A MODEL FOR THE TEACHING OF IMAGING INFORMATICS, A PLATFORM IN BIOMEDICAL INFORMATICS, IN A FUTURE INTEGRATED NATIONAL HEALTH INSURANCE SYSTEM IN SOUTH AFRICA

BY

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DECLARATION

I hereby declare that the work submitted here is the result of my independent investigation. Where help was sought, it was acknowledged. I further declare that this work is submitted for the first time at this university/faculty towards a Philosophiae Doctor degree in Health Professions Education and that it has never been submitted to any other university/faculty to obtain a degree.

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DEDICATION

I dedicate this thesis to my late parents, Ben and Ria Botha, who encouraged me to study and create an inheritance that cannot be spent or wasted.

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LIST OF ABBREVIATIONS AND ACRONYMS

ABII	**American Board of Imaging Informatics**
AMIA	**American Medical Informatics Association**
BMI	**Biomedical informatics**
BMIDS	**Multiple biometric identification systems**
CC	**Coefficient of concordance**
CHE	**Council on Higher Education**
CIIP	**Certification for Imaging Informatics Professionals**
CPAS	**Certified PACS Associate**
CT	**Computed tomography**
DICOM	**Digital imaging and communication in medicine**
DHET	**Department of Higher Education and Training**
DoE	**Department of Education**
DoH	**Department of Health**
EHR	**Electronic health records**
EMR	**Electronic medical records**
EPR	**Electronic patient records**
FHIR	**Fast Health Interoperability Resources**
HEQSF	**Higher Education Qualifications Sub-Framework**
HI	**Health informatics**
HIC	**Health Insurance Commission**
HIS	**Hospital information system**
HL7	**Hospital Level Seven**
HPCSA	**Health Professions Council of South Africa**
ICT	**Information and communication technology**
IHE	**Integrating the Healthcare Enterprise**
IMIA	**International Medical Informatics Association**
IP	**Internet protocol**
IT	**Information technology**
LAN	**Local area network**
MRI	**Magnetic resonance imaging**
NHI	**National health insurance**
NHIS	**National health insurance system**
NHS	**National Health Service**

NHP	**National Health Programme**
NHSF	**National Health Standards Framework**
NQF	**National Qualifications Framework**
OSI	**Open systems interconnection**
PACS	**Picture Archiving Communication Systems**
PARCS	**PACS Administration Registry and Certification Association**
PBRCT	**Professional Board for Radiography and Clinical Technology**
PET	**Positron emission tomography**
PHI	**Public health informatics**
PIS	**Physician Information System**
RDP	**Reconstruction and Development Programme**
RIS	**Radiology Information Systems**
RSNA	**Radiology Society of Northern America**
SAHIA	**South African Health Informatics Association**
SAQA	**South African Qualifications Authority**
SIIM	**Society of Imaging Informatics in Medicine**
SPECT	**Single photon emission computed tomography**
TCP	**Transmission control protocol**
UK	**United Kingdom**
US	**Ultrasound**
USA	**United States of America**
WAN	**Wide area network**
WHO	**World Health Organization**

SUMMARY

Keywords: Teaching model, imaging informatics, National Health Insurance system, radiographer, integrated, holistic student development, medical imaging informatics

In this research project, the researcher conducted an in-depth investigation into imaging informatics, to develop a teaching model in imaging informatics, applicable to the South African context.

Imaging informatics in the digital radiology department is a division of medical imaging informatics and a study level in biomedical informatics, and function on a cellular or organ system level (Huang 2014a:631). It involves Picture Archiving Communication Systems (PACS), Radiology Information Systems (RIS), radiographic digital imaging modalities and a secure network for storing, retrieving and communicating of medical information and DICOM (digital imaging and communication in medicine) images. In digital radiology departments, in private and public healthcare institutions, it is usually the IT specialists (or manager) and the PACS administrator that is responsible for ensuring a smooth exchange of health information.

Currently, no registered, accredited training programme in imaging informatics is available in South Africa. The objectives of the study were:

- To gather data regarding imaging informatics nationally and internationally; and
- To develop a teaching model for imaging informatics, a platform in BMI, in a future integrated NHI system in South Africa.

The researcher used a mainly quantitative research approach to collect quantitative and qualitative data through three structured questionnaires and a three-round Delphi technique. The target population involved radiographers, IT specialist, PACS administrators and system managers. Purposive sampling was used to select the samples from each of the different research populations. The research design was appropriate, as it assisted in answering the research questions within a pragmatist paradigm.

Six summated themes regarding imaging informatics principles were derived from the first

two questionnaires and incorporated into the development of the first Delphi questionnaire. The categories of the professional practices of imaging informatics professional in the third structured questionnaire were also included in the first-round Delphi questionnaire. The three-round Delphi survey resulted in consensus achieved for 142 of the 184 statements (categories). Stability was proclaimed on an additional 37 statements. Only five categories were excluded after round three.

The information retrieved from the literature review during Phase 1 of the study regarding BMI platforms and training; imaging informatics principles and teaching courses; learning theories, teaching strategies and models; and the categories where consensus was reached, and stability proclaimed, were used to develop the teaching model for imaging informatics in a future integrated National Health Insurance system.

From the conclusions, it is clear that the teaching model developed through this study will be useful for developing and implementing a curriculum for imaging informatics teaching and learning in South Africa.

A MODEL FOR THE TEACHING OF IMAGING INFORMATICS IN A FUTURE INTEGRATED NATIONAL HEALTH INSURANCE SYSTEM IN SOUTH AFRICA

CHAPTER 1

ORIENTATION TO THE STUDY

1.1 INTRODUCTION

Since the emergence of medical informatics as separate disciplines more than five decades ago, it has been introduced into the curricula of most medical schools. Medical informatics can be related to the historical stages of computer science; however, the emergence of medical informatics as a separate discipline has depended on formal education for assistance and elevation to a scientific field. Although diverse names with different meanings have been suggested for the field of medical informatics, the ones currently used interchangeably in the literature include medical informatics, biomedical informatics (BMI) and health informatics (Mantas 2016:92; Chi & Pavilcek 1999:37). In this research study, the term BMI will be used as an umbrella term, that includes imaging informatics.

In the United States of America (USA), the early years of medical informatics education were conceptualised and instigated by the International Medical Informatics Association (IMIA).

Since early 2000, medicine rapidly transformed into a digital environment, with radiology playing a leading role in the changes. Picture Archiving Communication Systems (PACS) have become almost ever-present in medical facilities in the USA, and the development and maturation of PACS have made it a vital factor in patient care (Branstetter IV 2010:i).

Radiologists have realised that they need a dedicated team for the smooth operation of PACS and for managing workflow in a digital imaging environment. Radiologists initially considered involving information technology (IT) professionals but realised IT professionals might have difficulty with the clinical underpinning of PACS. The need for a dedicated team lead to the creation of the PACS administrator, who could be, for example, an IT professional or a radiographer (technologist). Motivated, self-taught workers emerged from different backgrounds, and were eager to learn and find ways to overcome their lack of medical knowledge; they formed a bridge between IT and clinical communities (Branstetter

IV 2010:i). Terms, such as radiology informatics and PACS administrator, which were used during the initial development and implementation of informatics in diagnostic imaging, were later replaced by imaging informatics and imaging informatics professionals (Branstetter IV, 2010:v).

In this research project, the researcher conducted an in-depth investigation into imaging informatics, to develop a teaching and learning model for imaging informatics. The teaching and learning module could benefit radiographers and IT specialists who wish to advance their careers in the imaging informatics field in South Africa. The researcher investigated aspects of the different platforms that exist in BMI, in order to contextualise imaging informatics. The researcher used information from literature and information gathered from respondents, who were qualified diagnostic radiographers, IT or e-Health information specialists and PACS administrators; vendors' (who sell and service BMI and imaging informatics technology) applications specialists and PACS administrators, and lecturers in imaging informatics and digital imaging physics at higher education institutions that offered radiography programmes in South Africa, to achieve the goal of the study.

The teaching and learning model could enhance postgraduate education and training of professionals involved in the imaging informatics environment in South Africa. The professionals may include radiographers (or radiological technologists, as they are called in the USA), PACS administrators and information technologists working in the imaging informatics environment, and BMI technologists working on different levels of BMI, such as health informatics and e-Health.

In this chapter, the researcher will orient the reader to the study by providing background to the research problem, followed by the problem statement, the research questions, the overall goal and the aim and objectives of the study. The demarcation of the study and an explanation of the significance and value of the research will also be covered in this chapter. A brief overview of the research design and methods of investigation will then follow. A brief layout of the succeeding chapters and a summary concludes the chapter.

1.2 BACKGROUND TO THE RESEARCH PROBLEM

The purpose of the background section is to outline the different platforms of BMI and their current integration. In addition, the chapter provides a brief explanation of current teaching and learning programmes in imaging informatics and BMI.

1.2.1 Biomedical informatics

According to Huang (2014b:631), medical informatics or BMI can be categorised into four different platforms, namely, bioinformatics, on a molecular level; imaging informatics, on a cellular or organ system level; clinical informatics, on the level of an individual healthcare system; and public health informatics, on a population level. In these four levels, the concepts as well as the methodologies overlap each other.

Bioinformatics can be defined as the application of computer calculations to organise and understand information related to biological macromolecules (Luscombe, Greenbaun & Gerstein 2001:83). Succinctly, bioinformatics serves as an information system for managing molecular biology and has several applied applications. The union between information technology and molecular biology is attributable to life being information technology (Pandey & Divyasheesh 2016:56). Genes determine the physiology of any living organism and genes can also be seen as genetic information technology of the human body (Luscomb *et al.* 2001:83).

Clinical informatics, which forms part of health informatics on a personal level, involves the subspecialty that involves medical specialists transforming healthcare through analysing, implementing, designing and evaluating communication and information systems. By using clinical informatics, the medical specialist can improve patient care, enhance access to medical care, improve the health outcomes of populations and individuals, and reinforce the relationship between patients and clinicians (ACGME 2016:1). Therefore, clinical informatics refers to the use of information technology by and for clinicians in the healthcare sector. Another field in health informatics is nursing informatics (Maryniak 2013:2). While clinical informatics usually operates on the individual healthcare level, public health informatics operates on a population level (Huang 2014b:631).

Public health informatics (PHI) refers to the systematic information and computer application in public health practice. The health IT professional is mainly involved in troubleshooting and managing infrastructure issues, while the PHI specialist makes use of computer science information to support decision-making and achieve goals relating to public health (White 2013:25).

Imaging informatics (Huang 2014b:631), includes PACS (cf. 2.4.4.4), radiology information systems (RIS) (cf. 2.4.4.3) and the imaging modalities (McEnery 2013:2) (cf. 2.4.4.2).

Imaging informatics plays an important role in BMI in hospital operations. A good relationship between the imaging department (radiologists) and the hospital leadership is vital, and steps should be in place to ensure a continuous effort to maintain this relationship (Branstetter, Bartholmai & Channin 2004:245). Digital images created in the radiology department play a vital role in the medical specialist's daily tasks as a diagnostic, treatment or operational guide, in the ward and in their surgical procedures (Kohli, Dreyer & Geis 2015:719).

