Research methodology - Nuclear project management 1 - Nuclear project management 2 - Research project

Table 15: Skills outcomes covered by modules offered by NWU (not in any particular order)

	Skills outcomes	Covered by NWU modules
Nuclear Materials, Physics and Chemistry	- Participate in the material specifications and material testing programmes	- HTR fuels and materials
Fuel and	- Understanding of fuel management	- PWR technology

Waste	philosophies and related safety demonstrations - Ability should be obtained to establish facilities for the testing of processes relating to the PWR fuel fabrication for uranium conversion processes through powder metallurgy processes and mechanical engineering assembly components.	- HTR technology - Reactor safety
Analysis, Design and Engineering	- Nuclear lifecycle - All phases of design, manufacturing and production and quality assurance - Conduct designs according to specifications and requirements - Ensure designs and physical drawings meets requirements and specifications - Specify, conduct, plan, manage and control analyses - Compile design reports - Meticulous skills in reactor accuracy - Analytical skills are required in reactor accuracy - Verification and validation of computer codes	- Nuclear Engineering 1 - Nuclear Engineering 2 - Reactor analysis - Advanced Reactor Analysis 1 - Reactor Safety - PWR technology - HTR technology - HTR fuels and materials - PBMR design - Covered in undergraduate studies and a pre-requirement for enrolling for the Master's degree
Regulatory aspects	- Licensing	- Reactor safety
Health, Safety and Radiation	- Health and safety - Radiation protection - Application of the knowledge base to evaluate safety cases in those areas - Understanding of deterministic accident analysis	- Nuclear Engineering 1 - Reactor safety
Project Management	- Contract expert consultants as and when required and manage the contractual relationship - Identify possible suppliers for components and build relationships with the suppliers - Building and maintaining stakeholder	-Nuclear Project Management 1 -Nuclear Project Management 2

	relationships - Report progress to management or stakeholders	
Systems, Processes and Procedures	- Develop, execute and maintain all relevant and necessary processes and procedures - Monitoring systems - Obtain and discuss requirements with system engineers - Assist and advise system engineers in compiling specifications - Negotiate requirements with system engineers - Provide technical feedback to other parts of company within the appropriate process - Manage the processes for area of responsibility	- Project management
Other	- Communication skills (excellent demand of the spoken and written English) - Participate in component qualification programmes - Facilitating and managing performance	- Covered in undergraduate studies and a pre-requirement for enrolling for the Master's degree - Research methodology - Project management

Table 16: Competencies outcomes covered by modules offered by NWU (not in any particular order)

	Competency outcomes	Covered by NWU modules
Materials, Physics and Chemistry	- Reactor kinetics	- Nuclear Engineering 1 - Nuclear Engineering 2 - Reactor analysis
Fuel and Waste	- Waste management - Transport of fuel - Fuel temperature measurement - Fuel temperature coefficient calculation	- Nuclear Engineering 1 and 2 - Reactor safety - HTR technology - PBMR design
Analysis, Design and Engineering	- Decommissioning - Decontamination - PRA	- Nuclear Engineering 2 - Reactor safety - PWR, HTR technology

	- Specialised nuclear technology - Facility operations - Computer literacy and information technology - Arithmetic and mathematical reasoning and numeracy	- PBMR Design - Covered in undergraduate studies and a pre-requirement for enrolling for the Master's degree
Regulatory aspects	- Regulatory requirements and guidance - Authorisation - Inspection, investigation and auditing techniques	-Nuclear Project Management 2 - Reactor safety
Health, Safety and Radiation	- Nuclear security - Radiation protection - Deterministic safety analysis or assessment - Emergency planning, preparedness, and response - Safety and protection-focused analytic techniques	- Reactor safety - Nuclear Engineering 1 - Nuclear Engineering 2
Project Management	- Legal operations - Leadership - Planning - Negotiation - Conflict management - Performance, project, quality, knowledge management - Organisational understanding - Building and maintaining stakeholder relationships - Stakeholder management - Information technology and HR management - Finance management - Corporate governance - Engineering and configuration management - Facility quality management systems - Compliance assurance and enforcement	- Reactor safety -Nuclear Project Management 1 -Nuclear Project Management 2
Other	- Communication competencies - Report writing, presentations	- Research Methodology - Covered in undergraduate

	- Interpersonal competencies - Nuclear Plant Operation - Training and development - Articulating and cascading the vision and values - Facilitating and managing performance - Business understanding - Teamwork and co-operation - Conceptual, analytical, innovative thinking - Analytical thinking, problem solving and decision-making	studies and a pre-requirement for enrolling for the Master's degree - Soft skills
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Table 14, Table 15 and Table 16 show that the outcomes required by the South African nuclear industry are mostly met by the modules already registered. The following knowledge, skills and competencies need to be clearly incorporated in the curriculum:

- Knowledge on plate-out analysis and in-core behaviour
- Knowledge on plant engineering and relevant analysis
- Knowledge on technical and enterprise systems, processes and procedures
- Skills on how to develop and maintain technical, quality and management processes and procedures
- Knowledge on nuclear materials and chemistry (specifically water, uranium and fluoride)
- Skills in the material specifications and material testing
- Knowledge and skills on fuel cycle, fuel temperature measurement, temperature coefficient calculation and waste classification and management
- Knowledge and skills on the verification and validation of computer codes
- Knowledge and skills on mathematical model development
- Knowledge, skills and competencies on regulatory aspects, including licensing, inspections, auditing and investigation techniques in the South African environment
- Knowledge and skills on regulatory requirements and guidance, authorisation, compliance assurance and enforcement
- Knowledge and skills on the evaluation of safety cases, accident analysis and application of conservatism in criticality safety demonstration
- Knowledge, skills and competencies in emergency planning, preparedness, and response
- Skills on Facility Operations and Quality Management Systems
- Knowledge, skills and competencies on report writing and presenting
- A simulated control room of an actual reactor can be very helpful in developing the necessary operating and safety competencies for the nuclear industry.

4.6.1.2 Blended learning

The modules that will be presented as part of the collaborative programme can be delivered by using a blended-learning method. This blended-learning model will include distance e-learning aspects, as well as face to face contact sessions. (See Chapter 6 for more information).

4.6.2 Research

Research is a fundamental part of any Master's degree. Research studies can be completed in the following options of Master's degrees:

- Option A Master's degree: comprehensive research dissertation (172 credits research);
- Option B Master's degree: research dissertation (92 credits research); or
- Option C Master's degree: mini research dissertation (44 credits research).

It is important that the research completed by students registered in the collaboration programme be industry-specified and oriented. Table 17 provides research topics that were specified by the nuclear industry. Actual case studies from the nuclear industry can contribute to excellent research topics.

Table 17: Research topics specified by SA nuclear industry

Nuclear Materials, Physics and Chemistry	Fuel and Waste	Analysis, Design and Engineering
- Diffusion study - Femtochemistry (SiC Improvement) - Application of nuclear physics - Ag migration and plate-out study - SiC nanotubes study - Si Isotopes study - Impact of CVD conditions on SiC layer - Graphite dust study, life extension (radiation damage), characterisation and feedstock (coke) - Heat-resistant concrete	- Fuel modelling - Nuclear fuel cycle - Waste heat recovery and use - Waste management	- Improvements in the manufacturing process and the related efficiencies - Reactor design and analysis - Understanding of adjacent fields of product design - Control and instrumentation - CF control rods - Limitations for NPP Utilisation

- | | | |
|---|--|--|
| - High-temperature materials
- Passive cooling | | |
|---|--|--|

4.7 ENTRY REQUIREMENTS FOR THE PROGRAMME

The entry requirement for the Master's degree in nuclear engineering offered by the consortium is any four year engineering Bachelor's degree. Students not in possession of a Bachelor's degree in mechanical or chemical engineering degree must register for the bridging modules: ***Thermal-Fluid Sciences*** and ***Mathematics for Nuclear Engineers***, in order to obtain knowledge and skills in the problem solving of thermal-fluid problems. Students will complete these bridging modules before starting with the programme modules (see paragraph 4.6.1) that contribute credits towards obtaining the Master's degree in nuclear engineering.

4.8 REGISTRATION OF PROGRAMME

All new programmes presented by higher-education institutions have to be accredited and registered before they can be presented. The collaborative programme for delivery of a Master's degree in nuclear engineering by South African universities will also have to be accredited and registered. According to Prof. Themba Mosia, institutional registrar at the North-West University (2009) the accreditation and registration process for the collaboration program will include the following steps:

4.8.1 Internal approval

Each institution will present the collaborative programme at its own institutional committee for academic standards and registrations for internal approval. It is important that details on the collaborative delivery method are shared with the committee. After the internal approval of the programme at a participating university has been completed, the external accreditation and registering processes can commence.

4.8.2 Registration and funding (DHET)

Each participating university will complete an application at the Department of Higher Education and Training (DHET) for subsidy purposes. The closing date for this application is around mid-April and mid-October. Each university will apply as a separate institution, while each university's application documentation will include detail on the collaborative delivery method.

4.8.3 Accreditation (HEQC)

Within three weeks from the approval from the DHET, each participating university will have to complete an online application for accreditation from the Higher Education Quality Committee (HEQC), which falls under the Council on Higher Education (CHE). Once again, each university will separately apply for accreditation but will mention the collaborative delivery programme. According to the Council on Higher Education website (CHE, 2009), the evaluation panel constituted by the HEQC will recommend one of three options: provisional accreditation, provisional accreditation with conditions, or no accreditation.

Two years after the provisional accreditation has been authorised, the HEQC will revisit each institution to re-evaluate the accreditation.

4.8.4 Registration (SAQA)

After the accreditation of the programme has been completed, each participating university will have to apply for registration from the South African Qualifications Authority (SAQA). SAQA will publish the new programme in a Government Gazette for comments from the public. If no issues are raised within 30 days, the programme will be registered in the National Qualifications Framework (NQF). If questions are raised, a meeting will be held to discuss these queries.

SAQA will also present the programme to the government as part of the National Learning Record Database (NLRD).

4.8.5 Parallel universities (HEQC)

HEQC will send the application for the programme to all parallel universities to evaluate and give feedback to the HEQC. As this programme is a collaboration effort between South African universities, this step in the registration process should be handled quickly. If authorisation is attained, the programme is registered.

4.9 QUALITY ASSURANCE

To ensure the quality of the programme offered by the consortium and participating universities, the Steering Committee will have to put quality control processes into place that will be implemented by the programme director and the participating universities. These quality control processes will include the minimum quality control actions performed and processes already implemented at all the participating universities. The process of presenting the collaboration programme should undergo internal and external quality control.

4.9.1 Internal quality control

The internal quality control of the programme will be handled by the programme director. The following aspects should be considered in setting up the internal quality assurance processes:

4.9.1.1 Programme curriculum

- The participating universities will ensure that the curriculum meets their minimum academic standards.
- The curriculum should be created by taking cognisance of the needs of the nuclear industry.
- The curriculum should be approved by the Department of Education.

4.9.1.2 Design of the modules

- Appropriate pedagogical principles, active learning and student-centred learning should be incorporated in designing the modules.
- The modules should be designed according to the needs of the nuclear industry.
- The modules should be designed according to the universities' internal quality control.

4.9.1.3 Delivery method and learning resources of the modules

- The students taking the modules will complete a questionnaire for feedback on the delivery method of the modules.
- Learning resources should be evaluated according to the universities' internal quality control.

4.9.1.4 during the delivery of the modules

- The students will complete a questionnaire for feedback on the teaching quality and effectiveness of the lecturer.
- The students will complete a questionnaire for feedback on all other delivery aspects of the modules.

4.9.2 External quality control

The external quality control of the programme will be handled by the Steering Committee and personnel appointed by the Steering Committee with input from the Advisory Board. The following aspects should be considered in setting up the external quality assurance processes:

4.9.2.1 Assessment

- The Steering Committee will appoint external moderators with input from the Advisory Board.
- The external moderators will evaluate the modules.
- The external moderators will evaluate the examination papers.

4.10 CONCLUSION

In this chapter a concept for a collaboration effort between South African universities to present nuclear education at Master's degree level was clarified. Suggestions towards the development and implementation of the curriculum, entry requirements to the programme, governance structure, administration and quality assurance processes were provided.

As this model was explained in concept form, details will have to be finalised once the consortium has been established. These details include the following:

The consortium should obtain input from the international nuclear industry and complete a thorough GAP analysis between available international curriculums and the needs of the international industry for the content of the curriculums, before finalizing the South African curriculum. Furthermore, all administration, academic and quality assurance processes should be developed by keeping in mind the participating universities' academic freedom.

The financial model in the form of a budget for the consortium will be discussed in the following chapter, Chapter 5.

CHAPTER 5: FINANCIAL MODEL

5.1 INTRODUCTION

In the previous chapter the concept for a collaboration effort between South African universities to present nuclear education at Master's degree level was discussed. In this chapter the financial models that were developed for the independent external consortium as well as for the participating universities for 2010 – 2017 will be provided and discussed. Furthermore, two different scenarios of input to the financial models in the form of the number of Master's degree and Ph.D. students in the programme will be investigated. The collaboration programme will be modelled as a financial system and the financial subsidy grant model will also be verified.

5.2 EXTERNAL CONSORTIUM

The financial model that was set up for the external consortium is in the format of a budget for the term 2010 to 2017.

5.2.1 Expenses

The external consortium will carry the costs of presenting the programme, including its modules. Permanent personnel in the form of a programme director and programme administrator will be appointed to manage the programme in the external consortium. The budget of the consortium will therefore include the following expenses:

1. Course expenses
 - Course development
 - International lecturers
 - National lecturers
 - Teaching assistants
 - Moderators
2. Permanent personnel salaries
3. Other expenses
 - Operational
 - Marketing
 - Office rent

These expenses are adjusted by a list of variables that serves as input to the model. (See Table 18) The values shown are for illustrative purposes only, for example: 10 students per

participating university at the start of the programme. These values will have to be agreed on by the collaboration participants. The total expenses and an adjustable reserve contingency fund is payable by the consortium.

Table 18: Budget for the consortium (variables)

Budget for the Consortium 2010 - 2017: Variables

	2010	2011
	Amount (R)	Amount (R)
EXPENSES		
1.1 Masters courses		
Number of first year registrations	60	72
First year 35% payable	R 7,396	
Second year 35% payable	R 7,396	
Third year 30% payable	R 6,338	
1.2 Temporary Personnel		
Number of courses developed	13	1
Course Development (per course)	R 50,000	
International Lecturers (per course)	R 60,000	
National Lecturers (per course)	R 30,000	
Teaching Assistants (per course)	R 10,000	
Moderators (per course)	R 3,000	
1.3 Continue rate		
Discontinue after first year	10%	
Discontinue after second year	5%	
Discontinue after third year (before completing)	0%	
1.4 Options of Masters Degrees		
Option A	10%	
Option B	20%	
Option C	70%	
TOTAL		
2 Permanent Personnel		
Number of Program Directors	1	1
Program Director salary	R 600,000	
Number of Coordinators	1	1
Program Coordinator salary	R 200,000	
TOTAL		
3 Other Expenses		
3.1 Operational Budget		
Telephone and Courier	R 27,000	
Tuition and Training	R 4,000	
Assets and Maintenance	R 6,500	
Catering and Entertainment	R 30,000	
Furniture	R 70,000	R 3,000
Travel Expenses	R 115,000	
Computer, network and other equipment	R 86,000	R 9,200
Other Office Expenses	R 37,000	
Other Administration Expenses	R 34,000	
Banking fees	R 2,000	
Marketing Budget	R 50,000	
Rent of offices	R 80,000.00	
TOTAL		
TOTAL EXPENSES		
Increase (inflation) per year	9.0%	
Reserve contingency fund	5.0%	
External Funding Required		

5.3 PARTICIPATING UNIVERSITIES

The financial model that was established for the participating universities is in the format of a budget for the term 2010 to 2017.