BMI incorporates an interdisciplinary combination of platforms that are used in the health informatics environment for storing, retrieving and communicating medical data. The medical data can originate from various sources, such as biological applications, healthcare-related activities, and preclinical or clinical research (Carlton & Adler 2013:263; Carlton, Adler & Balac 2020:329). The operational requirements of some clinical and diagnostic departments at hospitals differ from those of the hospitals. These hospital departments used to involve mainly radiology (RIS and PACS), cardiology (cardiovascular image and information management systems, or CIIMS & PACS) (Calero 2009), pharmacy (pharmacy information systems) (Alanazi, Al Rabiah, Gadi, Househ & Al Dosar 2018:1; White & Hohmeier 2015:247), pathology, and clinical laboratories (laboratory information management systems and PACS) (Jones, Johnson & Batstone 2014:179; Michel 2009:17). The different information systems needed by these departments could fall under the same informatics structure as the hospital information system (HIS) of the hospital (Huang 2014b:287).

A HIS is an electronic management system that is responsible for executing the following tasks in the healthcare environment: clinical and medical activities relating to patient care; administration of daily business transactions in a hospital; hospital performance and developing long-term projections or goals of the hospital (Huang 2014b:287). It can be said that a HIS integrates all clinical, administrative and financial applications in a hospital (EMR Consultant 2013:Online). However, electronic medical records (EMR) used to be an application used mainly in conjunction with the physician information system (PIS) of the hospital (EMR Consultant 2013:Online).

Previously, some people used EMR, electronic health records (EHR) and electronic patient records (EPR) as synonyms, however, there is actually a significant difference between these concepts. EMR was initially used in the same way as the PIS, for medical purposes by clinicians, mainly for diagnosis and/or treatment (Garrett & Seidman 2011; Weeks

2013:137). An EMR contains treatment and medical records of patients, over a period of time, in a particular hospital or practice – these records replaced the old paper files of patients. However, EMRs did not often leave the hospital or practice, and patients' records still needed to be printed and delivered/mailed to specialist clinicians (Huang 2014b:403; McEnery 2013:1). EHRs focus on the health of the patients in totality. These records are used to facilitate interaction and share patients' health information with other service providers. With EHRs, patient information moves with patients, and everyone involved in a patient's care can access the information (cf. 2.3.3.2) (Garrett & Seidman 2011:Online). According to the Promotion of Access of Information Act, 2000, of South Africa, even patients may access their EHRs (Kumar & Wambugu 2016:3; RSA DOJ & CD 2000:40).

In medical imaging departments employing clinical informatics on BMI platforms, access policies and physical device and network protection are essential and should be applied according to internal rules and security norms (Carlton *et al.* 2020:337). In BMI, the availability of sensitive patient data to all relevant service providers and the patients themselves poses a high confidentiality risk. Tampering with this personal information may result in identity theft, incorrect diagnosis and/or treatment, and even death. In the USA, the purpose of the Health Insurance Portability and Accountability Act of 1996 (HIPAA) was to establish confidentiality and privacy procedures for private information within the healthcare enterprise (Edemekong & Haydel 2019:Online). The South African Protection of Personal Information Act, No. 4 of 2013, was promulgated to promote the protection of personal information processed by public and private bodies (RSA DOJ & CD 2013).

Quality control and biometric informatics should play a vital role in BMI. Quality control in health informatics includes the security management of personal information exchange on a local area network (LAN) and/or wide area network (WAN) (Carlton *et al.* 2020:332). Biometric informatics (identification) enhances security and prevents the abuse of passwords or the need for multiple passwords. Multiple biometric identification systems (BMIDS) are being developed, and include, for example, palm vein scanning, fingerprint identification systems, iris reading, and voice recognition (Gardiyawasam Pussewalage & Oleshchuk 2016:1163-1166; Keen 2011:Online).

Considered to be components of EMR, HIS (used by hospitals) and RIS (used by diagnostic imaging departments) deal with patient data other than imaging data and combine it with the digital images in the PACS. These three integrated systems form the cornerstone of the EHR systems (Huang 2014b:403). RIS forms an integral part of imaging informatics and is referred to as the core system of a digital imaging department's electronic management of patients' information (Carlton *et al.* 2020:329; McEnery 2013:1).

1.2.1.1 *Imaging informatics*

Radiology information systems

RIS, the main electronic management systems of radiology departments, support clinical and administrative operations in the imaging department. Administration operations include the billing system, which is interactive with the RIS. The RIS and HIS configurations are very similar, but RIS is on a much smaller scale (Huang 2014b:390). Exploitation of PACS integrated with the EHR, HIS and RIS plays an essential role in patient-focused care and transforming productivity in radiology departments globally (Carlton *et al.* 2020:329).

All events or information (for example, scheduling and examination start and end times) of a patient associated with the events, are triggered in the RIS and then sent, in real-time, to the PACS (Huang 2014b:403). The main function of PACS is storing, retrieving, and distributing digital radiographic (medical) images (Carlton & Adler 2013:263). PACS have four main components: imaging systems, workstations, a secure network (LAN and/or WAN) and archives (Huang 2014b:219).

The imaging systems in the radiology department, also called x-ray modalities, are where the digital radiographic images are created. Imaging modalities in radiology include three broad categories, which is based on the imaging output, namely, single, multi-slice and hybrid imaging modalities (cf. Section 2.4.4.2, page 53) (Peck 2018:42-43). A diversity of these imaging modalities can be interfaced, by adapting the Digital Imaging and Communications in Medicine (DICOM) standard, to create an integrated healthcare system (Huang 2019:124). DICOM standards are involved in communication and participation in sharing digital radiographic image information (Huang 2019:127–129). The digital images are then viewed on the RIS or modality workstation of the radiographers and the reporting monitors of the radiologists. The PACS archive is where the new images are linked to the patients' older images and stored for viewing or retrieving, for comparison with the latest images (Huang 2019:99).

Picture archiving communication systems

PACS was introduced in the USA in 1982 (Van de Wetering & Batenburg 2009:127) and has become a mature, integrated part of healthcare. The PACS system was designed to streamline all operations in an integrated patient care delivery environment (Van de Wetering & Batenburg 2009:128), and PACS integration with HIS, RIS and EHR provides hospitals with a solid framework. A survey done in European countries (2006) found that Finnish hospitals had the highest (70%) adoption of PACS in the hospital environment; however, the average adoption in other countries was only 33% in 1982 (Van de Wetering & Batenburg 2009:129). In some European countries, PACS is deployed in most academic hospitals (Samei, Seibert, Andriole, Badano, Crawford, Reiner *et al.* 2004:314).

Interfacing the RIS with the PACS is based on the Hospital Level Seven (HL7) interface, via the transmission control protocol/internet protocol (TCP/IP) through ethernet (Branstetter IV 2010:38). HL7 is "a standard series of predefined logical formats for packaging healthcare data in the form of messages to be transmitted among computer systems" (Sengstack & Boicey 2015:65). The HL7 interface uses a normal messaging protocol for bridging gaps between the organisation's patient registration program, record resolution, and EMR. Healthcare providers use computer programs, which vary for the different services rendered; however, these various programs are not always able to communicate with one another (Indrajit & Verma 2007:66–67). By supplying a framework for the integration, exchange, retrieval and sharing of EHR or EMR, HL7 mitigates the communication problem. HL7 interfaces supply a secure and encrypted method of 'transferring' files. The HL7 messages are delivered utilising the present HL7 version, V2 standard for the transferal of medical and administrative information amongst software systems. HL7 messages are layered on the application layer (Level 7) of the open systems interconnection (OSI) protocol of the International Standards Organization. HL7 stipulates virtually no limitations on the communication protocols that could be used in the lower layers of the computer interface (Cordos, Orza, Vlaicu, Meza, Avram & Petrovan 2010:1295; Peck 2018:37). IP is a set of rules that dictates how computers send data to one another. IP works on the network layer of the OSI model, often in combination with TCP on the internet layer (Shiranzaei & Khan 2015:397).

A great deal of work by imaging informatics professionals was created by the network setup in healthcare establishments (Peck 2018:36), and it motivates professionals in the imaging informatics environment to further their studies in network-based teaching and learning programmes. With a better understanding of prospective problems and configuration possibilities, the professionals will be able to enhance the dependability of digital imaging departments (Peck 2018:36).

The smooth integration of PACS with the RIS and the daily running of PACS needs dedication and teamwork. The informatics in radiology departments used to be referred to as radiology informatics (RI), but it was renamed by the Society of Imaging Informatics in Medicine (SIIM, 2020) to imaging informatics when other specialities (department) in healthcare, in addition to radiology, needed similar services (Branstetter IV, 2010:v). These specialist department include, for example, clinical laboratories, pathology, urology, cardiology, surgery, obstetrics and gynaecology (Furness 1997:253; Beals 2001:327; Bouzas-Mosquera, Alvarez-García & Cuenca-Castillo 2008:1064).

Previously, in the private hospital environment in South Africa, PACS was used mainly in radiology departments, because private radiology practices are mainly independent practices (Health Market Inquiry Panel, 2016). Private radiology practices in South Africa do not usually integrate with private hospitals' networks, instead, they work through the hospital network to provide PACS access for physicians and other healthcare professionals, in the wards and operating theatres in the hospital. Urologists, cardiologists, pathologists and other medical specialists have their software programs for EMR or EHRs of patients (cf. 1.2.1). These medical specialists also run their own internal 'mini-PACS' systems for archiving and retrieval of digital images (NIBIB & ONC 2011:2).

In the public hospital environment, most radiology departments have upgraded from analogue to digital radiography, but in South Africa, the implementation of PACS in radiology is currently restricted to mostly academic hospitals. Although the Department of Health supports the adoption of PACS by the entire public hospital system, PACS is still not successfully operational in all public hospitals, even after numerous attempts to deploy it. This failure means patients in rural areas, in particular, are not receiving adequate healthcare, because clinicians lack access to the public PACS system and cannot access the integrated health records of patients (Triegaardt 2013:1).

To address the above-mentioned problems, a report, *National Health Standards Framework for Interoperability in e-Health in South Africa* (RSA CSIR & NDoH, 2014), was commissioned by the National Department of Health. The purpose of the report was to provide a foundation for future interoperability regarding the heterogeneous information technology platforms of the e-Health system. It represented the "first step towards a complete health enterprise architecture specification in South Africa", and towards a healthcare system with total interoperability across all levels in the health system, including both public and private healthcare systems (RSA CSIR & NDoH 2014:7). The integration of

RIS and the image management PACS is essential for a seamless workflow.

1.2.2 National Health Insurance system

In a future integrated national health insurance (NHI) system, healthcare for South African citizens will involve quality healthcare for all South African citizens (Sekhejane 2013:2). According to Sekhejane (2013:1), an NHI system has been modelled in various countries in Africa (Uganda, Ghana and Nigeria) and beyond (e.g. the United Kingdom (UK), several other European countries, and USA). These countries report successes and failures. Successes are a longer life expectancy for the population, better disease control, lower mortality rates in relation to childbirth, and continuous economic growth in the country. Failures relate to government inefficiencies, inadequate welfare policies, and inadequate healthcare expenditure (Mackenbach & McKee 2013:2-18). There is a chance that South Africa's future integrated NHI system may work well if implemented according to the NHI policy; however, some elements might make the system impractical. These elements include uneven resource distribution and health workers with inadequate professionalism and ethical standards (Sekhejane 2013:2).

The South African Constitution, Section 27 (2) of the Bill of Rights (1996), stipulates that access to basic healthcare is a human right (RSA DOJ & CD 2018). Consequently, the state must ensure that all South African citizens have fair and respectable access to basic healthcare (Sekhejane 2013:1). In 2011, South Africa made history when the Green Paper (RSA 2011:3) on the NHI was launched. The current national health system in South Africa undermines the human rights of lower-income and unemployed citizens to proper healthcare – these citizens do not have the money to afford private medical insurance (Sekhejane 2013:2). A small percentage of citizens in the higher income groups have private medical insurance, which give them access to private healthcare. This proposed NHI system, which is being implemented in three phases over 14 years, starting in 2012 and ending in 2025, is a public-private sector partnership. Predictions are that the private sector might suffer medium- to long-term losses in this partnership, due to unsustainable features in the private sector, such as,

- High costs that are linked to high service charges;
- Provider-induced utilisation of services; and
- Over-servicing of patients based on a fee-for-service method (Sekhejane 2013:2).

The first phase rollout of the NHI (2012-2017) was characterised by alarming allegations by citizens regarding the appalling treatment of patients by healthcare workers at a public hospital. Possible reasons named for the poor treatment were workers' lack of skills, and absence of a professional code (Sekhejane 2013:3).

Matsoso and Fryatt (2013) believe that technology will play an important role in the improvement of outcomes and service delivery in the new NHI system. The cost-effectiveness of new information communication technologies, which will be employed to help transform the health system, will have to be assessed. The ideal is to have integrated information of all patients' HIS, EMR, EHR, RIS and PACS as part of the BMI of the new NHI system. These integrated BMI platforms must be managed by skilled professionals in the BMI technology field, to ensure confidentiality of personal information. Service delivery in the radiology department, with the implementation of a digital workflow, is moving toward patient-centred care, which will not be possible without adequate trained healthcare professionals and imaging informatic professional (Martin-Carreras & Cook 2019:Online; Ranschaert 2016:5–6). Therefore, professional training (in the workplace) and formal education programmes (through higher education) will need to be in place to ensure that skilled professionals are available (Matsoso & Fryatt 2013:4).

1.2.3 Professional training in biomedical informatics

In the hospital environment, health IT or general IT specialists are usually responsible for the following tasks: workflow; IT infrastructure security and integrity; and troubleshooting on the EMR, EHR, and HIS platforms of BMI.

However, in imaging informatics in digital radiology departments, it is usually the responsibility of the PACS administrator and the IT manager (including an IT team) to ensure an uninterrupted workflow, adequate security and troubleshooting on the RIS and PACS platforms (Kumar & Wambugu 2016:4). The vendor application specialist usually conducts professional training in the workplace, in BMI and imaging informatics, after equipment has been installed.

1.2.3.1 *Health informatics training*

According to the South African Health Informatics Association (SAHIA), undergraduate training in health informatics was first discussed at a capacity-building workshop at the 2013 Health Informatics South Africa conference. Currently, SAHIA, in collaboration with e-Health in the public health sector, is focussing on interoperability of eHealth (SAHIA n.d.). Several universities, including Durban University of Technology, University of Cape Town and Nelson Mandela University, offer formal teaching and learning programmes in e-Health, telemedicine or bioinformatics for postgraduate students. e-Health programmes focus on health informatics on a personal and a population level. All-inclusive health coverage is provided or represented mostly by three measurements: health services presented to meet the need of individuals, the whole population and to groups of population – these three levels form part of the e-Health training programmes (WHO 2016a:1). Imaging informatics is a separate platform and does not form part of these programmes.

Health informatics education and training are offered at several higher education institutions in South Africa; most of these programmes are postgraduate qualifications (RSA DoH 2012:18). Currently, several South African higher education institutions are investigating the training gap of the other platforms of health informatics and BMI. The University of KwaZulu-Natal has instituted a characteristic BMI training programme in South Africa, in collaboration with the Information Training for Global Health Programme of Fogarty International Centre, National Institution of Health, USA, of which the main focus is bioinformatics (Seebregts, Mars, Moodley, Fraser, Human, Fourie *et al.* 2006:1). Imaging informatics does not form part of this teaching and learning programme developed in BMI at the University of KwaZulu-Natal.

1.2.3.2 *Imaging informatics training*

According to Law and Zhou (2003:148), PACS training started 20 years ago in the USA, and refresher courses have been offered annually at the meetings of the Radiology Society of Northern America (RSNA). The target audience of these courses were radiologists and physicians. A new trend in PACS training in the USA started around 2003, with an emphasis on how to operate workstations. Training shifted to the core components of imaging informatics, which included HIS, RIS, PACS, digital imaging modalities, computer software, storage of images and communication networks between these systems (Huang 2014a:8, 10). Imaging informatics training usually takes place in the clinical environment during normal working hours, also called in-service training. Radiographers and IT specialists in the radiology department had obtained most of their imaging informatics knowledge, during and after PACS installation, from the vendor’s imaging informatics specialist or imaging informatics application specialist, in the workplace. A service-level agreement contract between the radiologist and the company installing the equipment usually include a training agreement (Seikh 2016:111; Diagnostic Imaging 2003:1). The main disadvantage of in-service training is that a high workload in a very busy department makes it difficult to train people during working hours (cf. Section 4.2.3 page 128). The trend in imaging informatics education and training is to make use of a RIS and PACS simulator, which is a setup of RIS and PACS workstations for the purpose of providing intensive training to PACS administrators, so that they are able to handle the workflow. This setup is usually in a room off-site, which simulates the RIS and PACS environment and the working conditions in the radiology department. However, viewing the workstation in the imaging informatics environment is still necessary for the training of clinical and clerical personnel. The training of these personnel in hospitals is done during working hours in the live PACS environment (Law & Zhou 2003:149).

PACS administrator or imaging informatics certification courses are available at several higher education resources in the USA and Canada (ABII 2018a; Nagy, Bowers, Reiner & Siegel 2005:253). These courses usually include IT components, such as computer basics, operating systems, database basics, data representation, network technology and basic security concepts. The administration and management components include, for example, project management, PACS procurement and deployment, configuration and change management, acceptance testing, maintenance and administration services, supervising modality integration and data migration and virtual network archive challenges. The clinical components include the basics of body planes, directions and views in digital imaging, anatomical systems of the human body and imaging examples, computed and digital radiography and other specialised modalities, such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), nuclear medicine imaging (NMI) and hybrid modalities, like positron emission tomography (PET) combined with CT or MRI.

Private teaching companies, such as Michener Institute in Canada, and OTech Consulting in Texas, offer PACS teaching and learning courses. These courses usually include formal education in the classroom and practical training sessions. OTech has been travelling to countries on continents like Asia and Australasia, and to northern Africa to conduct PACS training workshops (Oosterwijk 2018:Online). Oosterwijk has travelled to South Africa twice since 2018, to offer the PACS Administration Registry and Certification Association (PARCA) course, Certified PACS Associate (CPAS), an American certification course, to South African imaging informatics professionals (IN2PACS Academy 2018:Online). The courses are presented in cooperation with IN2PACS. In addition to being attended by South African PACS administrators or imaging informatics professionals, the courses are also attended by radiographers and information technologists from other sub-Saharan countries.

1.3 PROBLEM STATEMENT

The problem that was addressed in this study, was the absence of formal teaching and learning programmes available for imaging informatics (PACS administration) in South Africa, at the start of the research project. The teaching model developed in this study can be implemented and developed as a registered postgraduate teaching and learning programme in imaging informatics.

1.4 RESEARCH QUESTIONS

In order to address the problem as identified, the following research questions were addressed in this research study:

i. What should the necessary components for imaging informatics, in a new NHI system in the South African context, be?
iii. What should be included in a model for the teaching and learning of imaging informatics in a new, integrated NHI system in South Africa?

1.5 OVERALL GOAL OF THE STUDY

The study's overall goal is to improve the training/education of radiographers and IT specialists in a future integrated NHI system by developing a model for the teaching and learning of imaging informatics in South Africa.

1.6 AIM OF THE STUDY

The aim of the study was to develop a model for the teaching and learning of imaging informatics in a future integrated NHI system in South Africa.

1.7 OBJECTIVES OF THE STUDY

Botma, Greeff, Mulaudzi and Wright (2010:93) are of the opinion that assertions included in the purpose of a study relate to the objectives of the study. Embedded in the objectives is procuring solutions to research questions, furthermore, the objective may involve aims, such as recommendations, guidelines or models (Polit & Beck 2018:93).

To conceptualise and contextualise the research, a literature review was done in Chapter 2 to provide an in-depth understanding and application of imaging informatics in this research study.

To achieve the aim of the study, two objectives were pursued. The two objectives of this study are related to the research questions in the following ways:

i. To gather data regarding imaging informatics nationally and internationally.
This objective addresses research question 1

ii To develop a teaching model for imaging informatics, a platform in BMI, in a future integrated NHI system in South Africa.
This objective addresses research question 2

1.8 DEMARCATION OF THE FIELD AND SCOPE OF THE STUDY

This study was conducted in the field of Health Professions Education. However, the study was interdisciplinary, as it forms a bridge between Health Professions Education, imaging informatics, a study level in BMI, and radiography. The results of this research can be used to develop a curriculum for imaging informatics in South Africa and could add value to the learning process of radiographers and IT PACS administrations in South Africa.

The participants in this research study comprised two groups. The first group was divided into three categories: a) qualified radiographers and radiographer PACS administrators, b) physics lecturers teaching digital imaging and PACS at South Africa's eight higher education institutions that offered radiography programmes, and c) imaging informatics specialists, e-Health specialists or IT PACS administrators working in imaging informatics environments in public or private hospitals or digital x-ray imaging departments or vendors (selling and servicing imaging informatics technology) applications specialists or PACS administrators involved in professional training after PACS installations. The second group included an expert group of imaging informatics professionals, gathered from radiography, medical imaging IT management, imaging informatics teaching, imaging informatics consultant, vendor PACS administrator and radiology backgrounds.

1.9 VALUE, SIGNIFICANCE AND CONTRIBUTION OF THE STUDY

This section will outline the value, the theoretical and practical significance and the contribution of the research study.

1.9.1 Value

At the commencement of this study, no imaging informatics teaching and learning programmes were available in South Africa. Radiographers appointed in PACS administration positions at private and public hospitals in the Eastern Cape frequently request job descriptions for PACS administrators from the Department of Radiography at the Nelson Mandela University, and expressed interest in a formal PACS administration course.