5.3.1 Expenses

The expenses to run the collaboration programme of each of the participating universities will include the following:

1. Research expenses
 - Master's degree bursaries
 - Ph.D. bursaries
2. Permanent personnel salaries
3. Other expenses
 - Operational
 - Marketing

5.3.2 Income

The participating universities will receive income in the form of class fees and subsidy grants, depending on the number of students registered for the programme.

5.3.3 Class fees

Each participating university will specify their own class fees payable by students registering at their institution for the Master's degree in nuclear engineering programme.. In this way, class fees for all participating universities will be equal. Universities will therefore receive class fees from students registered at their own institution.

5.3.4 Subsidy grants

Participating universities will receive subsidy grants from the government in the form of teaching input, teaching output and research output subsidies. These amounts are calculated by specified factors, student numbers and government-allocated grant amounts as was described in paragraph 3.3.1. Subsidy calculations were included in the financial model for participating universities.

The income, expenses and subsidy calculation variables are adjusted by a list of variables that serves as input to the model. The values shown are for illustrative purposes only and need to be agreed on by the collaboration participants. (See Table 19 and Table 20)

Table 19: Budget (income) for participating University (variables)
BUDGET: South African Universities 2010 - 2017: Variables

		2010	2011
		Amount (R)	Amount (R)
INCOME			
1	Research Funding		
1		R -	
2		R -	
	TOTAL		
2	General Income		
1		R -	
2		R -	
	TOTAL		
3	Class fees and subsidy income		
3.1	Masters class fees		
	First year 35% payable	R 7,396	
	Second year 35% payable	R 7,396	
	Third year 30% payable	R 6,338	
	Number of masters student registrations		
	Number of first year registrations	10	
	Increase in first year registrations	20.0%	
	Max of first year registrations	20	
3.2	Masters subsidy income		
	Continue rate of Masters Degree Students		
	Discontinue after first year	10%	
	Discontinue after second year	5%	
	Discontinue after third year (before completing)	0%	
	Percentage Masters students complete in 2 years	20%	
	Percentage Masters students complete in 3 years	80%	
	Masters Degree Options (Students)		
	Option A	0%	
	Option B	0%	
	Option C	100%	
3.2	PhD subsidy income		
	Continue rate of PhD Students		
	Discontinue after first year	10%	
	Discontinue after second year	10%	
	PhD		
	PhD Publication income per graduant	80,000	
	PhD continue from M graduants	0.0%	
	Number op first year PhD students at start of program	0	
	Percentage PhD students complete in 3 years	20%	
	Percentage PhD students complete in 4 years	80%	
	TOTAL		
	Minus Contribution to University	20%	
	TOTAL INCOME		

Table 20: Budget (expenses) for participating University (variables)

EXPENSES		
1	Research Expenses	
	Masters degree Bursaries amount	R 80,000
	Percentage of M students obtaining bursaries	0%
	PhD Bursaries amount	R 160,000
	Percentage of PhD students obtaining bursaries	0%
	Other	
	TOTAL	
2	Courses Expenses	
2.1	Masters courses	
	Covered by the Consortium	
	TOTAL	
3	Personnel Expenses	
	Number of Research personnel	1
	Professor	R 600,000
	Number of Administrative personnel	2
	Programme administrator	R 250,000
4	Other Expenses	
4.1	Operational	
	Telephone and Courier Services	13,000.00
	Travel expenses	50,000.00
	Catering and Entertainment	15,000.00
	Furniture	10,000.00
	Assets and Maintenance	7,700.00
	Computer, network and other equipment	60,000.00
	Other Administration Expenses	13,500.00
	Facilities / Office rent	15,000.00
	Other Office expenses	3,600.00
	Banking fees	300.00
	Marketing	R 10,000
	TOTAL	
	Inflation	9.0%
	TOTAL EXPENSES	
	INCOME - EXPENSE	
	Balance from previous year (Opening balance)	
	Closing Balance	

5.4 SCENARIO 1: PURELY OPTION C MASTER'S DEGREE STUDENTS IN PROGRAMME

As discussed in paragraph 3.2, the nuclear industry of South Africa prefers nuclear engineers to be trained by offering primarily coursework at Master's degree level. In this paragraph, the financial implications will be discussed by creating the following scenario:

Nuclear engineers will be trained by offering primary course work Master's degrees from participating universities. Therefore, all Master's degree students register for an Option C Master's degree and no Ph.D. students are registered in the programme. In this scenario, universities conduct the minimum possible research in a post-graduate programme.

5.4.1 Scenario 1: Attributes

5.4.1.1 Participating universities

The variables that serve as input to the Participating Universities financial model were set to the values as shown in Table 19 and Table 20. This includes:

- Number of first year registrations for the Master's degree programme per university: **10** (completing an Option C Master's degree)
- Increase of first year Master's degree registrations from 2010-2017: **20%**
- The Master's degree registrations per year increase to a maximum of: **20**
- Number of Ph.D. registrations in programme: **0**

5.4.1.2 External consortium

The variables that serve as input to the consortium's financial model were set to the values as shown in Table 18 for 2010. An assumption of **six** participating universities in the collaboration programme provides a total number of **60** (10 students x 6 universities) first year registrations for the Master's degree programme.

5.4.2 Scenario 1: Outcomes

5.4.2.1 Participating universities

The class fees and subsidy income received by a participating university is shown in Figure 14. The subsidy grants will only be received from 2012 onwards because of the two-year lag period in governmental subsidy allocation. The income will increase from R74 k in 2010 to R1,5 m in 2017.

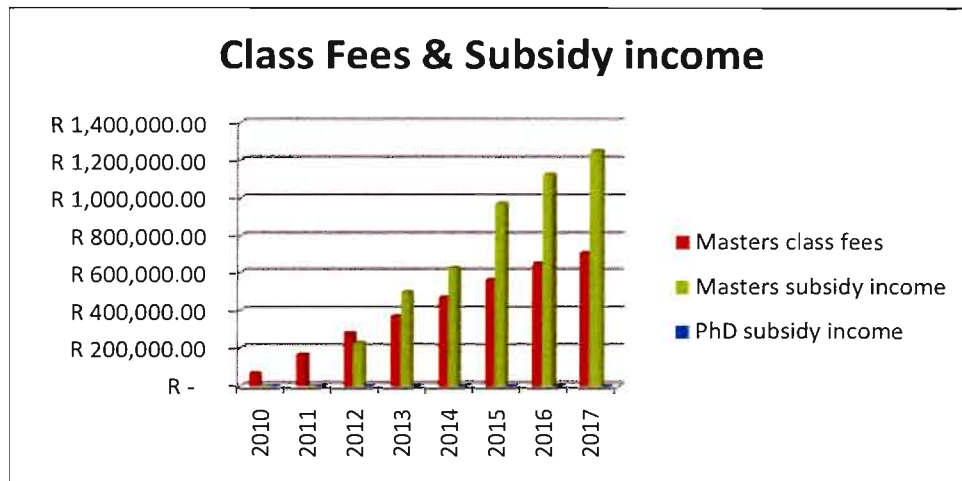


Figure 14: Participating university class fees and subsidy income (Scenario 1)

On the other hand, the permanent personnel salaries and operational expenses per university will increase from R1,2 m in 2010 to R2,2 m in 2017, as seen in Figure 15.



Figure 15: Participating university expenses (Scenario 1)

The net cash flow effect will result in a negative cash flow of R1,2 m in 2010 and R623 k in 2017, as indicated in Figure 16.

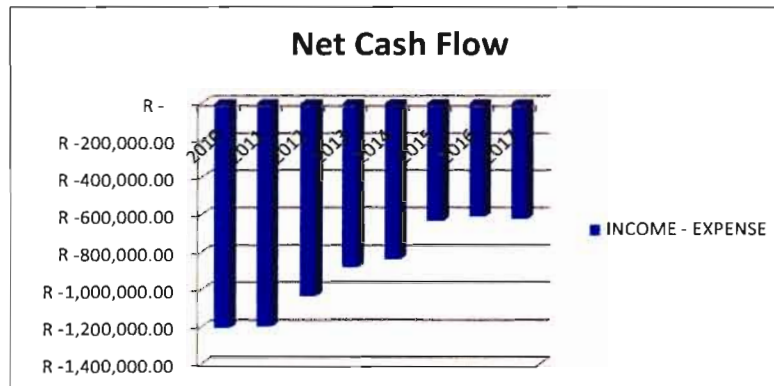


Figure 16: Participating university net cash flow (Scenario 1)

5.4.2.2 External consortium

The consortium will carry the costs of presenting courses as part of the programme offered, as well as other operational costs and salaries. These expenses are shown in Figure 17.



Figure 17: Consortium expenses (Scenario 1)

Including a reserve contingency fund of five per cent, the total external funding required by the consortium to run the programme amounts to R2,99 m in 2010 to R3,65 m in 2017 (shown in Figure 18).

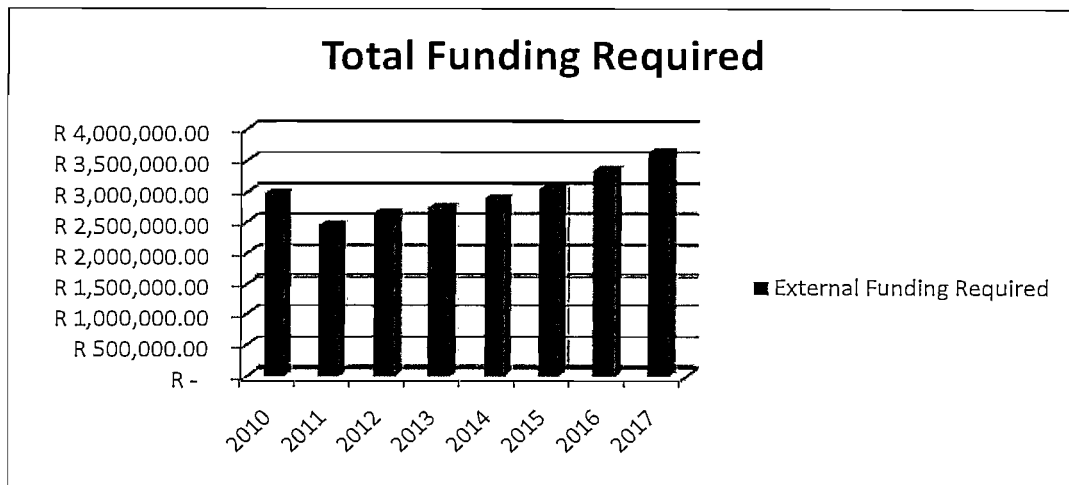


Figure 18: Consortium total funding required (Scenario 1)

5.4.3 Scenario 1: Conclusions

In this scenario, only Option C Master's degree students and no Ph.D. students were registered in the programme. Figure 16 clearly shows the participating universities operating with a negative cash flow.

It is clearly not financially viable or sustainable for universities to present a post-graduate programme that is primarily course-based. An alternative will be investigated in Scenario 2.

5.5 SCENARIO 2: OPTION A, B AND C MASTER'S DEGREE STUDENTS AND PH.D. STUDENTS IN COLLABORATIVE PROGRAMME

In this paragraph, the financial implications will be discussed by creating the following scenario:

Nuclear engineers will be trained by registering for Option A, B and C Master's degrees as students in the collaborative programme. A percentage of graduated Master's degree students will continue to register for a Ph.D. at a participating university. In this scenario, universities will therefore have the opportunity to conduct research in their specific field of study.

5.5.1 Scenario 2: Attributes

5.5.1.1 Participating universities

The variables that serve as input to the participating universities' financial model are set to the same values as for Scenario 1, but incorporating the following:

- Master's degree class fees:
 - First year 35% payable: $R7,396 \times 2 = \mathbf{R14, 792}$
 - Second year 35% payable: $R7,396 \times 2 = \mathbf{R14, 792}$
 - Third year 30% payable: $R6,338 \times 2 = \mathbf{R12, 676}$
- Percentage of students completing an Option A Master's degree: **10%**
- Percentage of students completing an Option B Master's degree: **20%**
- Percentage of students completing an Option C Master's degree: **70%**
- Number if Ph.D. students to start in the programme: **2**
- Percentage of Ph.D. students continuing from a Master's degree: **20%**

5.5.1.2 External consortium

The variables that serve as input to the consortium's financial model were set to the same values as for Scenario 1. The outcomes of the external consortium in Scenario 2 will therefore be similar to the outcomes of Scenario 1.

5.5.2 Scenario 2: Outcomes

5.5.2.1 Participating universities

The Master's degree class fees, Master's degree subsidy income and Ph.D. subsidy income received by a participating university are shown in Figure 19. It can be seen that the Master's degree and Ph.D. subsidy grants will only be received from 2012 onwards because of the two-year lag period in governmental subsidy allocation. This total income will increase from R118 k in 2010 to R2,8 m in 2017.

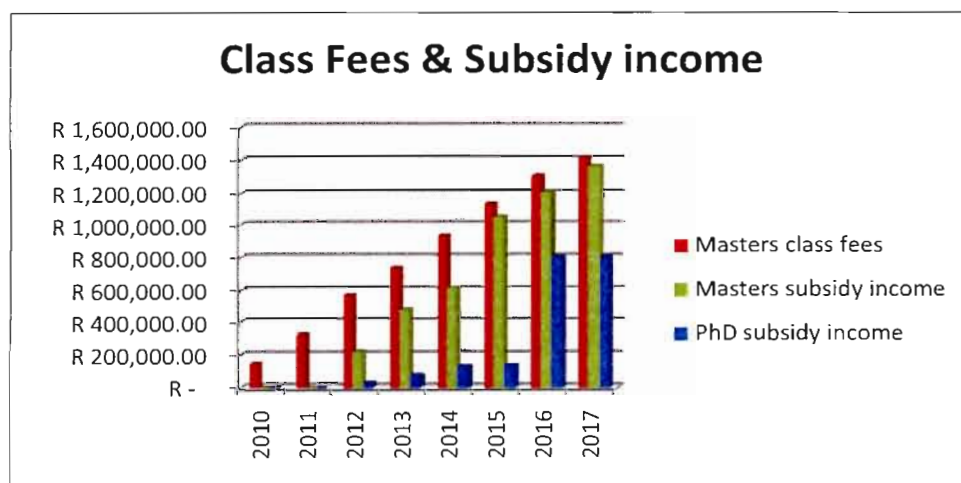


Figure 19: Participating university class fees & subsidy Income (Scenario 2)

Similarly to Scenario 1, the permanent salary and other operational expenses per university will increase from R1, 26 m in 2010 to R2,19 m in 2017 (See Figure 15).

The net cash flow effect will result in an initial negative cash flow of over R1 m in 2010, increasing to a positive cash flow of R312 k in 2017 as indicated in Figure 20.

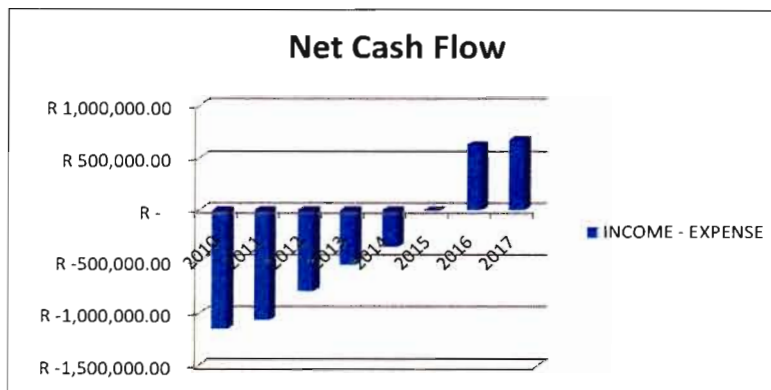


Figure 20: Participating university net cash flow (Scenario 2)

5.5.3 Scenario 2: Conclusions

In this scenario, registered Ph.D. students were added to the financial model and Master's degree students were registered in Option A, B and C programmes according to the suggestion of Yashin Brijmohan, technical capacity development manager at Eskom in paragraph 3.2. The result, as seen in Figure 20, is that the participating universities will eventually obtain a positive cash flow and be able to provide a good return on investment by 2015 onwards. The initial loss will be discussed in paragraph 5.6.1: Initial funding in the financial system.

5.6 COLLABORATION PROGRAMME FINANCIAL SYSTEM

The collaboration programme should be regarded as a total system with students as inflow and graduates as outflow (See Figure 21). The system includes the consortium and an assumption of six participating universities. In this section, the total financial system will be modelled with the input used in Scenario 2. The purpose of modelling the total financial system is to determine the cost per unit (cost per graduate student through the collaboration programme).

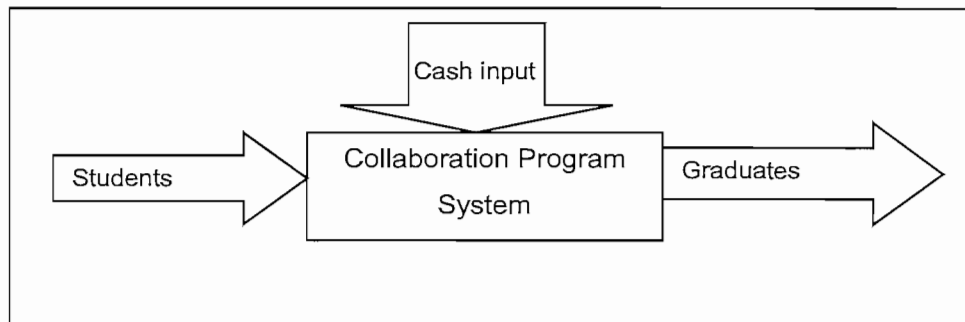


Figure 21: Collaboration programme simplified financial system to model cost/unit output

The cash input to the system includes:

- Industry funding to the consortium
- Subsidy grants to the participating universities
- Class fees received by the participating universities

The expenses within the system includes:

- Operational expenses of the consortium and participating universities
- Permanent personnel salaries of the consortium and participating universities
- Course expenses covered by the consortium
- Marketing expenses by the consortium and participating universities
- Office rent by the consortium

The system cash input and expenses are shown in Figure 22. This financial system, simplified, is also shown in Figure 23. The collaboration model as a financial system will have an initial negative cash flow of R6,5 m. From 2014 onwards, the financial system shows a positive cash flow. In 2017 this positive cash flow will be equal to R8,5 m. From the initial negative cash flow of the financial system, it is clear that funding will be required to start the programme.

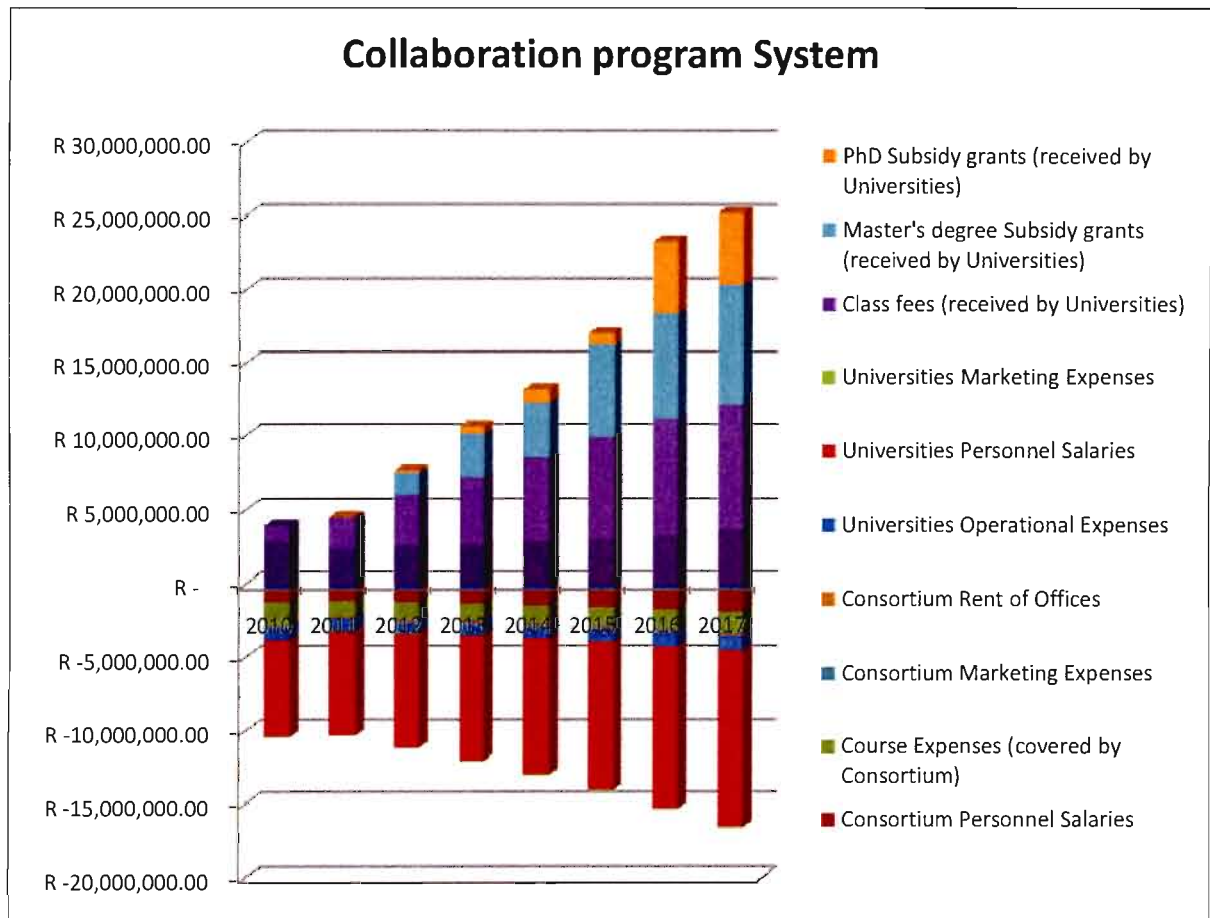


Figure 22: Collaboration programme financial system (2)

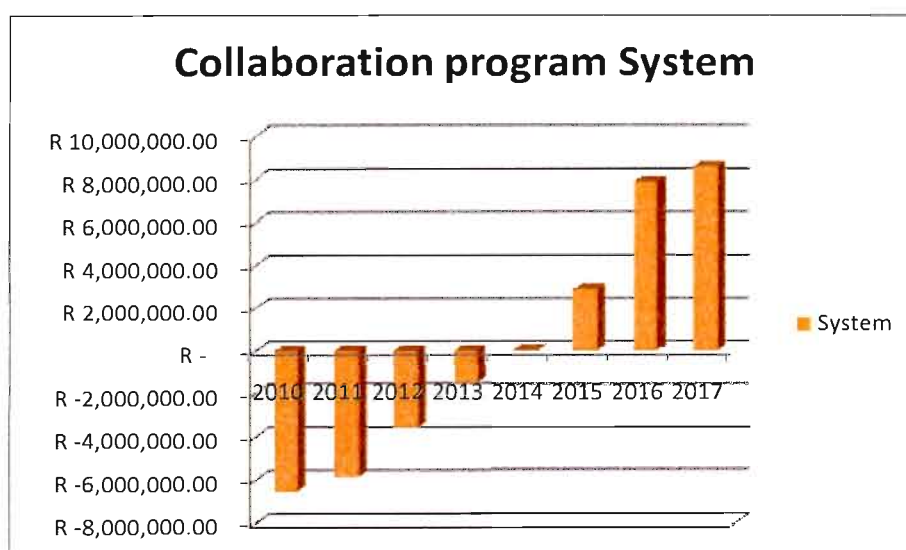


Figure 23: Collaboration programme system simplified

5.6.1 Initial funding in the financial system

As discussed in the previous paragraphs, a source of funding will be required to establish and start the programme at the participating universities and at the independent consortium. As the consortium and participating universities educate nuclear engineers at a Master's degree level according to the needs of the nuclear industry, funding from the nuclear industry will be expected. The collaboration programme will also develop the nuclear skills in South Africa and therefore governmental funding would be a fine investment.

In Figure 24, an estimation is provided of net cash flow per university if external funding of R1,15 m per year (decreasing with ten per cent per year) per university were received from 2010 to 2014 and a final amount of R520 k in 2015. From 2016 onwards, no external funding will be expected from the participating universities. Each university will contribute funding from 2012 onwards (increasing with nine per cent inflation from 2016 onwards) towards the expenses of the consortium. If six universities were to participate in the programme and contribute towards the expenses of the consortium, the external funding required by the consortium will decrease significantly from 2014 onwards as shown in Figure 25.

The net cash flow per university will decrease from 2011 onwards as external funding received will decrease and funding provided to the external consortium by the participating university will increase. The cash flow per institution will stabilise from 2016 onwards at R69 k per year.

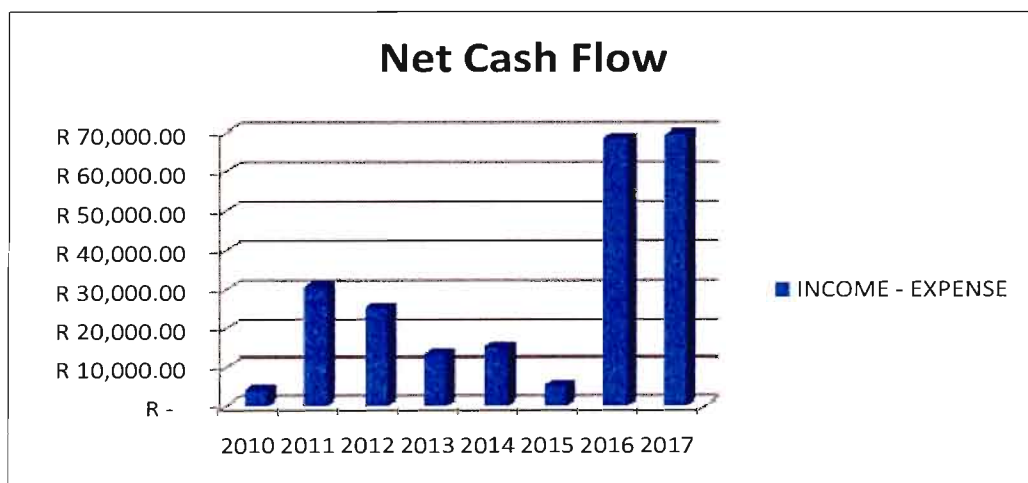


Figure 24: Participating university net cash flow including funding (Scenario 2)

Figure 25 provides the total external funding required by the consortium that is not covered by the funding received from the participating institutions. The funding required by the consortium will be covered by the participating institutions from 2015 onwards.

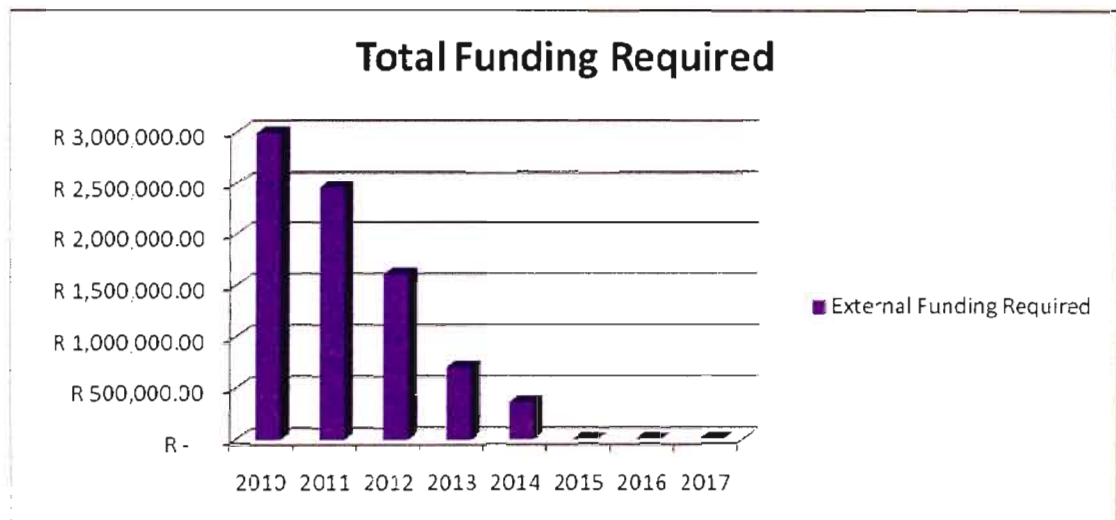


Figure 25: External funding required by the consortium

The total external funding that will be required by the system (the consortium and participating universities) is provided in Figure 26. The total funding decreases per year and from 2016 onwards, no external funding will be required to uphold the programme.

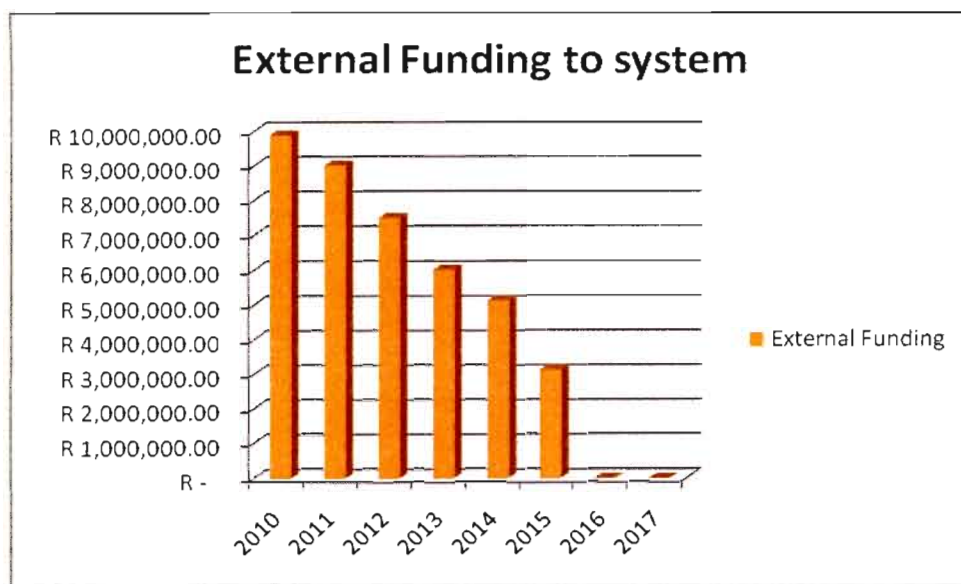


Figure 26: External funding to the system

5.6.2 Cost per student in the programme

The total cost per student in the programme was calculated by taking into account the total external funding required to establish and uphold the programme. The cost per student in the programme is shown in Table 21.