The teaching and learning model developed by this study could be used to implement a curriculum for IT and radiography PACS administration or imaging informatics professionals in South Africa. The value of this research will be high-quality patient care, patient-cetred care (Itri 2015:1842), as a result of knowledgeable professionals working in the field of imaging informatics (Martin-Carreras & Cook 2019:Online; Ranschaert 2016:5–6). The professional will be able to manage a PACS system efficiently and effectively, to ensure optimal turnaround times in digital diagnostic imaging departments. The formal education programme's quality will be ensured, as it needs to be registered with the South African Qualifications Authority (SAQA) and the Health Professions Council of South Africa (HPCSA, 2016) and would, therefore, be fit for the purpose for training in the South African context. Radiographers and IT specialists wanting to engage in the formal education programme at a higher education institution will receive value for the money spent; an accredited qualification will increase their professional standing and skills; and they will have a more specialised field to choose from. After completion of the programme, the professional will be able to engage in PACS administration much sooner than their predecessors had been. The programme could also contribute to reduce variation between institutions.

1.9.2 Significance

The study will contribute significantly to postgraduate academic education programmes for diagnostic radiographers, PACS administrators and imaging informatics specialists, and to the significant role the diagnostic radiographer will be able to play in the PACS administration team and the clinical environment. The imaging informatics teaching model could drive advanced practice for radiographers forward in a South African context and provide another pathway of specialisation. The study could also contribute to the development of a curriculum for imaging informatics, which will equip general IT specialists wishing to further their studies in imaging informatics, health informatics, medical informatics or BMI.

1.9.3 Contribution

A teaching and learning model in imaging informatics was developed, which could serve to improve the training of radiographers and IT specialists to become certified imaging informatics professionals in a future integrated NHI system in South Africa. This model may be incorporated to assist in the integration of the total system, to improve quality and service.

1.10 PARADIGMATIC PERSPECTIVE

According to Kuhn (1970:175), a paradigm is a complete collection of the beliefs, values and techniques that are shared by representatives of a specific population. It is also called a theoretical approach or a 'lens' that the researcher uses to view and gather knowledge in order to address a research topic. The particular theoretical approach used usually includes its own ontology (what is reality/what exists) and epistemology (theory of knowledge) views (Matthew & Ross 2010:34).

Various empirical investigations were used in order to answer the research questions. The investigations were done to explore the themes, subthemes and topics that could be included in the teaching and learning model, not the PACS administrators/imaging informatics professional, radiology departments or any other narrated aspects.

A pragmatist paradigm was used in this study to allow an empirical investigation into the research questions, and also, due to the elements of qualitative data produced from the quantitative survey research. The flexible pragmatist viewpoint allowed the researcher to focus on the face value of the facts in imaging informatics, but also, on her believes that effective resolutions in instruction, which typically involve students and teachers, should also develop the changing perspective of a digital age. The independency between the researcher and the respondents allowed for an objectively (ontological assumption) realistic, true deduction (epistemological assumption) from the researcher's side (Assalahi 2015:313–315). Furthermore, to reach the aim of the study, which is the imaging informatic teaching model, the research was necessitated to use the pragmatic approach, not just regarding the data collection process but also the final product of the study, which will have a large pragmatic approach. The use of more qualitative methods in the relation to the open-ended questions in the three structured questionnaires and specifically the Delphi survey with comments from the respondents, the researcher wanted to open up the "catchment" area for data collection as wide as possible. The Delphi is based on what were mined from the literature – the contents of the Delphi came from the literature used for the three structured questionnaire as well as other publications, which illustrate the pragmatic approach taken. It allows the researcher, as the Delphi characteristics is unpacked, to say that consensus is the most important to decide what must be included, could be included with edits, or should be excluded in the teaching model. Also, reliability is measurable; therefore, the centre of attention was on reliable and valid research instruments (Kumar 2019:273–276).

1.11 CLARIFICATION OF CONCEPTS

Researchers explore a phenomenon with the intent of understanding it or contributing to its incidence or the experience of it. Concepts, as language structures are the most basic symbolic constructions by which humans categorise reality. Concepts are the messengers of meaning through which a differentiation can be made amongst two kinds of meaning, namely "connotative and denotative" meanings of concepts (Sekhar Rao 2017:2; Botes 2002:23). Connotative points to the characteristics of concepts, whereas denotative refer to the precise, dictionary definition of a concept (Sekhar Rao 2017:2). A further distinction can also be made between uses of subjective and conventional connotations. A subjective connotation is closely related to an individual's viewpoint and experiences attached to a concept in a real-life scenario, whereas the conventional connotation is the recognised meaning decided upon for the sake of communication. It infers that researchers within the same field and, more specifically, in a similar paradigm, usually share explicit conventional connotations. Therefore, dictionary definitions (denotations or theoretical definitions) of concepts are needed to allocate operational definitions to concepts and enable the development of a concept measuring instrument (Botes 2002:24). Hence, in the next section denotative meaning and conventional connotative meaning will be discussed in relation to the following concepts:

Model: The word *model* can be defined in many different ways depending on whether it is an adjective (1831), verb (1613) or noun (1570s): the context in which it is used, be it education, science, engineering, business, motor manufacturing or fashion (Merriam-Webster.com Dictionary n.d.:Online). The term model is derived from the French, *modelle* (1570s), from *modello* in Italian, which has its origin in the colloquial Latin term *modellus,* the petite form of the Latin word modulus (Online Etymology Dictionary n.d.:Online). Basically, a model is used as a smaller physical representation, pattern, description or plan of something to explain the mechanism of an applied system or episode (Collins Online Dictionary 2020:Online). In education, a model of teaching, defined as the portrayal of the learning and teaching context, includes the conduct of lecturers and learners while the lesson is offered through that model (Joyce, Weil & Calhoun 2015:4). A model should be built for a specific intent, and in a way to reduce the complicatedness of the real context (Walliman 2020:316). In the context of this study, a model refers to a teaching model for imaging informatics in a future integrated NHI system in South Africa.

Teaching: Teaching in general is the procedure of attending to people's needs, capabilities and state of mind, and intervention to enable them to discover particular entities, and go further than the given. In education, teaching can be delineated as engagement with students to facilitate their understanding and application of knowledge, notions and procedures. Teaching comprises design, subject selection, provision, evaluation and reflection (Kaya & Akdemir 2016:iii). In the context of this study, teaching refers to the teaching of imaging informatics to radiographers and IT specialist to enable them to become certified PACS administrators or imaging informatics professionals.

Imaging informatics: Imaging informatics, previously called radiology informatics and also known as medical imaging informatics, is a study level of biomedical informatics, on the cellular tissue and organ system level. The main purpose of imaging informatics is to enhance the usability, efficiency, reliability and accuracy of medical imaging facilities within the healthcare enterprise. Imaging informatics is dedicated to the review of how data regarding, and comprised within, medical images is recovered, analysed, improved, and exchanged all over the medical enterprise (Huang 2019:29). In the context of this study, imaging informatics refers to the informatics used in digital diagnostic radiology departments to create, review, archive, analyse, retrieve and compare digital diagnostic images.

Integrated: Integrated can be defined as connecting the distinct component to deliver a harmonious, interconnected whole (Merriam-Webster n.d.:Online). Integrating the Healthcare Enterprise (IHE), is an invention from the industry together with healthcare professionals to enhance the manner in which computer systems share health information. IHE was founded in 1998, with the intension to enhance communication of different standards such as HL7 and DICOM. Integrated healthcare will enhance service delivery to patients and referring physicians. Integrated into the context of this study relates to the integration of the private and public healthcare funding systems in South Africa (pooled finances) to provide better healthcare to all citizens with the introduction of an NHI system. It also, relates to the integration of health informatics in the public health sector in South Africa.

National Health Insurance system: National health systems (NHS) exist in many countries globally. NHS is based on NHI, which is a health funding system that is structured to pool finances to provide access to good-quality, inexpensive health service on a personal level to all citizens in a country (Schütte, Acevedo & Flahault 2018:1–2). NHI systems, in the context of this study, relate to the NHI model that the South African government wants to implement to ensure quality healthcare to all citizens.

1.12 RESEARCH DESIGN AND METHODS

Research design is a strategy that indicates how to continue in research to determine what kind of correlation exists between variables (Bless, Higson-Smith & Sithole 2013:66; Kumar 2019:209). The entire design of a research study is determined by the demands of the research questions (Bless *et al.* 2013:390; Kumar 2019:208).

1.12.1 Research design

The research design for this study was mainly quantitative, and used a contextual, descriptive, exploratory and non-experimental approach, with qualitative elements applied through open-ended questions in structured questionnaires (Burns, Grove & Gray 2011:77). An in-depth literature review was done on the current interoperability status of BMI platforms in health systems, with a specific focus on imaging informatics, and the development plan, to ensure future sustainability (Burns *et al.* 2011:77).

1.12.2 Methods of investigation and flow of the study

1.12.2.1 *Phase 1 – Literature review*

Phase 1 in this study, Chapter 2 informs the study context and provides a conceptual framework which supported the background and informed the research problem and study aim. It included an investigation of the current situation regarding imaging informatics in South Africa and abroad. Furthermore, various teaching and learning models and their components were investigated to establish the information that are included in such a model. The literature review also aided in questionnaire development.

1.12.2.2 *Phase 2 – Questionnaires*

Three self-administered questionnaires were used to gather information from three distinct groups of respondents, regarding a) diagnostic radiographers' knowledge and formal education and learning in imaging informatics, collected from registered qualified radiographers and radiographer PACS administrators; b) physics module contents concerning imaging informatics principles, gathered from digital imaging and PACS lecturers at radiography departments at higher education institutions; and c) the responsibilities and knowledge of information technologists and IT PACS administrators, gathered from IT specialist and system managers in the imaging informatics environment. Self-administered, mostly structured, questionnaires were therefore used to collect quantitative data (cf. Appendices A, B, C).

1.12.2.3 *Phase 3- Delphi study*

The data gathered from the questionnaires were analysed and arranged into themes, subthemes and statements to construct a questionnaire for the Delphi study. The Delphi questionnaires were distributed to a panel of 15 professionals working in the imaging informatics environment, who were considered to be knowledgeable about the field. The questionnaires were distributed amongst the respondents for three rounds to enable a consensus to be achieved on all the statements. After the third round, statements without total consensus were reported as such, and data collection ceased (cf. Appendices D, F, H)

1.12.2.4 *Phase 4 – Development of the model*

The data obtained from the Delphi study were analysed and then used to compile a teaching model for imaging informatics, for application at a higher education institution. Six of the nine sequence steps suggested in the elaboration theory were applied in the development of the model. The sequence steps will be discussed in Chapter 3.

A more detailed description of the population, sampling methods, data collection techniques, data analysis, reporting, and ethical considerations will be provided in Chapter 3. The schematic overview of the study presented in Figure 1.1 outlines the research activities.