Table 21: Cost per student (collaborative program)

	Students in program	External cost of program	Cost per student
2010	60	R 9,893,025.00	R 164,883.75
2011	72	R 9,014,178.75	R 125,196.93
2012	86	R 7,508,797.25	R 87,311.60
2013	103	R 6,018,608.16	R 58,433.09
2014	120	R 5,136,138.75	R 42,801.16
2015	120	R 3,120,304.38	R 26,002.54
2016	120	R 331.77	R 2.76
2017	120	R 361.63	R 3.01

The cost per student of presenting the collaboration programme will initially be R165 k. The establishment of the consortium and programme is the cause for this initial large cost per student. From 2011 onwards, the cost per student will decrease substantially and from 2016 onwards, it will be negligible, as practically no external funding will be required.

5.6.3 Collaboration programme financial system conclusions

In this paragraph, the collaboration programme was modelled to obtain a cost per student in the collaboration programme. Initial external funding will be required to establish the collaboration system. This initial funding required will decrease and after six years, the programme will be financial self-sustainable and viable.

5.7 VERIFY FINANCIAL SUBSIDY MODEL

Included in the participating universities' financial model is a model to calculate the subsidy grants earned by the university as explained in paragraph 3.3.1. To determine the accuracy of the subsidy grant model, it will be verified by using the Master's degree in nuclear engineering programme offered by the Post-graduate School for Nuclear Science and Engineering at the NWU.

5.7.1 Verification data

To determine the accuracy of the subsidy grant model used in the participating universities' financial model, it will be verified by using actual financial information of the programme offered by the NWU. The information in Table 22 will serve as input to the subsidy model:

Table 22: Input to subsidy model (2006 and 2007)

Information	Actual number (2006)	Actual number (2007)
First-year registrations:		
• Master's degree Option A	0	0
• Master's degree Option B	0	16
• Master's degree Option C	3	2
• Percentage on 2-year M programme	40%	40%
• Percentage on 3-year M programme	60%	60%
• Ph.D. students	2	1
Second-year registrations:		
• Master's degree Option A	0	0
• Master's degree Option B	2	2
• Master's degree Option C	3	1
• Percentage on 2-year M programme	40%	40%
• Percentage on 3-year M programme	60%	60%
• Ph.D. students	0	2
Third-year registrations:		
• Master's degree Option A	0	0
• Master's degree Option B	0	1
• Master's degree Option C	0	2
• Percentage on 2-year M programme	40%	40%
• Percentage on 3-year M programme	60%	60%
• Ph.D. students	0	0
Fourth-year registrations:		
• Ph.D. students	0	0
Graduations:		
• Master's degree Option A	0	0
• Master's degree Option B	1	2
• Master's degree Option C	0	2
• Percentage on 2-year M programme	40%	40%
• Percentage on 3-year M programme	60%	60%
• Ph.D. students	0	0

5.7.2 Verification outcomes

The subsidy calculated by using the financial subsidy grant model explained in Paragraph 5.3 is shown in Table 23.

Table 23: Subsidy calculated by model (2008 and 2009)

Subsidy	2008 (2-year lag after 2006)	2009 (2-year lag after 2007)
Master's degree subsidy	R292,968.00	R854,827.00
Ph.D. subsidy	R41,109.00	R70,509.00
Total subsidy	R334,077.00	R925,336.00

The **actual** subsidy grant allocations calculated for the Post-graduate School for Nuclear Engineering is shown in Table 24 and Table 25.

Table 24: Master's subsidy actual calculations

Master's Subsidy	2008 (2 year lag after 2006)	2009 (2 year lag after 2007)
Teaching Input	R 189,021.82	R 652,382.34
Teaching Output	R 3,432.23	R 25,622.62
Research Output	R 45,181.55	R 179,965.30
Total	R 237,635.60	R 857,970.26

Table 25: Ph.D. subsidy actual calculations

Ph.D. Subsidy	2008 (2 year lag after 2006)	2009 (2 year lag after 2007)
Teaching Input	R 34,236.58	R 86,629.53
Teaching Output	R -	R -
Research Output	R -	R -
Total	R 34,236.58	R 86,629.53

5.7.3 Verification results

The calculated subsidy amounts for 2008 and 2009 are compared to the **actual** calculated subsidy amounts for 2008 and 2009 in Table 26.

Table 26: Verification results

	Master's degree subsidy		Ph.D. subsidy	
	2008	2009	2008	2009
Calculated subsidy (1)	R292,968.00	R854,827.00	R41,109.00	R70,509.00
Actual subsidy (2)	R237,635.60	R857,970.26	R34,236.58	R86,629.53
Deviation (2-1)	R-55,332.40	R3,143.26	R-6,872.42	R16,120.53
Deviation percentage	23.28%	0.37%	20.07%	18.61%

The deviation percentage for the modelled subsidy income from the **actual** subsidy income calculations for the Post-graduate School for Nuclear Science and Engineering at the NWU is 23.28%, 0.37%, 20.07% and 18.61%, according to Table 26. The average deviation percentage is equal to 15.53%. This relatively small deviation percentage verifies that the subsidy model included in the financial model is accurate enough to be used for financial estimations for the collaborative programme.

5.8 CONCLUSION

In this chapter the financial models that were developed for the independent external consortium as well as for the participating universities for 2010 – 2017 were discussed. Furthermore, two different scenarios of input to the financial models in the form of number of Master's degree and Ph.D. students in the programme were investigated.

The collaboration financial system was modelled. Including initial external funding to the system, it was found that the system will be financially sustainable and viable. The financial subsidy grant model was verified. The results obtained clearly showed that the subsidy model included in the financial model is adequately accurate to be used for financial estimations for the collaborative programme. The subsidy model should however be revised for using the financial information in actual collaborative calculations.

CHAPTER 6: COLLABORATION PROGRAMME DELIVERY SYSTEM

6.1 INTRODUCTION

In the previous chapters, the model to deliver a collaborative Master's degree in nuclear engineering by South African universities was discussed. This programme will consist of courses or modules and research to be completed by registered students. In this chapter the requirements of the programme delivery system will be discussed. The delivery system includes the delivery of the programme courses or modules and research projects.

Furthermore, the blended learning method as a possibility for delivering the courses to the geographically dispersed students will be investigated. Attention will be paid to the blended learning methodology, its advantages and characteristics. The delivery method applied to the collaborative programme will then be discussed. Lastly, the model as implemented will be discussed from where conclusions will be drawn.

6.2 REQUIREMENTS OF THE DELIVERY SYSTEM

The programme delivery system is dependent on the following aspects:

- **Geography:** The programme is a collaboration effort between South African universities that are geographically dispersed. Students in the programme will register at participating universities either full-time, or part-time while employed. The delivery system will therefore have to accommodate geographically dispersed students.
- **Bandwidth:** In South Africa, the lack of adequate bandwidth is currently creating problems in the online environment. This can be a possible cause for concern if methods of online learning were used that require broadband.
- **National course schedule:** As part of the collaborative delivery of the programme, a national schedule should be introduced.
- **Availability of specialised lecturers:** The programme is dependent on the availability of specialised lecturers to present the courses. These specialised lecturers should have the necessary background and experience in the nuclear industry. They may not be available on a full-time basis in South Africa.
- **Availability of research promoters:** Research in different forms is an essential part of the Master's degree in nuclear engineering programme offered collaboratively. Supervisors to guide students in their research projects in the field of nuclear engineering are an important aspect in the delivery of the programme.

The requirements for a delivery system for the programme should be met by the model that will be implemented to deliver the programme. In the following paragraphs a method for delivering the programme courses, the blended learning method, will be described.

6.3 BLENDED LEARNING

6.3.1 What is blended learning?

Blended learning is a learning methodology that blends online learning with traditional methods of learning (Thorne, 2003:2). Blended learning effectively combines different modes of delivery, models of teaching and styles of learning (Heinze & Procter, 2004:2). These styles of learning that are combined are self-paced learning, live e-learning and face-to-face classroom learning (Alonso *et al.*, 2005:15).

Blended learning also combines different training "media" to create an optimum training delivery method for a specific programme (Bersin, 2004: xvi). Figure 27 shows blended learning as an overlap between pure face to face learning and online learning.

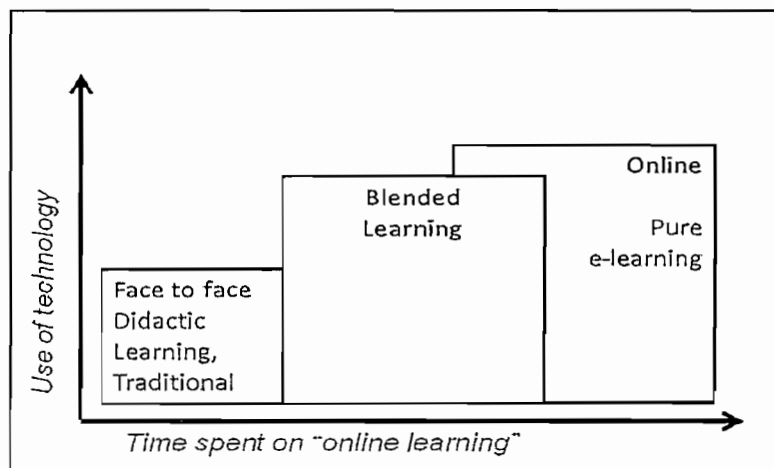


Figure 27: Conception of blended learning (Heinze & Procter, 2004:2)

6.3.2 Advantages of blended learning

The advantages of blended learning include the following:

- **Optimising development cost and time:** By combining costly online programmes and simpler self-study resources, the cost and time of blended learning development can be optimised (Singh, 2003:7).

- **Presentation cost reduction:** Live specialised instructor-led training translates into expensive transportation and accommodation expenses. These costs can be reduced by minimising face to face learning.
- **Distance barriers eliminated:** By combining e-learning methods with instructor-led training, learners can access learning material anywhere before physical contact sessions.
- **Time flexibility:** Blended learning offers the opportunity for self-study any time that the learner chooses to do so (Alvarez, 2005).
- **Create social environment:** One of the disadvantages of distance learning is a lack of social interaction. By introducing conventional face to face in the learning process, a social environment is created (Heinze & Procter, 2004:9).

6.3.3 Approaches to blended learning

The two approaches to blended learning as identified by Bersin (2004, 57-78) will be explained in this paragraph.

6.3.3.1 Approach 1: Programme flow model

The programme flow approach includes synchronous steps of face-to-face, online, self-study learning. This allows learners to feel engaged in their studies so that they can plan the training over time. Furthermore, it enables lecturers and students to formally track progress of the learning process, because it is easy to follow, modify and maintain.

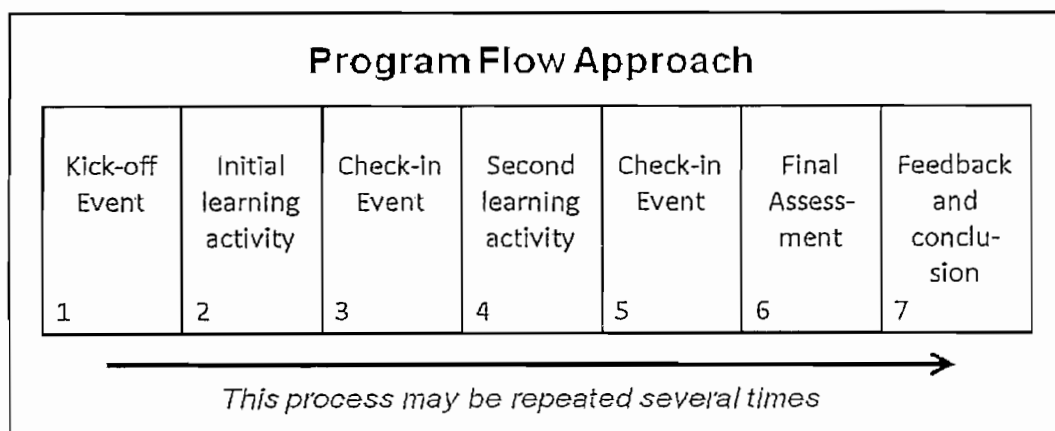


Figure 28: Program flow approach (Alvarez, 2005)

6.3.3.2 Approach 2: Core-and-spoke approach

The core-and-spoke approach for blended learning is easier to develop in stages than the programme flow approach. Because the learner can plan their studies ahead in the programme

flow approach, courses should be developed before the implementation phase starts. On the other hand, the core-and-spoke approach can be developed over time. The key in the development of the core-and-spoke approach is to build the core curricula of a course and then add supplemental materials over time. This approach assumes that students taking the courses are self-motivated learners who do not necessarily complete the course at the same time. The approach is flexible, allowing the developers to tailor a programme to learners' individual styles and interests.

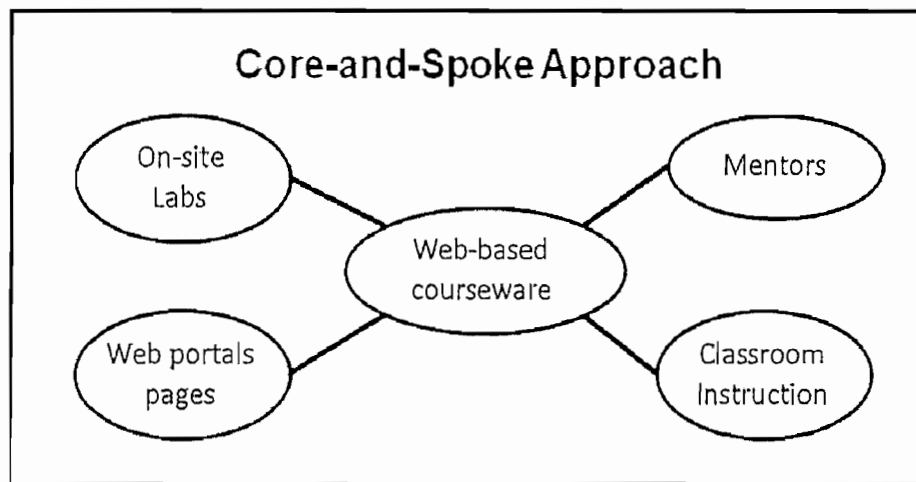


Figure 29: Core-and-spoke approach (Alvarez, 2005)

6.3.4 Methods of blended learning

Blended learning includes combinations of the elements shown in Figure 30, according to Carman (2002):

- **Live elements:** This is synchronous, instructor-led learning, for example teaching students in a physical classroom or via a live virtual classroom.
- **Self-paced learning:** This learning completed by the students, is Internet-based via CD-ROM training.
- **Collaboration:** Environments where students communicate with each other and the lecturer via e-mail, online chatting or threaded discussions.
- **Assessment:** Learning transfer is assessed after self-paced learning events or face-to-face knowledge transfer sessions.
- **Performance support materials:** Resources that enhance learning retention and transfer, for example PDA downloads or printable references.

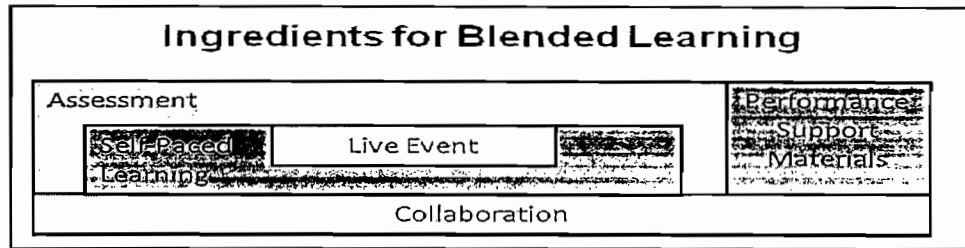


Figure 30: Ingredient elements for blended learning (Carman, 2002:4)

Alvarez, S (2009) provides the following specific blended learning models:

- E-learning self-study blended with other media or events
- Instructor-led programme blended with self-study e-learning
- Live e-learning-centred with other media
- On the job training-centred
- Simulation and lab-centred

According to Singh (2003:4-5), blended learning can combine the following dimensions:

- Off- and online learning
- Self-paced and live, collaborative learning
- Structured and unstructured learning
- Custom content with off-the-shelf content
- Learning, practice and performance support

6.4 COLLABORATIVE MODEL: BLENDED LEARNING DELIVERY OF COURSES

The blended learning methodology as discussed in the previous paragraph can be applied to the presentation of courses in the programme that will be collaboratively offered by South African universities. The blended learning delivery method as applied to this programme, as well how it will meet the requirements of a delivery system will be explained in this paragraph.

6.4.1 Concept

Each course within the programme will be delivered to all the students at all participating universities at the same time. This will be co-ordinated with the use of a national course schedule. Students registered in the programme will be geographically dispersed over South Africa and specialised lecturers are usually internationally located or are working in the nuclear industry. This provides the opportunity for the blended learning methodology to be implemented in the delivering of courses.

The blended learning delivery method applied in the collaborative programme modules will be:

- Developed according to the programme flow approach; and
- an instructor-led programme blended with self-study e-learning and a self-paced and live, collaborative learning.

The delivery of each course will be executed in the phases seen in Figure 31:

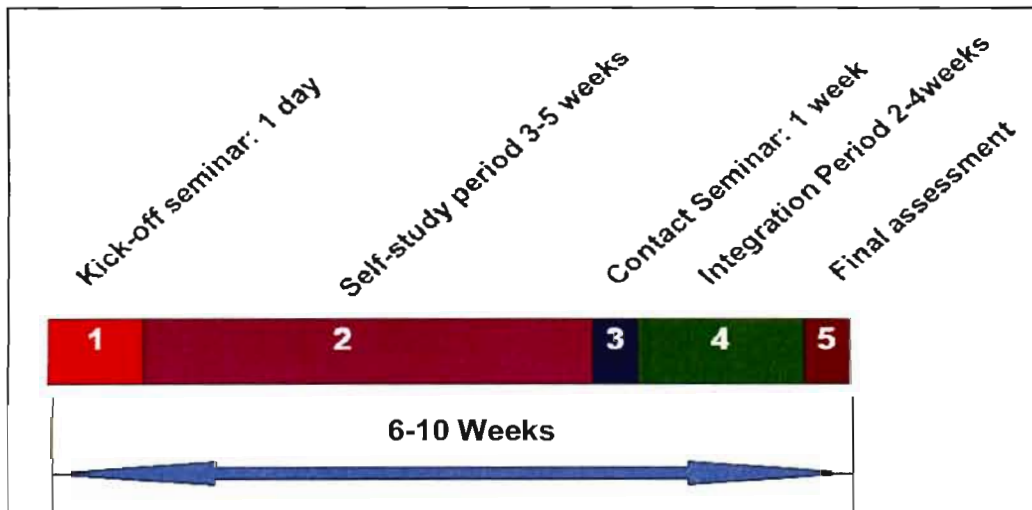


Figure 31: Blended learning course delivery (Fick, 2008:5)

Each course in the programme contributes 16 credits towards the total 180 credits to obtain a Master's degree in nuclear engineering. These 16 credits are equal to 160 hours of work to be completed by each student in the specific module. The phases of delivery of a module as well as the credits and hours of work per phase are provided in Table 27.

Table 27: Phases of delivery (hours of work and credits)

Phase of delivery	Hours of work per day	Days	Total Hours of work	Credits
Kick-off Session	8	1	8	0.8
Guided self-study period	3	20	60	6
Contact lecture period	8	5	40	4
Post-lecture period	2.5	20	50	5
Final Assessment	2	1	2	0.2
Total	-	47	160	16

6.4.2 Participants in the delivery of the course

The following participants will play a primary role in delivering the courses:

- **Lecturer:** The lecturer will have specialised knowledge and experience in his/her field of study;
- **Teaching assistant:** The teaching assistant (TA) will play an important role in assisting the lecturer in delivering the course as he has already successfully completed the course; and
- **Students:** They will register for courses.

6.4.3 Steps in the blended delivery method

6.4.3.1 Kick-off session

The duration of the kick-off session is usually one day. During this session, the lecturer or teaching assistant of the course will ensure that the students understand the:

- Rationale and context of the course;
- teaching and learning methodology;
- e-learning process;
- outcomes and assessment criteria; and
- access to study resources.

The kick-off session can be implemented by one of the following methods:

- **Face-to-face contact session:** The lecturer of the course, with the assistance of the teaching assistant, provides the lecture to the students in a face-to-face contact session.
- **Virtual contact session:** The lecturer will communicate with the group of students taking the course via video-calling facilities.
- **Pre-recorded video session:** A video recording of the lecturer presenting the lecture can be recorded prior to the kick-off session date, which will be distributed to the students.

6.4.3.2 Guided self-study period

The guided self-study phase is usually three to five weeks. During this period, students acquire background knowledge, terminology and theory. The teaching assistant guides the students through the work with the aid of a web-based learner management system (LMS) such as SAKAI, Blackboard or Moodle. He therefore continually collaborates with and facilitates the students via the LMS, ensuring continuous engagement with the learning process. Regular online self assessment opportunities are an effective way to encourage students to continuously engage with the study.

The learning strategy of this period is:

- To move through the material at a brisk pace;
- develop a wide overview of the subject matter; and
- not to expect any integration of knowledge nor complicated implementation of equations or calculations. This is best left for the contact week.

6.4.3.3 Contact lecture period

The duration of the contact, face-to-face lecture step is usually one week. This lecture period will be facilitated by the lecturer of the course. The teaching assistant may assist in presenting the lectures. During the contact lectures, the lecturer will give tasks and assignments to assist the student to integrate knowledge that was already obtained during the self-study period and in this way facilitate the development of higher-level skills and competencies.

The purpose of this period is:

- Integration and contextualisation of knowledge, as a wide overview of the course material has already been completed in the guided, self-study period; and
- To develop design and calculation skills through the application of knowledge obtained in the guided, self-study period.

6.4.3.4 Post-lecture period

The post-lecture period will typically be two to four weeks. During this period, similarly to the guided-self-study phase, the teaching assistant will continually collaborate with and facilitate the students via the LMS.

The purpose of the post-lecture period is to integrate the knowledge and skills already obtained. This is done with the aid of individual and/or group projects. The web-based LMS is once again used to facilitate the process. Projects and assignments are posted to the course web site on LMS and can be graded online by the lecturer or TA.

6.4.3.5 Final assessment

After the post-lecture period assignments, the students should be ready to complete the final assessment. This final assessment can be done in the form of an examination, presentation or a portfolio.

6.4.4 Modules outcomes

Each course/module consists of certain knowledge, skills and competency outcomes that should be reached by the student in the process of taking that course. As explained in the previous paragraphs, these outcomes are achieved by students in different periods of the blended learning model.

Figure 32 indicates that knowledge is obtained during the guided, self-study period. This knowledge is integrated into skills during the lecture period. Engineering competencies are developed as part of the post-lecture period. All of these outcomes should be tested in the final assessment.

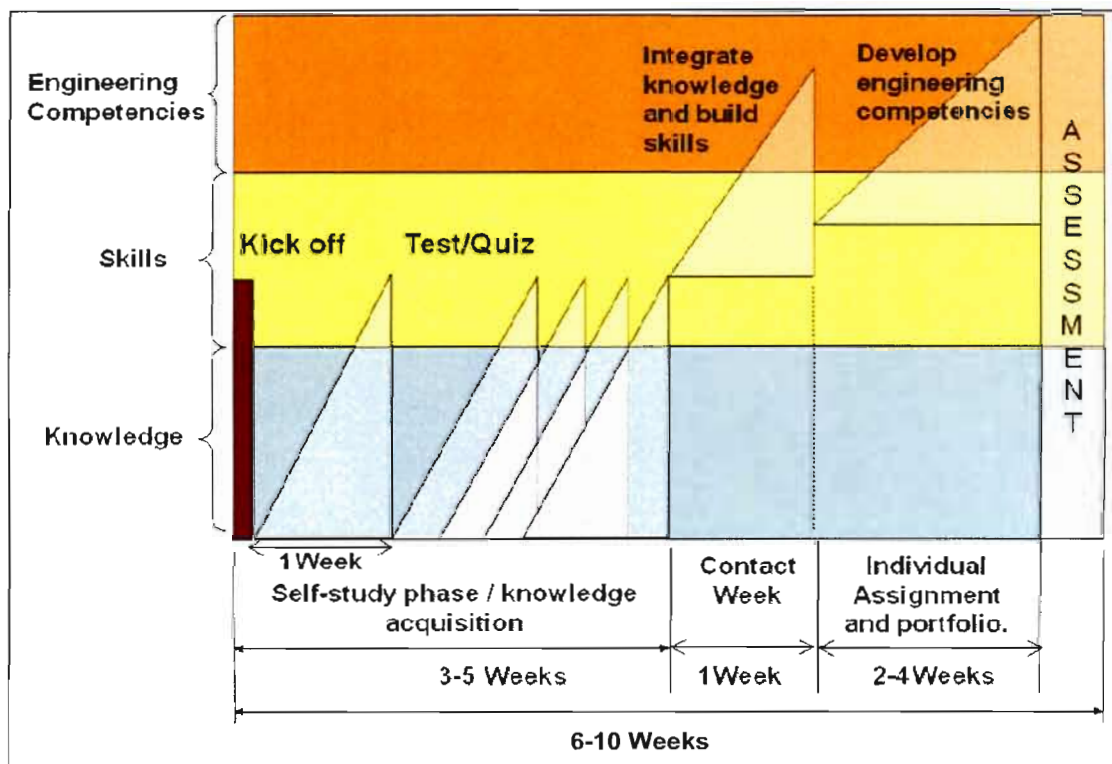


Figure 32: A pedagogical model for the blended learning process (Fick, 2008:9)

6.4.5 Requirements of the delivery system

This blended learning delivery system will meet the following requirements as identified in Paragraph 6.2:

- **Geography:** The blended delivery method will accommodate students that are geographically dispersed as only one week of face-to-face lectures are scheduled per module.

- **Bandwidth:** The limited bandwidth in South Africa could possibly create problems in the guided, self-study period as online learning will be used. A minimum of 100Mbps service in small institutions and 1Gbps in large institutions should be available (Mullins, 2010:5). It is important that a solution for this limited bandwidth will be investigated or that modules are delivered effectively by keeping this bandwidth problem in mind.
- **National course schedule:** As part of the collaborative delivery of the programme, a national schedule for all the modules presented by the consortium will be introduced.
- **Availability of specialised lecturers:** The programme is dependent on the availability of specialised lecturers to present the modules. These specialised lecturers will be contracted by the consortium.
- **Availability of research promoters:** Research will be conducted at each separate institution, although as part of the collaborative programme. It is therefore the responsibility of each institution to provide research supervisors and resources for the students registered at their institution.

6.4.6 Conclusion

The concept for the delivering of courses in the collaborative programme via a blended learning methodology as well as how it will meet the requirements of a delivery system was discussed. In the next paragraph a study will be discussed where this model was implemented for the delivery of a Master's degree in nuclear engineering.

6.5 BLENDED LEARNING DELIVERY METHOD IMPLEMENTED

The Postgraduate School for Nuclear Science and Engineering at the North-West University (NWU) currently offers a Master's degree in nuclear engineering. The blended learning method as explained in paragraph 7.3 was implemented in the programme offered by the NWU in 2008 and 2009.

To obtain quantitative feedback on the effectiveness of this delivery method, questionnaires were distributed to students after they had completed courses presented by the blended delivery method. Three of the courses were delivered in 2008 and three in 2009. The answers to the questions will serve as data that can be analysed to draw conclusions from.

6.5.1 Methodology: Questionnaire

To obtain quantitative feedback on the effectiveness and quality of the blended delivery method and content of courses, a questionnaire was distributed to the students who completed the

following courses (in order of questionnaire distribution dates) as part of programmes offered by the North-West University:

1. Nuclear Engineering 1 (NUCI 511 Diploma programme) 2008
2. Radiation and the Environment (NUCI 576 Diploma programme) 2008
3. Nuclear Project Management (NUCI 879 Master's programme) 2008
4. Nuclear Engineering 1 (NUCI 511 Master's programme) 2009
5. Nuclear Project Management (NUCI 879 Master's programme) 2009
6. Nuclear Engineering 2 (NUCI 883 Master's programme) 2009

Questions on the following topics were included in the questionnaire (See Annexure D for the complete questionnaire):

1. General information of the student
2. Study material and web-based LMS
3. Physical work environment, scheduling and time management
4. Course content
5. Lecture (classroom) week
6. Communication with lecturers and programme administrators
7. Examination preparation
8. Other

The answers to the following questions was analysed and will be discussed:

- Was the web-based LMS readily available to you at the start of the course?
- Is the network speed at your office adequate for the work that has to be done on the web-based LMS?
- How did you experience the communication with the lecturers in the guided, self-study period?
- How did you experience the communication with the lecturers in the lecture period?
- How did you experience the communication with the lecturers in the post-lecture period?
- How did the guided self-study work contribute to your preparation for the examination?
- How did the lectures contribute to your preparation for the examination?
- How did the post-lecture work contribute to your preparation for the examination?

6.5.2 Questionnaire data and results

In this paragraph, the answers received from the students who completed courses with the blended learning methodology was analysed and will be discussed. The data received from the questionnaire answers is shown in Figure 33 to Figure 40. In these figures, the courses are listed in order of delivery dates.

6.5.2.1 Was the web-based LMS readily available to you at the start of the course?

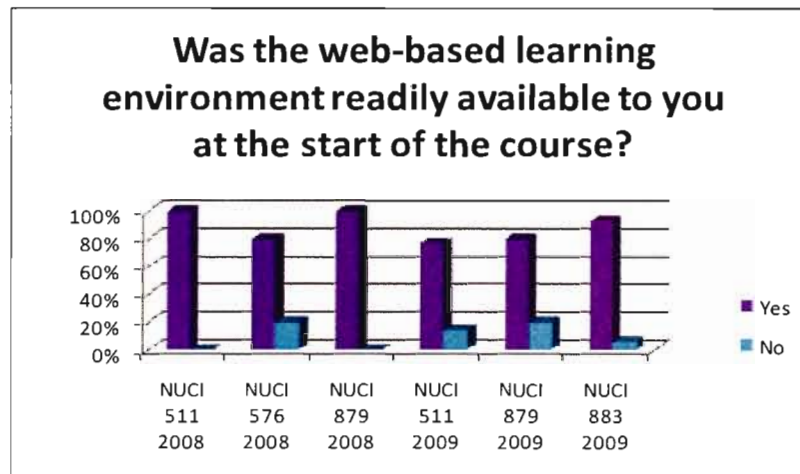


Figure 33: Question 1 result

In all courses, more than 77% of the students were able to access the web-based LMS at the start of the course. In the delivery of courses in the collaboration programme, all attempts should be made to increase this percentage to 100%. This could be done by making sure that the delivery system and processes set in place by the programme director include the early registering of students on the web-based LMS. The programme director should ensure that these processes are followed precisely by the TA and lecturer of a course.