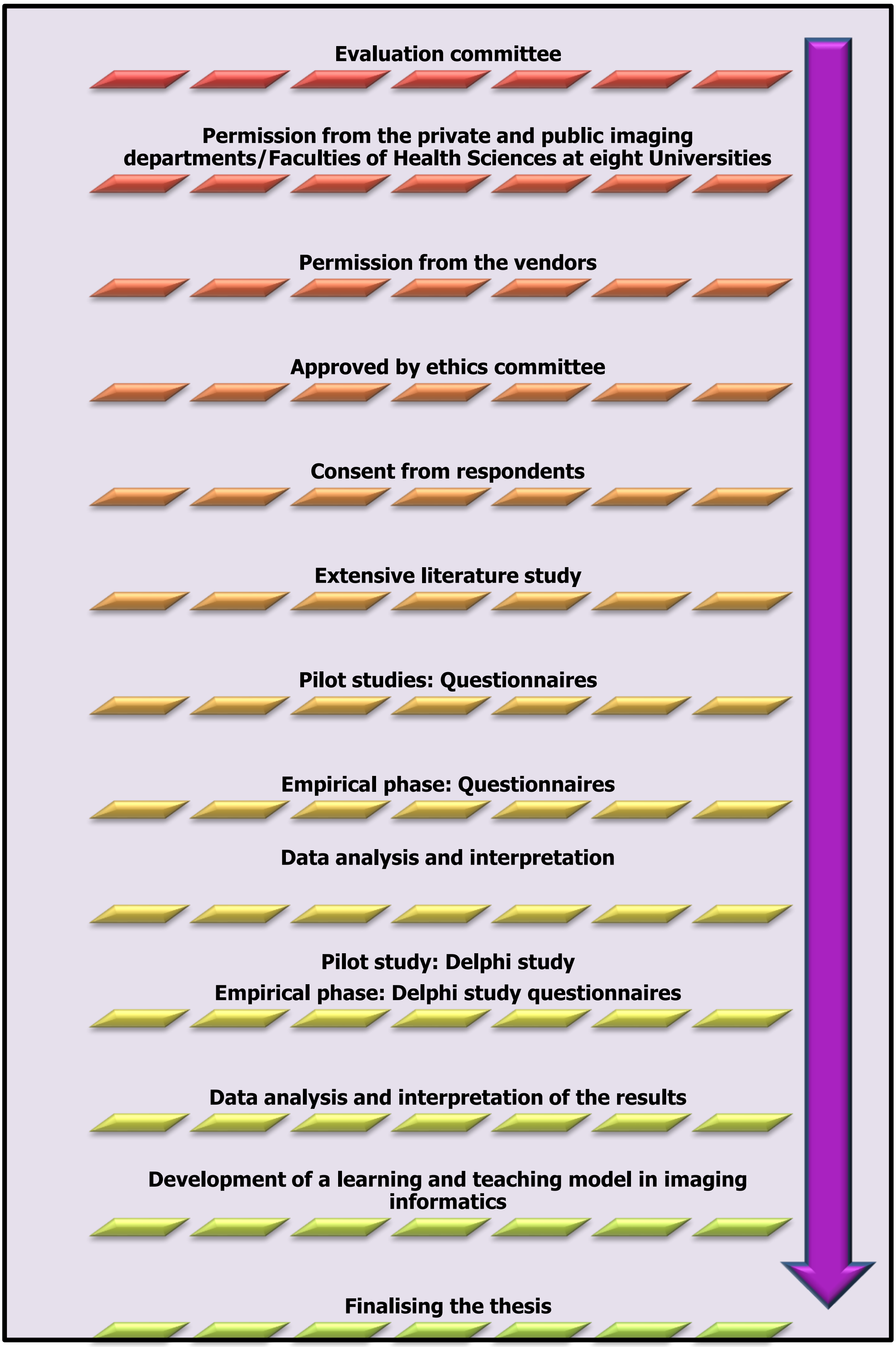


Figure 1.1: Schematic overview of the study

1.13 IMPLEMENTATION OF THE FINDINGS

A model, which is expected to serve to improve the teaching and learning of imaging informatics professionals in a future integrated NHI system in South Africa, was developed. This model may be incorporated to assist in the integration of the total system and to improve healthcare quality and service delivery to patients at public health institutions. The teaching and learning model will be implemented at a post-PhD level in education at a higher education institution in South Africa.

This report will be made available to the Professional Board of Radiography and Clinical Technology (PBRCT) of the HPCSA. In addition, the report will be sent to the National Research Foundation (NRF) and the Health and Welfare Sector Education and Training Authority (HWSETA). Articles from this report will also be submitted to accredited journals for publication, to enable further development of training for imaging informatics professionals. Presenting the final report at a South African Association of Health Educationalist (SAAHE) conference will be the last step in the implementation of the research findings.

1.14 ARRANGEMENT OF THE THESIS

The following section will provide a brief outline of the study and its layout.

Chapter 1, entitled ***Orientation to the study,*** provided background and context, listed definitions, the problem statement, and the scope, goal, aim and objectives, and described the research design and methods of this study.

Chapter 2, entitled ***Imaging informatics principles and teaching,*** informs the study context and provides a conceptual framework, which supports the background and informs the research problem and study aim.

In Chapter 3, entitled ***Research design and methodology,*** research design and methods will be described and validated, as will processes of methods used. Validity, reliability and ethical considerations will also be discussed.

Chapter 4, entitled ***Results and discussion for the structured questionnaire survey study***, will report on the data gathered from the first self-administered questionnaire.

Chapter 5, entitled ***Results, data analysis and findings of the Delphi survey**,* will report on data gathered from the Delphi study.

Chapter 6, entitled ***A model for the teaching of imaging informatics, a platform in biomedical informatics, in a future integrated National Health Insurance System in South Africa***, will present the outcome, namely, a comprehensive discussion of the proposed teaching and learning model, which will be contextualised against existing international programmes.

Chapter 7, entitled ***Conclusion, limitations and recommendations of the study***, will provide an overview of the study, including conclusions, limitations and recommendations in the study.

1.15 SUMMARY

Chapter 1 provided an orientation to the study, discussed the background to the problem, the problem statement, the scope of the study, the overall goal, and its aim and objectives. Also presented in this chapter was a brief introduction to the research design and research methods that were used. In conclusion, the chapter provided an outline of the thesis report and a synopsis of the following chapters.

The next chapter, Chapter 2, entitled ***Imaging informatics principles and teaching,*** the theoretical orientation and framework of the study will be discussed.

CHAPTER 2

IMAGING INFORMATICS PRINCIPLES AND TEACHING

2.1 INTRODUCTION

In Chapter 1, an orientation to the study was provided, which included the background, problem statement, scope of the study, the overall goal, aim and objective and an introduction to the methodology. Chapter 2, the literature review, will provide a conceptual framework to develop a model for teaching imaging informatics, in a future, integrated NHI system in South Africa.

Firstly, a discussion provides the necessary perspective on NHSs in various countries worldwide, and how South Africa's future NHI system compares to the international systems. Secondly, to give the reader an understanding of where imaging informatics fits in under the biomedical informatics 'umbrella', a brief discussion will follow on the different platforms involved in biomedical informatics, for example, bioinformatics, imaging informatics, clinical informatics, and PHI (Huang 2014b:631). The interoperability (RSA DoH 2014:7) between private health enterprises and public health institutions' BMI platforms will also be investigated. Thirdly, a comprehensive discussion on imaging informatics will report on the numerous types of hardware necessary to start a comprehensive imaging informatics network, the different software applications used, as well as the latest advances in imaging informatics. Lastly, an overview of radiography and IT teaching and learning programmes in South Africa will be provided to explain the study fields of the target groups in this research. A discussion on current teaching and learning programmes for imaging informatics will follow to conceptualise teaching programmes that are available abroad and in South Africa in this regard.

The researcher gathered information from accredited journal articles, books, imaging informatics teaching programme providers' websites and announcements in the media. Databases, such as EBSCOhost, Medline, Elsevier, Wiley, Biomed Central, InTech Open Access, Sage, ScienceDirect, Scopus, Google and Google Scholar, were used to gain access to sources of information that were relevant to this study. Information was obtained by using words or phrases representing all the elements of higher education, BMI and imaging informatics.

Figure 4.2 portrays a schematic overview of Chapter 2, the literature review. Literature searches were made according to the titles and subtitles displayed in this figure. The purpose of the literature review is to, inform the study context; to provide a conceptual framework that informs the background; to contextualise the research problem and the aim of the study; to inform the structured questionnaire and Delphi study design; and to establish the most appropriate type of teaching model to apply in the study (Machi & McEvoy 2016:21).

2.2 SCHEMATIC OVERVIEW OF THE CHAPTER

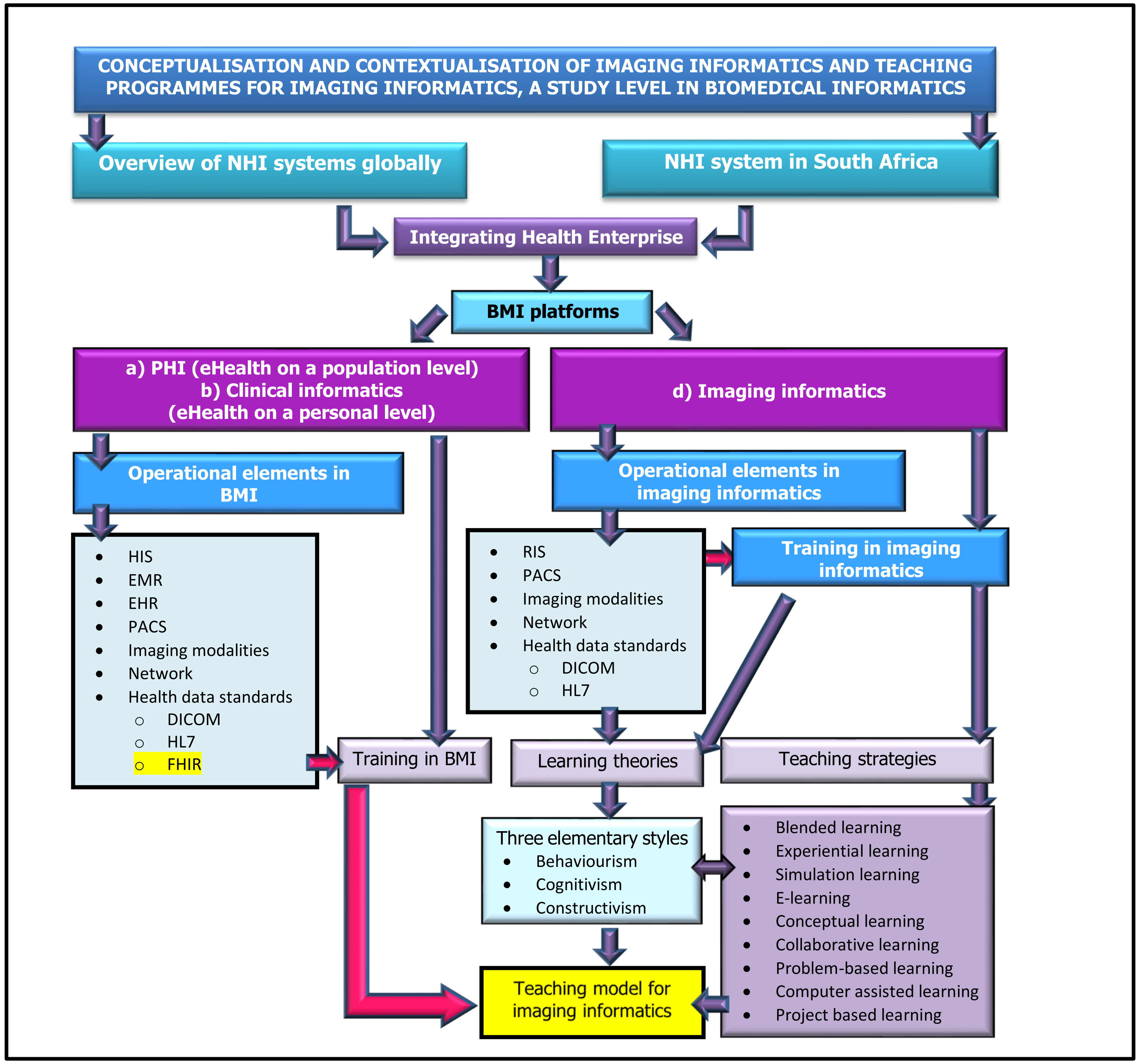


Figure 2.1: Schematic overview of the chapter (Compiled by the researcher, Grobler 2018)

2.3 NATIONAL HEALTH SYSTEMS

According to the WHO, a health system includes "all the activities whose primary purpose is to promote, restore and/or maintain health" (WHO 2013:9). NHSs exist in every country, whether it is an industrialised or a developing country. A country's NHS often reflects the history, dominant political ideology, and economic development of that country. The diverse circumstances in countries set the scene for a diversity of health systems. The characteristics of an NHS's components determine the type of health system a country will have (Roemer 1993a:335).