6.5.2.2 Is the network speed at your office adequate for the work that has to be done on the web-based LMS?

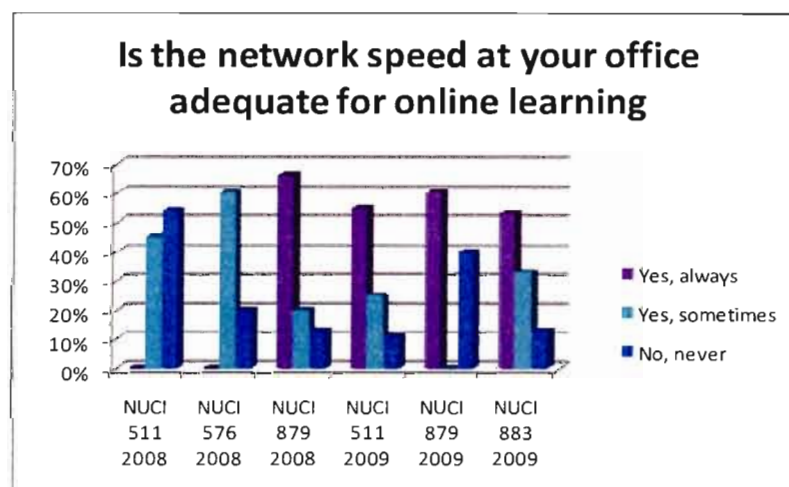


Figure 34: Question 2 results

South Africa is subjected to a bandwidth and network speed limitations. During the web-based, self-study phases where students have to access the internet regularly, this limitation in network speed could create problems. From Figure 34 it can be noted that with experience obtained in the delivery of courses with the blended learning methodology, the attempts to work around the bandwidth problem were successful. A recommendation is to investigate an alternative to increase bandwidth and network speed in order to make the use of online-learning more effective.

6.5.2.3 How did you experience the communication with the lecturers in the guided, self-study period?

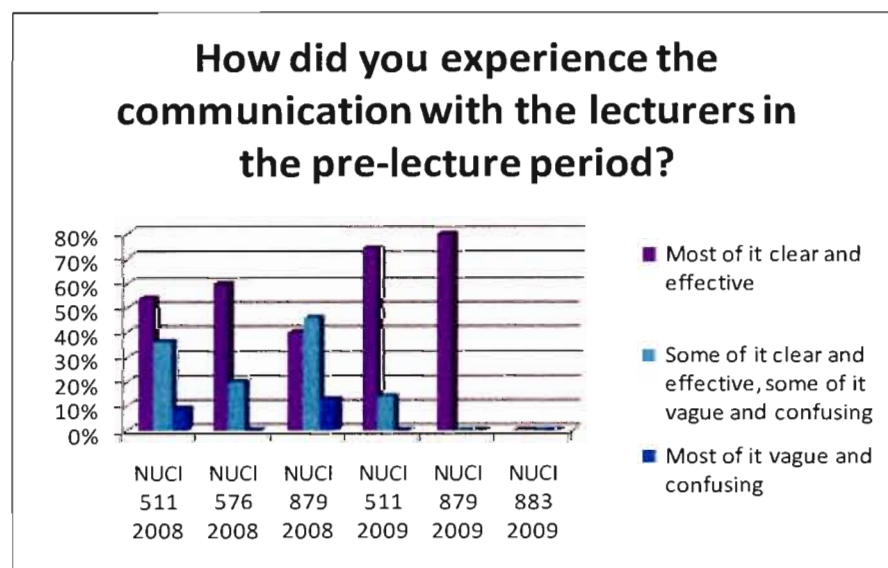


Figure 35: Question 3 results

In the virtual learning environment, communication with lecturers is of the utmost importance to create the complete learning experience. In this study, the opinion of the students was that their communication with the lecturers during the guided, self-study period was clear and effective.

6.5.2.4 How did you experience the communication with the lecturers in the lecture period?

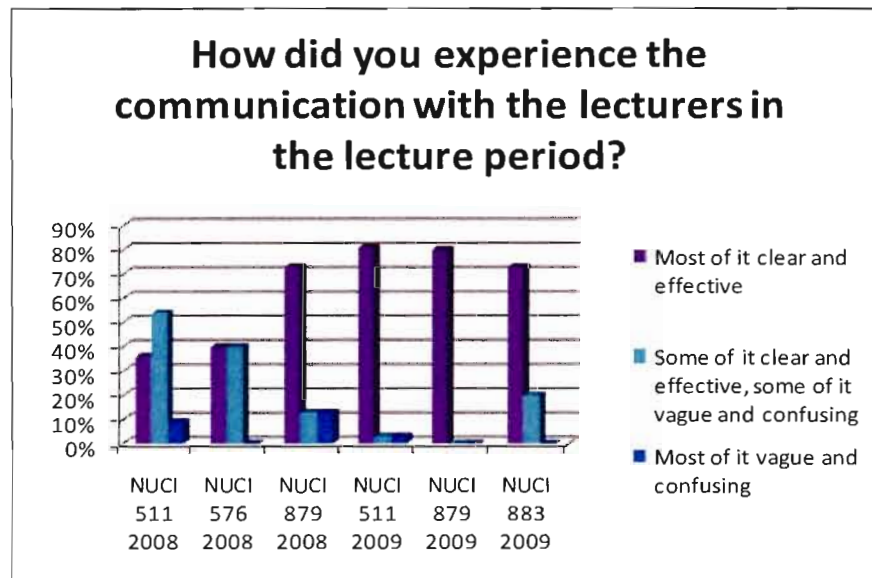


Figure 36: Question 4 results

The lecturers presenting the courses should have sufficient knowledge and experience in their field of study. They should therefore be selected according to a set of criteria. In this study, the opinion of the students was that their communication with the lecturers during the lecture period was mostly clear and effective.

6.5.2.5 How did you experience the communication with the lecturers in the post-lecture period?

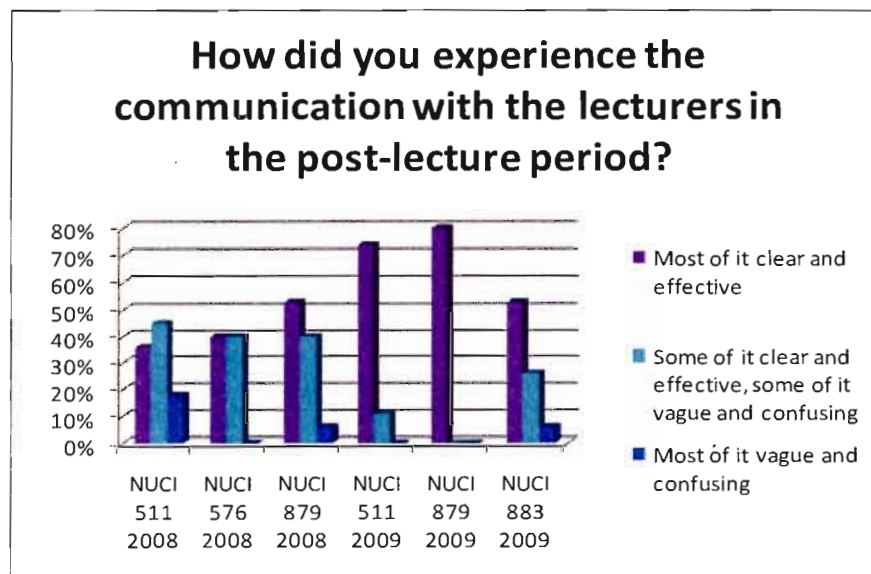


Figure 37: Question 5 results

The opinion of the students was that their communication with the lecturers during the post-lecture period was mostly clear and effective.

6.5.2.6 How did the guided, self-study work contribute to your preparation for the examination?

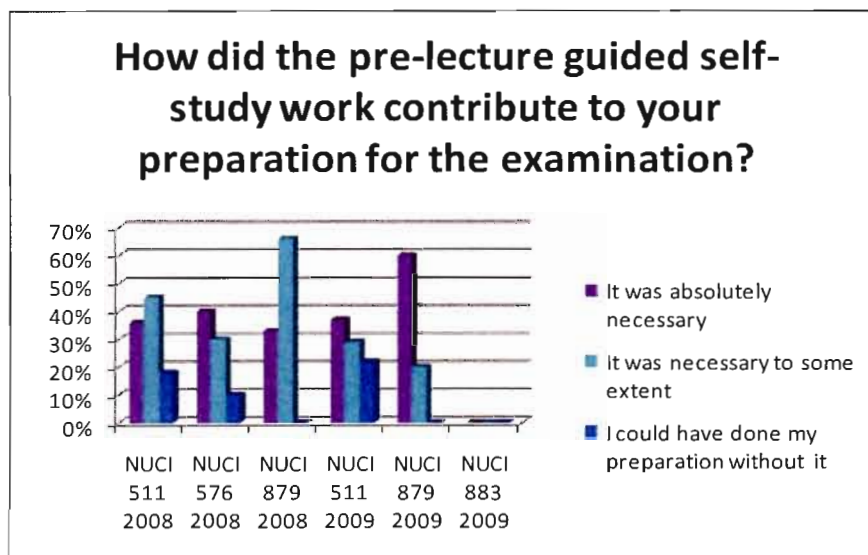


Figure 38: Question 6 results

In this study, the opinion of the students was that their work in the pre-lecture period mostly contributed towards achieving the outcomes of the course and preparing for the examination.

6.5.2.7 How did the lecture work contribute to your preparation for the examination?

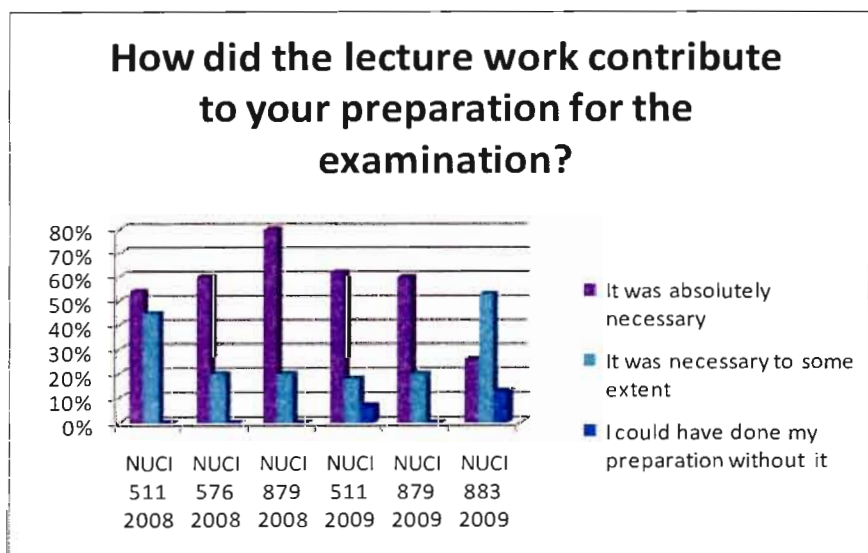


Figure 39: Question 7 results

The work that was done in the lecture period, according to the students, was even more important in their effort towards achieving the outcomes of the course and preparing for the examination. The lecture period is effective because of the guided, self-study work that the students had already completed.

6.5.2.8 How did the post-lecture work contribute to your preparation for the examination?

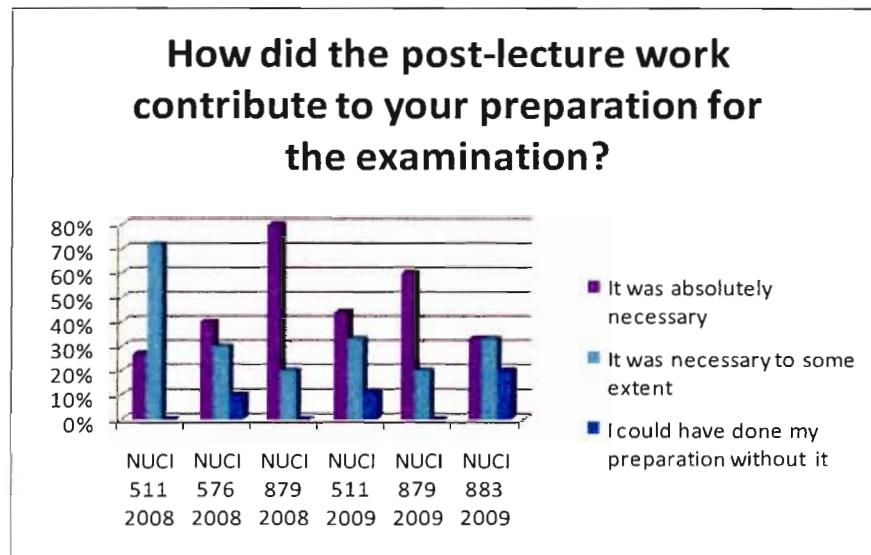


Figure 40: Question 8 results

The option of the students was that the work done in the post-lecture period mostly contributed towards their effort in achieving the outcomes of the course and preparing for the examination.

6.5.3 Questionnaire conclusion

In the previous paragraphs, the answers received from the students who completed courses with the blended learning methodology was analysed and discussed. From these discussions, a conclusion can be drawn that the blended learning delivery method has already effectively been implemented according to the feedback obtained from students in the programme offered by the North-West University. It can also be noted that there is room for improvement in a number of aspects that need special attention by the management of the Post-graduate School for Nuclear Science and Engineering at NWU.

6.6 CONCLUSION

In this chapter the requirements of the collaborative programme delivery system was discussed. The blended learning method and its advantages and characteristics were researched in order to consider this method as a possible delivering method for courses in the collaborative programme.

The implementation of this delivery model was also analysed. It should be noted that in developing the blended learning delivery method for the collaborative programme, special attention will have to be paid to the following aspects:

- Working with or creating a solution for the bandwidth and network speed limitations in South Africa;
- individualised learning comes at a cost, there will be limitations;
- before the implementation of the national schedule, detail planning will be necessary;
- selection and appointing of course lecturers;
- the total amount of time that it would take a lecturer to present a course should be considered when implementing the blended delivery method.
- creating the system and processes for delivery of the courses and making sure that this is followed by the teaching assistant and lecturers while presenting the courses. This will ensure that access to the web-based LMS is provided to all the students before the start of the course; and
- communication between lecturers and students is of the utmost importance during the guided, self-study periods via the LMS.

The model for applying the blended learning method to the collaborative programme was provided in this chapter. This model, as a concept, will have to be developed further and implemented once the consortium has been established.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

Nuclear power is an essential element to the solution for the greenhouse gas emission dilemma and , since 1960, it has been the world's fastest growing major source of energy. This nuclear revolution is experienced by many countries around the world. In July 2008, 35 new nuclear plants were under construction in fourteen countries.

In South Africa, the government has embraced nuclear power as a future energy source. Minister Dipuo Peters, South African Minister of Energy, has stressed the government seriousness of deploying nuclear energy to lower the country's emissions of greenhouse gasses. The development of nuclear technology ensures that the nuclear industry of South Africa could be one of the most innovative in the world.

The further development of the nuclear industry in South Africa can create up to a hundred thousand jobs across the value chain. This proposes a problem of a lack of qualified nuclear personnel. Ms B Sonjica, the previous Minister of Minerals and Energy, stated in February 2007 that the government will aggressively address nuclear skills development. Skills development in the nuclear environment will also help preserve the current nuclear knowledge.

Engineering skills are globally in short supply, and the retirement of qualified nuclear personnel and lack of adequate replacement is creating a global problem of a lack of nuclear skills. For the developing nuclear industry in South Africa, a broad range of skills need to be developed. Qualified nuclear engineers, as the economic enablers, are of the utmost importance but are not in a very high demand in numbers. This provides the opportunity for a collaboration model to be developed for the education and training of high-quality nuclear engineers without one particular institution taking the full financial responsibility as well as full responsibility for technical content to be transferred.

7.2 OBJECTIVE

As mentioned in chapter 1, the main objective of this research was the development of a business model for the collaboration between South African universities and South African nuclear industries for the delivery of a Master's degree in nuclear engineering. NIASA is driving the research to develop a collaboration business model for South Africa's current tertiary education environment.

In this research, the following specific objectives were achieved:

- The international trend for the collaboration between tertiary education institutions in nuclear education was studied in Chapter 2 as background for the development of a South African model;
- Existing South African collaboration models were researched in Chapter 2;
- As nuclear engineering education should be a result of a proactive exercise of estimation of the industry needs (Ishino, 2002:1), the needs for nuclear engineers as expressed by the South African nuclear industry were obtained in Chapter 3;
- In Chapter 3, the needs obtained of the nuclear industry were compared to the needs and drivers of the higher education environment for providing training at a Master's degree level in Chapter 3. This acted as foundation for the development of the South African collaboration model;
- A proposed model for collaboration between South African universities and nuclear industry for the delivery of a Master's degree in nuclear engineering was presented and discussed in Chapter 4;
- The collaboration programme was modelled as a financial system and the financial implications of the proposed collaboration model was provided and discussed in the form of budgets in Chapter 5;
- The collaborative programme courses could be presented by the delivery system as was presented. This delivery system, as implemented, was discussed and conclusions were drawn in Chapter 6;
- Finally, conclusions and recommendations on the research will be offered in this chapter.

7.3 CONCLUSIONS

7.3.1 Conclusions regarding existing international and South African collaboration models (Chapter 2)

Five primary international nuclear education collaboration models and five primary South African education collaboration models of different structures were researched. The characteristics of these models were summarised and analysed to provide a foundation from where a South African collaboration model for nuclear engineering education can be developed.

7.3.2 Conclusions on academic vs. nuclear industry needs (Chapter 3)

As stated by the South African industry leaders, nuclear engineers should be educated by completing courses at a Master's degree level at higher education institutions in order for them to have a broad field of knowledge in the nuclear field.

It was shown by the subsidy allocation formula for a primarily course-based Master's degree in nuclear engineering that it is not financially viable for any higher education institution and thus conflicts with the needs of the nuclear industry. A resolution is that if academic institutions should educate engineers based on the needs of the industry, external funding to academic institutions will be required to establish and possibly uphold the programme.

7.3.3 Conclusions regarding the collaboration model (Chapter 4)

A concept for a collaboration effort between South African universities to present nuclear education at Master's degree level was clarified. Suggestions towards the development and implementation of the curriculum, entry requirements to the programme, governance structure, administration and quality assurance processes were provided.

This collaboration model was explained as a concept; therefore details will have to be decided on by the consortium, once the consortium has been established.

7.3.4 Conclusions regarding the financial model (Chapter 5)

The financial models that were developed for the independent external consortium as well as for the participating universities for 2010 – 2017 were discussed. Furthermore, two different scenarios of input to the financial models in the form of number of Master's degree and Ph.D. students in the programme were investigated.

The collaboration financial system was also modelled. Initial external funding will be required to establish the collaboration system. This initial funding required will decrease and after six years, the programme will be financial self-sustainable and viable.

The financial subsidy grant model was verified and the results obtained clearly showed that the subsidy model included in the financial model is adequately accurate to be used for financial estimations for the collaborative programme.

7.3.5 Conclusions on the blended learning delivery model (Chapter 6)

The requirements for the collaborative programme delivery system were discussed. The blended learning method, its advantages and characteristics were researched in order to consider this method as a possible delivering method for courses in the collaborative programme. The implementation of this delivery model by NWU provides a successful foundation to be built upon.

The model for applying the blended learning method to the collaborative programme was provided. This model, as a concept, will have to be developed further and implemented by the consortium, once it has been once established.

7.4 RECOMMENDATIONS

7.4.1 Recommendations regarding existing international and South African collaboration models (Chapter 2)

The characteristics of existing international and South African collaboration models provide a foundation from where a South African collaboration model for nuclear engineering education can be developed. The concept for a collaboration model includes the following attributes:

1. The primary objective of the collaboration effort in South Africa should be to educate nuclear engineers according to the needs of the nuclear industry.
2. The consortium should be managed by an external governing body.
3. Government and/or industry funding should have to be obtained to establish and sustain the consortium and programmes offered.
4. Post-graduate programmes in nuclear engineering should be offered.
5. The network should be linked with other national and international nuclear education networks.

7.4.2 Recommendations on the academic vs. nuclear industry needs (Chapter 3)

The needs of the South African nuclear industry was obtained in this research, but for a thorough report on the total needs of the global nuclear industry, international nuclear industries will also have to be included. Furthermore, following the conclusions of this chapter, it is clear that if academic institutions should educate engineers based on the needs of the industry, external industry or government funding to academic institutions will be required to establish and uphold the programme.

7.4.3 Recommendations regarding the collaboration model (Chapter 4)

A concept for a collaboration effort between South African universities to present nuclear education at Master's degree level was explained. This model was only explained in concept form; therefore details will have to be decided on by the established consortium. Input from the international nuclear industry will also have to be obtained before developing the curriculum. Furthermore, a thorough GAP analysis will have to be completed between available international curriculums and the needs of the international industry for the content of the curriculums, before finalizing the South African curriculum.

The following risks will also have to be considered before establishing the collaboration:

- If funding is not obtained, this collaboration could result into an expensive, but fruitless exercise;
- if the accreditation and registration processes of approving the collaboration programme are not successful, the collaboration effort will be fruitless;
- a potential clash in the participating universities' internal academic processes or procedures may influence the decision making time and process;
- the academic freedom of the participating universities may be compromised.

7.4.4 Recommendations regarding the financial model (Chapter 5)

As concluded in the chapter on the financial model, the collaboration system will be financially viable and sustainable if external funding were provided to the system in the first four years of implementing. The consortium and participating institutions will have to be investigate the following before implementing the collaboration model:

- Possibilities for funding the commencement of this collaboration effort;
- the feasibility and sustainability the effort if more or less than six universities were to join the collaboration effort.

7.4.5 Recommendations on the blended learning delivery model (Chapter 6)

The implementation of a blended delivery method in the collaboration model was provided. In developing this blended learning method for the collaboration model, special attention will have to be paid to the following aspects:

- Working with or creating a solution for the limited bandwidth and network speed in South Africa;
- individualised learning comes at a cost, there will be limitations;
- before the implementation of the national schedule, detail planning will be necessary;
- selection and appointing of course lecturers;
- the total amount of time that it would take a lecturer to present a course should be considered when implementing the blended delivery method.
- creating the system and processes for delivery the courses and making sure that this is followed by the teaching assistant and lecturers while presenting the courses. This will ensure that access to the web-based LMS is provided to all the students before the start of the course;
- communication between lecturers and students is of the utmost importance during the virtual learning periods; and
- efforts to create a virtual learning community must be incorporated in the delivery model.

This blended delivery model, as a concept, will have to be further developed and implemented by the consortium, once established.

7.5 FURTHER RESEARCH POSSIBILITIES AND IMPROVEMENTS

Further studies may include:

- Developing the programme and curriculum for the proposed Master's degree in nuclear engineering;
- establishing this consortium as a network, into the international co-operation of nuclear education network of networks; and
- implementing the delivery method/model of the programme;

7.6 FINAL CONCLUDING REMARKS

The proposed model can be implemented into the South African tertiary education framework by the NIASA Subcommittee for Education. This model was designed to be scalable, to include or reduce participants, and portable, to be used in the delivery of other qualifications. Details of the model should be developed by the consortium, once established.

APPENDICES

Appendice A: NTEC programme timetable 2008 – 2009

MSc Nuclear Science & Technology Module Schedule Sept 2008 - July 2009						
* Core modules						
Module Title	Module held at	pre-course info issued on	Module Delivery	Assignment due	Exam date	
N32 Experimental Reactor Physics - 2nd year Part Timers	Vienna	29th August 2008	29th Sept - 3rd October 2008	1st December 2008	NO EXAM	
N04 * Decommissioning, Waste, Environmental Management	Westlakes	20th September 2008	20th - 24th October 2008	22nd December 2008	28th January 2009	
N03 * Radiation & Radiological Protection	Manchester	3rd October 2008	3rd - 7th November 2008	19th January 2009	9th February 2009	
N12 Reactor Thermal Hydraulics	Manchester	17th October 2008	17th - 21st November 2008	2nd February 2009	23rd February 2009	
N21 Geotechnical Aspects of Radioactive Waste Disposal	Westlakes	1st November 2008	1st - 6th December 2008	16th February 2009	9th March 2009	
N01 * Reactor Physics, Criticality & Design	Birmingham	8th November 2008	8th - 12th December 2008	23rd February 2009	16th March 2009	
N10 * Processing, Storage & Disposal of Nuclear Waste	Manchester	15th November 2008	15th - 19th December 2008	2nd March 2009	23rd March 2009	
N08 Particle & Colloid Engineering in the Nuclear Industry	Leeds	1st December 2008	5th - 9th January 2009	9th March 2009	NO EXAM	
N31 * Management of the Decommissioning Process	Birmingham	15th December 2008	19th - 23rd January 2009	23rd March 2009	15th June 2009	
N29 * Decommissioning Technology & Robotics	Lancaster	2nd January 2009	2nd - 6th February 2009	6th April 2009	6th May 2009	
N05 Water Reactor Performance & Safety	Imperial	16th January 2009	16th - 20th February 2009	20th April 2009	26th May 2009	
N02 * Nuclear Fuel Cycle	Manchester	23rd January 2009	23rd - 27th February 2009	27th April 2009	1st June 2009	
N22 Public & Political Aspects of Nuclear Decommissioning	Westlakes	2nd February 2009	2nd - 6th March 2009	5th May 2009	NO EXAM	
N07 Safety Case Development	Manchester	16th February 2009	16th - 20th March 2009	18th May 2009	22nd June 2009	
N24 Environmental Decision making Applied to Decomm	Westlakes	23rd February 2009	23rd - 27th March 2009	26th May 2009	NO EXAM	
N23 Environmental Impact Assessment	Westlakes	26th February 2009	30th March - 3rd April 2009	1st June 2009	NO EXAM	
N06 Reactor Materials & Lifetime Behaviour	Manchester	20th March 2009	20th - 24th April 2009	22nd June 2009	20th July 2009	
N14 Risk Management	City	11th April 2009	11th - 14th May 2009 (4 days)	13th July 2009	22nd July 2009	
N13 * Criticality Safety Management	Manchester	18th April 2009	18th - 22nd May 2009	20th July 2009	24th July 2009	
N32 Experimental Reactor Physics - Full Timers	Vienna	8th May 2009	8th - 12th June 2009	27th July 2009	NO EXAM	

Appendice B: Feedback on the specific needs of the SA nuclear industry for nuclear engineers

Eskom

John Gosling, Eskom's chief learning officer, was interviewed and the answers to the questions specified in paragraph 3.2.1 are summarised as follows.

Knowledge

As part of the education of nuclear engineers, the following topics of knowledge should be covered:

- Life cycle aspect:
The whole life-cycle of a nuclear plant will have to be covered. This will include birth of the plant, maintaining, operation criteria and decommissioning/close-down of a plant.
- Project management:
All nuclear project management processes, which include contractual conditions, environmental issues, licensing and financial aspects. These aspects should preferably be focused on the South African framework.
- Materials and water chemistry:
Nuclear materials and the effect of radiation on nuclear materials will have to be studied. As water chemistry determines the life of a plant, the requirements need to be understood.
- Fuel:
The design, handling, storage and transport as well as waste handling will have to be studied.

Skills and competencies

A nuclear engineer needs skills in the following areas: health and safety, radiation protection, licensing, monitoring systems, nuclear lifecycle and water chemistry. He should also understand the interface between a nuclear and conventional station.

In order to obtain nuclear plant operation skills, working in a simulated control room would be valuable. In this way, operating criteria, requirements and regimes as well as their effects can be tested and understood.

Research

Research can be conducted by students on actual projects or case studies from Eskom (Koeberg). An existing problem can be studied so that a student can research a solution or prevention to the problem.

PBMR

Jeff Victor, national capacity building manager at PBMR, was interviewed and the answers to the questions specified in paragraph 3.2.1 are summarised in the paragraphs to follow. In addition to providing answers to the questions, Jeff Victor provided the following explanation of what nuclear engineers carry out within PBMR:

Nuclear engineers, from PBMR's point of view, research and develop the processes, instruments, and systems used to derive benefits from nuclear energy and radiation. They design, develop, monitor, and operate nuclear plants to generate power. They may work on the nuclear fuel cycle - the production, handling, and use of nuclear fuel and the safe disposal of waste produced by the generation of nuclear energy - or on the development of fission energy. Some specialise in the development of nuclear power sources for naval vessels or spacecraft; others find industrial and medical uses for radioactive materials, as in equipment used to diagnose and treat medical problems.