2.3.1 Health systems models

Globally, healthcare systems follow general models, which include the Beveridge, Bismarck, NHI and out-of-pocket models. According to the Physicians for National Health Program (PNHP), for the Beveridge model, the government is the service provider and funds the service through tax revenue (PNHP 2010:1). The Beveridge model is used in the UK and is called "a single-payer national health service" by the PNHP (2010:4). At the other end, is the Bismarck model, which makes use of insurance systems, so-called medical aids or 'sickness funds'. These medical aid payments involve a joint contribution, paid by the employee and the employer. The Bismarck model is usually followed by privately-owned medical care centres (PNHP 2010:2). According to PNHP (2010:4), the Bismarck model applies to countries using "non-profit sickness funds" or social insurance, for example, Germany. In an NHI system that uses a combination of elements from Beveridge and Bismarck models, the service providers are from the private health sector, with payments coming from a government-run health insurance system to which all citizens contribute on a sliding scale according to remuneration. NHI "correspond[s] to single-payer national health insurance", as practiced in countries like Canada and Taiwan (PNHP 2010:4).

Reid's out-of-pocket model is used only in developed countries, which represents about 40 of the 200 countries in the world. In this case, people must pay for medical services provided on a cash basis for each consultation. The problem with the out-of-pocket model is that only rich people can pay for healthcare – the poor cannot afford to seek medical care. In some developing countries, people can go a lifetime without seeing a doctor (PNHP 2010:3). The out-of-pocket model is also called 'market-driven healthcare'. Mixed models are often used by some of the countries with this type of model, for example, Sweden (PNHP 2010:4).

2.3.2 National healthcare systems globally

The five principal component elements for analysing any health system in any country in any period of economic growth are resources (human resources, facilities, merchandise, and knowledge), organisation (government as the principal authority at different levels, public agents with health functions, the voluntary agent in healthcare, businesses and privately owned healthcare providers), management (health projections, executives, control and regulation), economic support (government tax income, social indemnity, elected insurance, contributions and individual households), and delivery of services (which stems from the availability of the other four elements) (Roemer 1993b:695).

According to Britnell (2016:para 1), one of the greatest mysteries about health systems globally is why numerous countries do not acquire what they invested in. Although the relationship between health spending and health service exists, some countries spend about half the money others do and achieve the same or better benefits. Although aspects such as cultural and lifestyle factors play a role in lower spending for the same benefits, healthcare management, delivery, and funding are also fundamental. Five factors that are often at play are integrated care, hospitals as health systems, standardisation and simplification, taking social care seriously, and payer power (Britnell 2016:para 2).

Integrated care means that a system should balance the two seemingly opposing forces of competition and collaboration. In Israel, health maintenance organisations pay for care and operate their facilities. Therefore, because providers work together, fewer patients are admitted to hospitals (Mossialos, Wenzl, Osborn, & Anderson 2015:87-94). *Hospitals become health systems* when they are placed at the centre of the management of a cluster of service providers. An excellent example of this is the change Singapore made to the management of their public health service providers in 2013 when they placed a reshaped hospital at the centre of each of the six clusters that make up Singapore's public health system (Britnell 2016:para 7; Mossialos *et al.* 2015:123-131). *In standardisation and simplification* of a public health system, the first step is to systematise clinical workflow through defining best practices, providing explicit guidelines, and ensuring consistent adherence (Britnell 2016:para 9). Secondly, best practice should be the default choice for staff and should be created by the development of IT systems that reinforce best practices into the daily work of personnel (Mossialos *et al.* 2015:18, 25, 48, 58, 159). Lastly, the 'skill mix' should be changed to enable the utilisation of skilled professionals mainly for their expertise (Britnell 2016:para 9). Although *social care* and healthcare are interlinked, the first does not always get the attention it deserves in all countries globally and is often the weak link in public health systems (Britnell 2016:para 2; Mossialos *et al.* 2015).

Japan acted in this regard in 2000 by implementing a 1-2% tax levy on people over 40 years old. This fund was used to establish a national care service for the aged population, and to provide funding for homes and residential and community care on a means-tested basis. *A means-tested basis* (payer power) is a process used to conclude if a person is entitled to financial assistance to obtain good medical care. People who earn less than the mean income bracket qualify to receive financial assistance for healthcare (Britnell 2016:para 11; Matsuda 2015:87-90). Countries with central single, or principal payers, such as Denmark, Norway, Spain and New Zealand, are consistently crowned, as the most efficient health systems, and their spending growth rate is slower (Britnell 2016:para 12). In contrast, countries such as the USA, Germany and the Netherlands have disparate payers and, therefore, higher rates of spending growth. Greater 'payer power' creates greater accountabilities, and there is a risk that the costs will be controlled beyond merely ordinary effectiveness (Britnell 2016:para 12-13; Mossialos *et al.* 2015:73, 103, 123).

For the purpose of this study, the NHS of five countries will be discussed in greater detail regarding their NHI system, integration of the BMI platforms and interoperability of these platforms, with the emphasis on imaging informatics.

Although people use the words integration and interoperability interchangeably, a difference exists between these two terms. With integration, the connection of applications serves to enable access to data on one system from another system. However, integration needs a 'third party' (software term - *middleware*) for translation and access of the data on the receiver end. In turn, interoperability involves a real-time exchange of data for sharing and interpretation in its original format without involving a third party. In the verbal communication scenario, it means that interoperability systems all speak the 'same language', but integration needs an interpreter (Roberts 2017:2; Shrestha 2015:52). At present, most of the data interchange on the health informatics platforms takes place in the form of integration. In the future, healthcare manoeuvres for immediate access will be imperative for high-quality patient care and prompt response (Roberts 2017:2; Shrestha 2015:52).

According to Roberts (2017:2), "true interoperability won't be an evolution – it will be a revolution", and will only be possible with substantial, focused thinking in the future.

Roberts (2017:3) states that the Office of the National Coordinator for Health Information Technology in the USA Department of Health took a leading role by setting guidelines to achieve interoperability in health information technology. Roberts (2017:3) is also of the opinion that doing so is a shared responsibility, and that providers of software should form partnerships with vendors in support of the Office of the National Coordinator's worldwide standards. Shrestha (2015:52) agrees with Roberts and states that inventiveness, such as that by the Integrating the Health Care Enterprise 'taskforce' that is responsible for creating shared integration standards, such as DICOM and HL7, have enabled multifaceted integration of and interfaces between the main elements involved in medical imaging informatics. According to Peck (2018:87), HL7 Fast Healthcare Interoperability Resources is a distinctive exchange standard, which is now deemed as a transmission standard for interoperability developments, and a current selling point to interoperability of developers' software applications.

Connected health or technology-enabled care gives healthcare professionals and caregivers easier access to the information needed for improved quality and results in the health and social care of patients (K. Taylor 2015:4). In the radiology department, the change from analogue imaging to digital imaging methods played a vital role in the move to effective patient-centred care. The implementation of an integrated imaging informatics system in the radiology department created a more effective workflow in the digital imaging environment, enabling shorter waiting times for patients (Itri 2015:1842). With interoperability integration in imaging informatics and the BMI platforms in healthcare, the radiologists and the physicians referring the patients for digital imaging examination can view the digital images of a patient at the same time at different locations, with live communication regarding the finding of the examination (Pearson 2017:Online).

2.3.2.1 *National health services in the United Kingdom*

The NHS in the UK was launched in England in 1948. "The birth of the NHS in the UK" was the result of an idea to provide good healthcare for all people, regardless of their financial status. Even today, the NHS remains free for all UK residents, except some charges for prescriptions and optical and dental services. In Scotland, Wales and Northern Ireland, the responsibility for healthcare is decentralised to the Scottish Government, Welsh Assembly government and the Northern Ireland assembly respectively (Bevan 2014:1-8). Taxation in each of these countries provides funding for the NHS. The core principles on which the NHS is based are that everyone's health needs should be met, it should be free at the delivery point, and it should not be based on the ability to pay, but on the clinical needs of an individual (Mossialos *et al.* 2015:43).

However, recent reports suggest that the NHS is troubled, due to various issues, among which financial cuts that affect the social care of adults, and pressure to focus on preventive and population healthcare. Health systems' ability to react to challenges rely on vigorous execution of a range of enterprises after dexterous planning. The process is not the 'just once' implementation type, but demands an active course, entrenched in and fine-tuned by evidence on influence (Dixon 2016:xiii). From a study done by HIMSS Europe (2014:12), 88% of hospitals within the four counties of the UK reported that their health systems are interoperable over several places. However, only 43% indicated that they have health systems interoperable with other organisations. The UK Department of Health Policy, at this stage, changed from 'replace all' to 'connect all'. Almost 80% of respondents indicated that they moved towards a strategy of integrating existing systems in healthcare technology, and 25% of respondents indicated that the main 'roadblocks' averting interoperability are technology, usefulness and execution of systems. The adoption of communication industry standards, like HL7, alleviated the problems encountered with interoperability and integration (HIMSS Europe 2014:13).

Two new models to integrate healthcare in the UK were piloted in 2016 under the Prime Minister Challenge Fund. The first model was to enhance UK's primary healthcare for complex patients (seen by diverse health professionals), which was grounded on health information sharing between diverse health professionals, based on a single patient registry. The second model was on interoperability between healthcare organisations, based on simultaneous response and communication by two health professionals from different organisations, on a single patient's health information (Meaker, Bhandal & Roberts 2018:110). From the study results of Meaker *et al*. (2018:111), it is evident that, for the NHS in the UK, integrated healthcare systems are essential for providing better care to the patients.