Knowledge

- Knowledge of international regulatory organisations and practices
- Knowledge of international codes and standards on safety and licensing
- Basic understanding of plant engineering analysis
- Knowledge on conducting of relevant analysis
- Ensuring the technical quality and correctness of analysis performed by team members
- Good understanding of procedures and concepts within own technical/subject area
- An understanding of procedures and concepts within other related technical/subject areas
- Basic understanding of nuclear regulatory requirements
- Knowledge of core neutronics and fuel management analysis
- Knowledge of core kinetics analysis
- Awareness of system core thermo hydraulics
- Awareness of system thermo hydraulics
- Awareness of code-to-code and code-to-experiment verification and validation analysis
- Awareness of methods and algorithm
- Knowledge of mathematical model development
- Awareness of treatment of uncertainty and use of conservatism
- Awareness of nuclear safety principles
- Awareness of accident scenario definition
- Problem identification
- Defining and planning of work

- Analysis understanding
- Report writing and formulating recommendations
- Record keeping and enterprise processes
- Technical reviews
- Training and mentoring
- Awareness of fuel performance analysis
- Awareness of fuel depletion and source term analysis
- Awareness of fission product transport analysis
- Core neutronics and fuel management analysis
- Awareness analysis of core kinetics
- Awareness of fuel depletion and source term analysis
- Awareness of fission product transport and plate-out analysis
- Awareness of radioactive waste characterisation

Skills

- Obtain and discuss requirements with system engineers
- Assist and advise systems engineers in compiling specifications
- Negotiate requirements with system engineers
- Conduct designs according to specifications and requirements
- Ensure designs and physical drawings meets requirements and specifications
- Specify, conduct, plan, manage and control analyses
- Contract expert consultants as and when required and manage the contractual relationship
- Compile design reports
- Report progress to management or stakeholders
- Participate in the material specifications and material testing programmes
- Participate in component qualification programmes
- Identify possible suppliers for components and build relationships with the suppliers
- Communication skills (excellent demand of the spoken and written English)
- Facilitating and managing performance
- Provide technical feedback to other parts of PBMR within the appropriate process
- Manage the processes for area of responsibility
- Develop, execute and maintain all the relevant and necessary processes and procedures
- Communication and project management skills
- Building and maintaining stakeholder relationships

Competencies

- Technical competence in reactor safety, reactor kinetics and radiation protection
- Safety culture
- Mathematically competent
- Using information technology
- Project management and communication competencies
- Team leadership
- Building and maintaining stakeholder relationships
- Organisational understanding
- Business understanding
- Facilitating and managing performance
- Articulating and cascading the vision and values
- Fuel temperature measurement
- Conceptual, analytical, innovative thinking
- Decisive insight

Research

- Materials
- Waste management
- Reactor design and analysis
- Femtochemistry (SiC Improvement)
- Fuel modelling
- Diffusion study
- Ag migration
- SiC nanotubes study
- Si isotopes study
- Impact of CVD conditions on SiC layer
- Graphite dust study
- Graphite life extension (radiation damage)
- Graphite characterisation
- Graphite feedstock (coke)
- Heat resistant concrete
- CF control rods
- High-temperature materials
- Control and instrumentation
- Passive cooling

- Ag plate-out study
- Waste heat recovery and use

Personal attitude

- Rigorous and prudent approach
- Questioning attitude related to safety aspects
- Analytical thinking
- Attention to detail
- Integrity
- Teamwork
- Empowerment
- Pride in performance
- Driving accountability
- Drive and energy
- Initiating action
- Cross-cultural awareness
- Impact and influence
- Strategic focus
- Attention to detail
- Broad scanning

NECSA

Dr. Pamela Dube, senior manager for learning and people development at NECSA, provided the following answers to the questions specified in paragraph 3.2.1 in a written format.

Knowledge

The following subjects need to be covered:

- Fuel cycle
- Licensing
- Siting of nuclear installations
- Chemistry (in general) and uranium and fluoride chemistry (in particular)
- Chemical and mechanical engineering principles

A course for nuclear engineering management focusing on PWR should be included in the curriculum.

Skills and competencies

Meticulous and analytical skills are required in reactor accuracy. Ability should be obtained to establish facilities for the testing of processes relating to the PWR fuel Fabrication for:

- Uranium conversion processes through powder metallurgy processes and mechanical engineering assembly components.
- All phases of design, manufacturing and production and quality assurance

Nuclear engineers are also expected to be scientifically-oriented and visionary.

Research

Applied research and the demonstration of technology and capability are required.

In the future, NECSA may need research in the following areas:

- Nuclear fuel cycle
- Improvements in the manufacturing process and the related efficiencies
- Understanding of adjacent fields of product design
- Application of nuclear physics
- Limitations for NPP Utilisation

NNR

Puleng Maseko, talent manager of the national nuclear regulator, and Dr. Jean Joubert, co-ordinator of the PBMR assessment in the assessment group of the NNR, provided the knowledge, skills and competencies needed from nuclear engineers employed at the NNR:

Knowledge

- Nuclear reactors and plant systems
- Core physics
- Thermal-hydraulics
- Nuclear facility behaviour under design, transient and accident conditions
- Fuel design and fuel in-core behaviour and depletion effects
- Criticality safety
- Computer codes – methodologies applied, assumptions made and interpretation of results

Skills

- Application of the knowledge base to evaluate safety cases in those areas
- Understanding of fuel management philosophies and related safety demonstrations
- Understanding of deterministic accident analysis

- Application of conservatism in criticality safety demonstration
- Verification and validation of computer codes

Generic competencies

- Analytical thinking, problem solving and decision-making
- Arithmetic/ mathematical reasoning/numeracy
- Computer literacy and information technology
- Self-management
- Communication, report writing, presentations
- Teamwork and co-operation
- Interpersonal competencies
- Initiative
- Organisational awareness
- Physical security
- Legal operations
- Finance

Management competencies

- Strategic thinking
- Planning
- Negotiation
- Training and development; conflict management
- Performance, project, quality, knowledge management
- Stakeholder management
- Information technology management and HR management
- Finance management
- Corporate governance

Technical competencies (general)

- Legal basis
- Regulatory requirements and guidance
- Authorisation
- Compliance assurance and enforcement
- Specialised nuclear technology

Technical competencies (specialised areas)

- Compliance assurance and enforcement
- Facility operations
- Engineering and configuration management
- Facility quality management systems
- Nuclear security
- Deterministic safety analysis or assessment
- PRA
- Nuclear safety
- Radiation protection
- Emergency planning, preparedness, and response
- Waste management
- Decommissioning, decontamination, and closure
- Transport of fuel
- Safety and protection-focused analytic techniques
- Inspection, investigation and auditing techniques

Appendix C: Description of modules offered by NWU

A short description of each of the modules offered by the NWU follows, as provided by the Post-graduate School for Nuclear Science and Engineering brochure of 2009.

Compulsory modules

The courses include the following content:

Nuclear Engineering 1

- Atomic and nuclear physics;
- nuclear reactors and nuclear power;
- interaction of radiation with matter;
- neutron diffusion and moderation;
- nuclear reactor theory;
- the time-dependent reactor;
- heat removal from nuclear reactors;
- radiation protection and shielding; and
- safety, the environment and reactor licensing.

Nuclear Engineering 2

- Design and operating principles of various nuclear reactors and fuel;
- licensing and safety considerations of various reactor types;
- fuel design basis of various nuclear technologies;
- nuclear fuel cycles;
- neutronics and coupled thermal-hydraulic;
- safety systems of various nuclear reactors; and
- fuel management and cost.

Reactor analysis

- Neutron nuclear reactions;
- nuclear chain fission reactors;
- neutron diffusion theory, transport theory, slowing down, energy distribution;
- resonance absorption;
- fuel burn-up; and
- nuclear reactor dynamics.

Reactor safety

- Safety concepts and radiation protection;
- defence-in-depth principle;
- source term and fission product transport;
- attenuation calculations;
- shielding design, reactor accidents and inherently safe reactors;
- deterministic and probabilistic risk analysis;
- reactor siting;
- environmental impacts; and
- reactor licensing.

Elective modules

The courses include the following content:

Thermal-fluid Systems Modelling 1

- Introduction to system simulation;
- fundamental principles of thermal-fluid simulation;
- integrated system simulation applied to various power plant configurations;
- introduction to steady-state heat exchanger simulation;
- steady-state incompressible and compressible pipe flow simulation; and
- transient simulation.

Computational Fluid Mechanics 1

Modern CFD with its extensions to multi-phase flows, structure interaction and systems approaches is wide and general and covers most of the issues and techniques that apply to the field numerical transport theory. It is applied to the Navier-Stokes equations within the multi-phase flow finite volume framework on arbitrary unstructured grids as implemented into commercial codes such as Fluent and Star-CD. An objective of the course is to give CFD analysts an understanding of the underlying structure of the software and methods that apply to commercial CFD software usually available as “black box” solutions. Equipped researchers are also interested in the field of transport phenomena simulation software development with a suitable background for code and methods development.

Pressurised water reactor technology

- Light water reactor core physics;
- design of fuel elements and core: design bases for Koeberg NPP core design;

- components of Primary system: design bases for MCP, PRZR (PORV and safety valves) SG, MSIV, GCT to ATM;
- components of reactor: design bases for reactor pressure vessel reactor internals, control rods;
- design bases transient and accident analysis: SAR requirements, ECCS acceptance criteria, design conditions of the PWR plants; and
- regulatory framework (NNR, NRC, IAEA): Codes, standards, specifications.

Advanced Reactor Analysis 1

- Neutron transport theory (S_n , P_n derivation);
- neutron diffusion theory (FD, codes) and energy distribution and thermalisation;
- reactivity changes (burn up, point kinetics); and
- introduction to Monte Carlo methods (basic equations, approaches, cross sections, statistics).

High temperature gas-cooled reactor thermal-fluid analysis

- Coolant choice and properties, solid materials thermal properties;
- pebble bed core properties: porosity distribution, flow distribution, pressure drop;
- heat production and distribution;
- core heat transfer phenomena and modelling: convection, dispersion, conduction, radiation; and
- numerical modelling of integrated heat transfer and fluid flow inside the reactor.

High temperature reactor fuels and materials

- Preparation of HTR fuel;
- fuel characteristics;
- burn up and fuel performance;
- radiation effects on fuel
- structural and radiation properties of graphite;
- high temperature materials; and
- material selection.

High temperature reactor technology

- Principal aspects of HTR and applications;
- core physics;
- thermo-hydraulic of core;
- reactor components;

- primary system components;
- design and lay-out of fuel elements and core;
- safety and licensing
- accidents analysis;
- operational aspects;
- coolant and materials (tribology of helium);
- intermediate and final storage;
- cost aspects; and
- development of HTR.

Nuclear project management

The purpose of the module is to use a problem-based learning technique to provide a thorough understanding of all aspects of project management theory and practice within a nuclear environment. The module will focus on the following key themes: planning, cost, and value management; project control; human issues in project management; strategic issues in project management; commercial and procurement law.

Pebble bed reactor design

- Physical processes in a reactor;
- modelling/computational representation of individual events in reactor operation;
- simulation of fuel cycles;
- reactor life and accident simulation;
- the interaction of individual events; and
- design project.

Appendice D: Blended delivery method verification questionnaire

1. General information:

1.1 What is your gender?

Male	
Female	

1.2 You have previous qualifications in the following (more than one can be indicated)

Mechanical Engineering degree	
Chemical Engineering degree	
Metallurgical Engineering degree	
Electrical Engineering degree	
Computer Engineering degree	
Other Engineering degree	
Diploma in Engineering	
Natural Sciences degree	
Diploma in Natural Sciences	
Other	

1.3 If you answered 'Other' in 1.2, please specify.

1.4 Will the knowledge, skills and competencies you obtain in taking these courses at the NWU contribute to your career plans?

Yes	
No	
Not sure	

1.5 If your answer at 1.4 was 'no', what is your motivation for taking the courses?

2. Study guides, access to eFundi, starting the course:

2.1 Was the web-based learning environment (eFundi) readily available to you at the start of the course?

Yes	
No	

2.2 If you answered 'no' at 2.1, describe any problems and the time span of the problems encountered.

2.3 Make a list of all the problems you encountered and suggest who you think had direct control over the possible solutions.

2.4 Was the study guide clear?

Yes. The whole study guide	
Yes, part of the study guide	
No, not at all	

2.5 Was the study guide helpful?

Yes. The whole study guide	
Yes, part of the study guide	
No, not at all	

2.6 Give your thoughts on the effectiveness of the study material?

3. Physical work environment, scheduling and time management:

3.1 How much time per day can you spend on the course? (Indicate the average time)

Less than 30 minutes	
Between 30 minutes and 1 hour	
Between 1 hour and 1½ hour	
Between 1½ hour and 2 hours	
Between 2 hours and 2½ hours	
Between 2½ hours and 3 hours	
Between 3 hours and 3½ hours	
Between 3½ hours and 4 hours	
More than 4 hours	

3.2 Do you have internet access at home?

Yes	
No	

3.3 Do you have internet access elsewhere than at home and at the office?

Yes	
No	

3.4 Did you work over weekends?

Yes, always	
Yes, sometimes	
No, never	

3.5 Explain the reason for your answer 3.4

3.6 Is the network speed at the office adequate for the work that has to be done on the web-based learning environment (eFundi)?

Yes, always	
Yes, sometimes	
No, never	

3.7 Explain any other problems experienced with the network at your office.

4. **Course content:**

4.1 What would you like to learn from this course? (What should the course content include?)

4.2 Were the outcomes of this course clear?

Yes, all of it	
Yes, some of it	
No, nothing	

4.3 Were the outcomes of this course relevant for knowledge you need in your current employment position?

Yes, all of it	
Yes, some of it	
No, nothing	

4.4 Motivate your previous answer at 4.3.

4.5 Were the outcomes relevant to your career plans for the future?

Yes, all of it	
Yes, some of it	
No, nothing	

4.6 Motivate your previous answer in 4.5

4.7 Did you find any overlap of information with other courses?

Yes	
No	

4.8 If you answered 'yes' at 4.7, give details on these overlapped information

4.9 Was the course well organised?

Yes	
No	
Not sure	

4.10 Please provide a reason for you previous answer (4.9)

5. Lecture Week:

5.1 Were the lecture's objectives adequately emphasised?

Yes, clearly	
Yes, vaguely	
No, not at all	

5.2 Was the lecture room suitable?

Yes	
No	
Not sure	

5.3 Please explain previous answer given at the previous answer (5.2)

5.4 Did the Lecturer demonstrate sufficient knowledge of the subject to the matter?

Yes, always	
Yes, sometimes	
No, not at all	

5.5 Did the lecturer adapt style and method to suit the group?

Yes, always	
Yes, sometimes	
No, not at all	

5.6 Did the lecturer encourage a high level of learner involvement and interaction?

Yes, always	
Yes, sometimes	
No, not at all	

5.7 Did the Lecturer maintain a friendly, positive learning environment throughout the sessions?

Yes, always	
Yes, sometimes	
No, not at all	

5.8 Did the lecturer address learner questions promptly and effectively?

Yes, always	
Yes, sometimes	
No, not at all	

5.9 Was the lecturer able to convey difficult material clearly?

Yes, always	
Yes, sometimes	
No, not at all	

5.10 Did the lecturer present the lectures enthusiastically?

Yes, always	
Yes, sometimes	
No, not at all	

5.11 Which of the lecturer's teaching did you regard as his / her best?

5.12 Which aspect of the lecturer's teaching did you regard as his / her weakest?

6. Communication with lecturers and administration personnel:

6.1 How did you experience the communication with the lecturers in the pre-lecture guided self-study period?

Most of it clear and effective	
Some of it clear and effective some of it vague and confusing	
Most of it vague and confusing	

6.2 How did you experience the communication with the lecturers in the lecture period?

Most of it clear and effective	
Some of it clear and effective some of it vague and confusing	
Most of it vague and confusing	

6.3 How did you experience the communication with the lecturers in the post-lecture period?

Most of it clear and effective	
Some of it clear and effective some of it vague and confusing	
Most of it vague and confusing	

6.4 How did you experience the communication about the course with your employers? (if relevant)

Most of it clear and effective	
Some of it clear and effective some of it vague and confusing	
Most of it vague and confusing	

6.5 Please provide detailed information on problems experienced regarding communication with the lecturers?

6.6 Give your ideas on how communication can be improved.

7. Examination preparation:

7.1 How did the pre-lecture week guided self-study work contribute to your preparation for the examination?

It was absolutely necessary for my preparation	
It was necessary to some extent	
I could have done my preparation without it	

7.2 How did the lecture work contribute to the preparation for the examination?

It was absolutely necessary for my preparation	
It was necessary to some extent	
I could have done my preparation without it	

7.3 How did the post-lecture work contribute to the preparation for the examination?

It was absolutely necessary for my preparation	
It was necessary to some extent	
I could have done my preparation without it	

8. Any other further ideas:

8.1 Give ideas for further improvement of the course.

8.2 Give ideas for further improvement of the programme from the NWU.

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