After almost a century of using analogue imaging methods in radiology, the UK started to move towards more modern, integrated digital imaging methods from the early 2000s. Radiology departments in acute NHS hospitals were equipped with a PACS and RIS and other digital applications, which included eRequesting and reports linked to the Electronic Patient Records (EPRs) of patients (Peck 2018:25). Health establishments in the UK have started to move towards integrating the different diagnostic departments, such as radiology and pathology, with their silos of medical imaging data, towards an integrated enterprise imaging system. The vendor-neutral archive makes the PACS system of a health institution go beyond radiology alone, to include imaging from other diagnostic departments and to position the patient as the core of diagnostic imaging (Scarisbrick 2017:Online). Scarisbrick (2017:Online) is of the opinion that integrated diagnostics for imaging informatics in diagnostic departments will depend on IT management, whereas the communication will be detached to an enterprise level.

2.3.2.2 *National health services in Australia*

The Australian government established the Health Insurance Commission (HIC) in August 1974. It manages the current Medicare Australia, which performs all the functions and provides all the services that were previously performed by the HIC (2009:Online). In Australia, funding for public hospitals comes from the state, territory and Australian government; administration is done by state and territory governments (Australian Institute of Health and Welfare 2014:1; Glover 2017:11). A range of health services is delivered and funded by the Australian government. Private healthcare insurance, which offers more options for service providers and quicker non-emergency treatment, is accessible without difficulty. In 2016, the distribution of the population between public and private healthcare was 50:50. Currently, the government has three 'safety nets' in place to assist patients who reach their out-of-pocket threshold (Glover 2017:11).

The Australian Digital Health Agency (ADHA) strategy states seven strategic outcomes that should be achieved by 2022 (Australian Government & ADHA 2017:5). One of these outcomes is that all Australian citizens will have a 'My Health record' by 2019, except if they opt not to have one (Hambleton & Aloizos 2019:S6). The outcomes include,

- Health information readily available whenever needed;
- Health information with secure exchange;
- High-quality data that have a universally known connotation and can be employed with confidence;
- Better accessibility and admission to prescriptions and medicines data;
- Digitally-empowered models of healthcare that motivate improved ease of access, safety, efficiency and quality;
- A workforce positively operating digital health technologies to provide healthcare; and
- A flourishing digital health business supplying world-class invention (Australian Government & ADHA 2017:5–7).

In a qualitative study done in Australia, Trankle, Usherwood, Abbott, Roberts, Crampton, Girgis *et al.* (2019:3), evaluated the Western Sydney Integrated Care Program's key strategies. One of these strategies involved IT for improving information sharing between healthcare providers. The combined Western Sydney, Integrated Care Program strategies, improved carer and patient encounters of healthcare and the ability of general practitioners to deliver healthcare in the community (Trankle *et al.* 2019:10). However, the healthcare providers expressed frustration about the lack of effective communication and sharing of information between health divisions.

2.3.2.3 *National health services in New Zealand*

In New Zealand, all permanent residents are eligible to access publicly financed health services. Non-residents, such as tourists, have to pay the full cost unless their health needs are due to accidents, in which case tourists are covered under New Zeeland's no-fault accident compensation scheme. Voluntary private health schemes that exist assure faster treatment and access to less urgent healthcare treatment. The annual general budget is based mostly on political urgencies for most publicly funded health services; national requirements are then set for the specific services, for implementation by the 20 district health boards, and may vary between district health boards (Mossialos *et al.* 2015:103). General practitioners set their fees, and co-payment has risen since government funding was reduced. Patients have to make co-payments for several items, such as general practitioner consultations and drugs prescribed by general practitioners. No general practitioner charges exist for children under the age of six years. However, there were plans to extend the age limit for the no-charge policy at general practitioners to 13 years in 2015. These days, payment charges are levied for any New Zealand residents in public hospitals (Mossialos *et al.* 2015:104).

The New Zeeland Ministry of Health is remodelling the digital healthcare environment with the development of a Digital Health Strategic Framework, which comprises aspiring goals and facilitating precedence, guidelines and assets evolving, responding to the changing digital healthcare environment (NZ MoH, 2019). The digital objectives of the strategy are,

- People should be in control of their health data.
- The use of digital facilities and health data should advance health results and equality.
- Digital facilities should allow healthcare providers to provide improved services.
- Digital facilities should amplify the performance of the public health environment.

- Data perceptiveness should deliver proof to produce and reinforce the informed decision.

The main enabler to the objectives will be integration and interoperability between the different BMI platforms, and medical imaging informatics platforms (NZ MoH, 2019).

2.3.2.4 *National health services in Canada*

In Canada, national healthcare is funded by taxes. Canadian citizens and permanent residents may apply to use public health insurance; once accepted, they do not pay for healthcare services. Public health services are accessed by presenting a health insurance card at a clinic or hospital. Different territories and provinces each have their own health insurance plans. Usually, emergency medical services are provided free of charge, even to patients who do not have government health cards. Visiting walk-in clinics in territories or provinces where one is not a resident, might include a fee charge (Government of Canada 2016:Online; Mossialos *et al.* 2015:21).

In Canada, the field of health informatics gained momentum during the last decade as a foundational component of a developing industry. The formation and use of electronic healthcare data are increasing exponentially and are moving rapidly outside the enterprise record. Digital Health Canada (2017:5) is of the opinion that digital health more effectively acts for the market of designers and users of digital health information. Today, digital health in Canada is seen as an industry; health informatics as a primary field and an essential requisite body of knowledge; Digital Health Canada links the Canadian community, incubates knowledge and endorses it, to speed up the positive transformation that digital healthcare can deliver.

2.3.2.5 *National health services in the United States*

Countries that had more successful health systems were investigated, and inspired reforms in the USA (Roemer 1994:8). In 2010, two federal statutes were passed, which began major landmark reforms in the country's national health system. These two acts set the scene for the United States National Health Act to institute single-payer financing, American universal health insurance programme. The already existing, publicly funded, privately provided Medicare will be improved and expanded. All USA residents, as well as all residents living in territories of the USA, are eligible to access, guaranteed by law, cost-effective, high-quality healthcare services irrespective of income, employment or status of healthcare (CRS 2015:1). The programme will cover all necessary medical services, with no co-payments and a free choice of service providers to all patients (CRS 2015:2; Mossialos *et al.* 2015:153).

The Affordable Care Act (so-called Obamacare) had been developed during the previous political dispensation (2010) to provide healthcare for low-income patients; however, it was compromised by the next political dispensation, which suspended subsidies to the health insurance companies serving these patients (Abutaleb & Mason 2017:Online).

According to Walsh and Rumsfeld (2017:2719), digital transformation in healthcare is lagging other digital technologies, like finance and entertainment, for numerous reasons. Standing out is the fact that healthcare systems are multifaceted, and the mere accessibility of novel digital health technologies will not transform healthcare provision. In the USA, EHRs made the first strides towards the digital transformation of healthcare. However, discontent and criticism overflowed, because it was seen mainly as an invoicing platform. Digital health vendors mention EHRs as the main obstructions to integrating their technologies into healthcare. The difficulties encountered with the digital health technology integration spurred the American College of Cardiologist (ACC) to launch a motivated Innovation Strategy in 2016. The ACC took a leading role by creating a 'roadmap' for cardiovascular care. The ACC partnered with several other stakeholders around the world with their innovation to assist in ensuring a positive outcome for the digital transformation of healthcare in the USA (Walsh & Rumsfeld 2017:2721).

The adoption of EHR in the USA supplied the scaffold for enterprise imaging (increasing access to radiology images in healthcare facilities) to progress and be accepted into the mainstream of medical imaging. Balancing enterprise imaging from the know-how acquired from its radiology origins without compelling a radiology-centred workflow across diverse clinical workflows is seen as one of the key issues for enterprise imaging (Whitfill 2016:521). Vreeland, Persons, Primo, Bishop, Garriot, and Doyle *et al.* (2016:552), established the design for authentic image sharing by 'strolling' through the roles that DICOM standards and cross-enterprise document sharing (XDS) play in the healthcare system.

An initiative to enhance the way that computer systems network medical information, comprising of images and reports, is called integrating the healthcare enterprise (IHE). Although IHE is not a standard, it makes use of accepted standards, like HL7 and DICOM, to achieve explicit medical workflows. These medical workflows are called integration profiles (Vreeland *et al.* 2016:553). The IHE integration profiles involved with images and reports exchange are XDS for distributing medical records, and cross-enterprise document sharing for imaging (XDS-I) for DICOM images sharing (Vreeland *et al.* 2016:553).

New web-based healthcare standards offer unmatched interoperability and intelligence. Standards, such as HL7 Fast Health Interoperability Resources (FHIR) and Web Access to DICOM Persistent Objects (WADO), Query based on identity for DICOM Objects (QIDO) and Store Over the Web (STOW) was introduced by RESTFul Services (RS) (Clunie, Dennison, Cram, Persons, Bronkalla & Primo 2016:601; Vreeland *et al.* 2016:553; DeJarnette 2009:9).

2.3.3 National health system of South Africa

In 1931, the president of the Medical Association of South Africa appealed for an NHS in South Africa. The appointed National Health Services Commission repeated this appeal in 1944, but it was rejected by the newly elected Nationalist government in 1948 (Benatar 1997:891). Fragmented and poor healthcare conditions also characterised the health service, it was a disintegrating system, in which hospital-centred care and private healthcare dominated (Benatar 1997:891). The populace that could afford private personal healthcare had access to healthcare service through tertiary government-subsidised care at no cost (Benatar 1997:891). Although the gross domestic product afforded health-care had increased from 5% to 8% in 1980, the public health sector hospitals still carried an ever-increasing burden of service users due to urbanisation, and the free status of healthcare at these facilities (Benatar 1997:892).

The first major changes in the healthcare system after apartheid (March 1994) were ushered in by the Reconstruction and Development Programme (RDP) and the National Health Programme (NHP), which were introduced in 1994 (Venturino 2013:1). NHP was introduced as a "district-based approach to primary care", which focused on community-based involvement and preventive care (Benatar 1997:892). Community-based health services were established all over South Africa, in 50 regions and 170 districts, and a shift in funding had to be implemented to create a balance between primary healthcare clinics and hospital-based service delivery. The fund shift, from academic hospitals to primary healthcare clinics, resulted in staff and, consequently, hospital bed reductions. The services that the academic medical centres had provided were broken down, due to the provincial census budget funding for each province, and the shift from hospital-based to community-based care (Benatar 1997:892; Venturino 2013:2). The health reforms of 1994 had numerous positive results. Unfortunately, the reforms did not yield the expected results, and health-related inequalities among South African citizens persist (Venturino 2013:3). In 2012, the second major healthcare reform was announced in the form of the White Paper on the new NHI (Venturino 2013:3).

2.3.3.1 *NHI system in South Africa*

The objectives of implementing the NHI and the reforms associated with it are to assure access to good quality healthcare for all South African citizens. The White Paper on the South African NHI (RSA DoH 2003) scheme specifies plans to provide national healthcare to all South African citizens by 2030. This NHI model is built on three 'pillars' that acts as a starting point, a way forward and an actuality review (Thulare 2016:7). The first pillar interrogates the explanatory outline, the purpose, analysis of the 'health financing policy' and achievable possibilities for restructuring by using the National Development Plan 2030 (RSA. The Presidency: National Planning Commission 2012). The second pillar aims to establish what the impact of general healthcare coverage would be on the population of South Africa. The third pillar refers to maintaining financial support, providing organisation guidelines and delivering information (Thulare 2016:7).

As stated before (cf. 1.2.2), this new NHI system will be implemented in three phases over 14 years. The first phase started in 2012 and the last phase will end in 2025. The partnership type will be a public-private sector collaboration (Sekhejane 2013:2). The NHI system is based on specified guidelines (Thulare 2016:8):

- *'The right to access healthcare in line with Section 27 of the Bill of Rights of the Constitution (South African Government 1996:33);*
- *Social solidarity;*
- *Equity;*
- *Healthcare as a public good;*
- *Affordability;*
- *Efficiency;*
- *Effectiveness; and*
- *Appropriateness'.*

Figure 2.3 sets out the envisaged NHI architecture in South Africa.

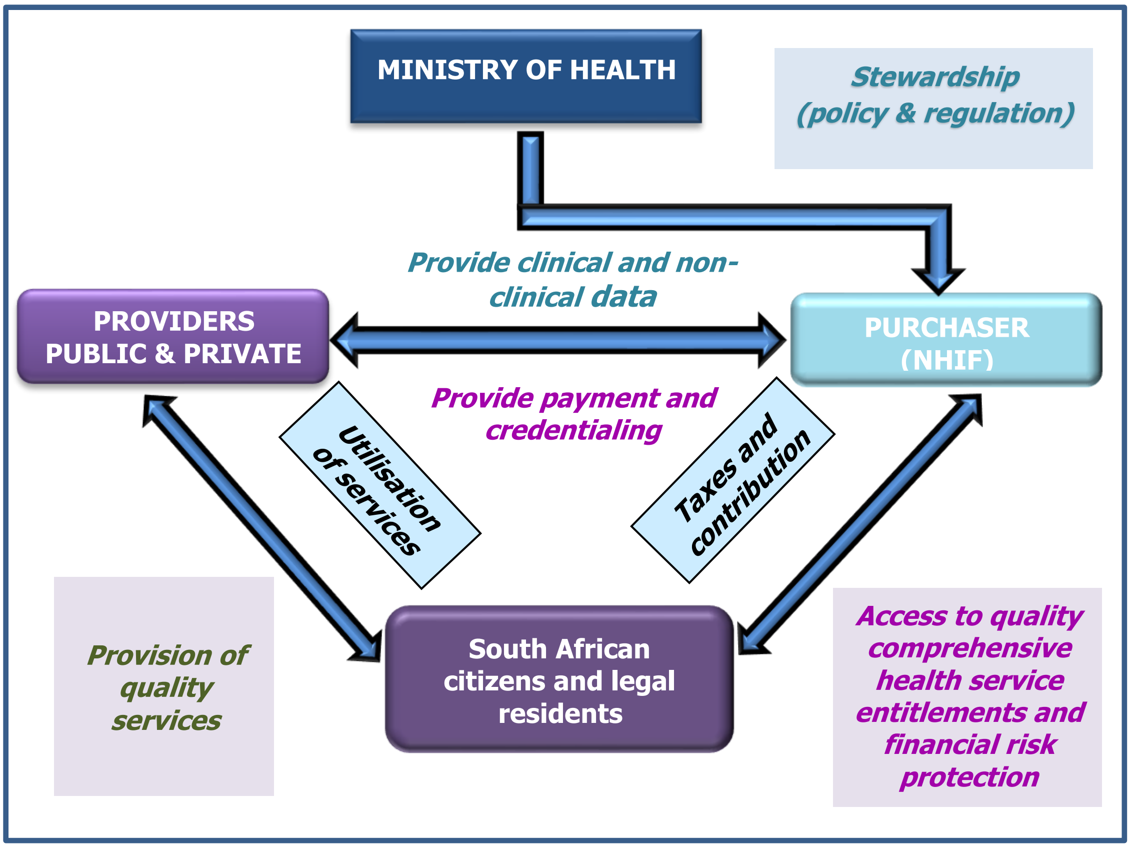


Figure 2.2: Envisaged NHI architecture/vehicle [adapted from Thulare (2016:8)]

The Ministry of Health will act as the policy and regulation providers (stewardship). Public and private health providers will provide quality service to all South African citizens and legal residents. The NHI will be funded by the government through taxes and contributions by South African citizens and legal residents who can afford to contribute. The National Health Insurance Fund will pay the service providers that will provide the clinical and non-clinical data (Thulare 2016:7-9).

The new NHI system was accompanied by an eHealth Strategy for South Africa, which, according to the WHO (2016b:Online), is based on the application of information and communication technologies (ICTs) in the health sector. ICT in eHealth encompasses, for example, tracking diseases, treating patients, monitoring public health, educating students and pursuing health research (RSA DoH 2012:7).

The ICT definition of eHealth incorporates an extensive field and includes the following elements (RSA DoH 2012:7):

- Electronic health or medical records, which enable the sharing of patient information from one point of care to another;

- Everyday health administration information, such as digital disease registers and district HIS;
- Fundamental registrations, such as births and deaths;
- Consumer health informatics, which is accessible to patients' or healthy people's data;
- Management of health knowledge, for example, guidelines for best practices that can be accessed electronically;
- mHealth (the "use of mobile and wireless technology to support the achievements of health objective"), for example, using mobile blood pressure monitors to collect patient data or cell phones to share information;
- Telemedicine, which refers to the use of ICT for providing remote healthcare;
- Virtual healthcare, which refers to healthcare professionals working as a team through ICT; and
- Health research using high-performance computing to handle big data volumes.

According to Meaker *et al.* (2018:110), integrating healthcare with the support of electronic information conversion is regarded as the main enablers to the prospective of NHS. Electronically recorded information flow and sharing are supported by two leading technology methods, integration and interoperability.

2.3.3.2 *Integration and interoperability in South Africa*

The National Health Normative Standards Framework (NHSF) for Interoperability in e-Health in South Africa (RSA CSIR & NDoH, 2014) was commissioned by the National Department of Health, to provide a foundation for future interoperability of the heterogeneous IT platforms in the e-Health system. The NHSF report focuses on national e-Health services that will be needed to support a national, person-centric health information basis. The national system's focus excludes the various IT platforms associated with technologies or devices in hospitals, laboratories, pharmacies or specific physicians' offices.

The BMI study levels in the new NHI system should be totally integrated, to ensure the provision of good medical services to all South Africans. Although the platforms used in imaging informatics (PACS & RIS) are well integrated, the platforms, for example, EHR, EMR, HIS, PIS and PACS as used in the hospital environment, are not always integrated (Triegaardt 2013:1). Also, the radiologic informatics platform RIS is seldom integrated with the hospital HIS platform, especially in private hospitals in South Africa. Furthermore, the proposed NHI system currently does not have full PACS integration nationally (Mars &

Seebregts 2006:4; Triegaardt 2013:1), due to heterogeneous IT programmes from different vendors and the costs involved in its implementation (RSA CSIR & NDoH 2014:7).

The national digital health strategy for South Africa, 2019-2024, was developed with the vision of 'Better health for all South Africans, enabled by person-centred digital health' (RSA DoH 2019:11). All citizens will be empowered to steer their personal health excursions by means of digital technologies.

Digital health intercessions are allied to the health sector primacies that will support the country in advancing the quality of healthcare, as well as assist the health system conversion for NHI. The digital healthcare priorities during the 2019-2024 period (RSA DoH 2019:11) were:

- To develop a complete EHR system that will advance patient management;
- To digitalise the business processes of health systems, which will embrace digitisation of numerous health systems to enhance effectiveness and quality at a managerial level such as human resource, and access to medicine;
- To establish an integrated platform and design for interoperability and safe sharing in information systems in the healthcare sector and ensure the interconnection of current patient-based information systems;
- To develop high impact mHealth for community-based intercessions, which will magnify health upgrade coverage to the vulnerable population groups such as the elderly, children and women; and
- To develop knowledgeable care workers in the digital health workforce, working to sustain digital health, as well as economic growth.

During the past two decades, private radiology practices and public healthcare institutions in South Africa rapidly transferred from analogue to digital imaging. The implementations of PACS, a subdivision in BMI, were introduced, which altered the workflow in clinical informatics and imaging informatics, to render increased clinical competence between healthcare providers and customers (patients) (Mulla in Abbas & Singh 2019:324–325). More qualified, skilled and knowledgeable professionals in health and imaging informatics are needed to ensure optimal workflow and highly patient-centred healthcare. Therefore, there is a need to develop an imaging informatics teaching model for future programme development.

The next section will provide an overview of the BMI platforms, to indicate how imaging informatics integrates into BMI.

2.4 BIOMEDICAL INFORMATICS

According to Biomedical Information Science and Technology Initiative (BISTI), a new period in biomedical informatics indicated the dawn of a new period in BMI. In a report, they convincingly approve the term BMI or health informatics as an 'umbrella', by naming main study fields or platforms in the field. BMI also signifies the union of computer and information sciences, which include domains such as biomedical research, health professions education, clinical practice, public health and imaging (BISTI 1999:1–3). According to Carlton *et al*. (2020:329), BMI (cf. 1.2.1) is represented by five subspecialties, namely, PHI (eHealth on a population level), consumer health informatics, clinical informatics (eHealth on a personal level), clinical research informatics and bioinformatics. All five of these subspecialties review the use of knowledge, data and information in order to improve human healthcare (Carlton *et al.* 2020:329). The three subspecialties related to imaging informatics are PHI (eHealth on a population level), clinical informatics (eHealth on a personal level) and bioinformatics, which will be introduced in the following sections.

2.4.1 Public health informatics (eHealth on a population level)

> *Imagine a public health system where all reportable disease and laboratory information is available within 24 hours of collection, analysis of the data for anomalies is ongoing and automatic, and alerts are distributed in an automated fashion to relevant members of both the public health and clinical community. Furthermore, a steady stream of electronic information from a wide variety of sources regarding the health status of every community would be collected, analysed, and disseminated continuously (Kukafka & Yasnoff, 2007:365).*

The vision above was considered as a futuristic scenario in the USA in 2001. It was also this vision that steered the start of the American Medical Informatics Association (AMIA) Congress in 2001, which connected public health and informatics communities, to work together to promote the growth and progression of PHI, that is, eHealth on a population level (Kukafka & Yasnoff 2007:365).

2.4.1.1 *What is eHealth?*

The WHO (2010:1) defines eHealth as "the use of information and communication technologies (ICTs) for health too, for example, treat patients, pursue research, educate students, track diseases and monitor public health". This brief definition covers a large area, including,

- EHR, which enables the sharing of patient data among stages of care (cf. 1.2);
- Normal health management data (e.g., electronic ailment records, electronic regional health information systems);
- Crucial record-keeping (computerised registration of births or deaths);
- Consumer health informatics (access for individual or patients to information on health);
- Management of health knowledge (e.g., ability to access and manage best practice guidelines electronically);
- mHealth (e.g., information sharing via mobile devices, or access or collect aggregate or patient data);
- Telemedicine (diagnosing and treating patients remotely with ICT);
- Computer-generated healthcare (professionals working together as a team via ICT); and
- Health research (handling large data volumes with high-performance computing) (WHO 2016a:11).

The National eHealth Strategy of South Africa adopted the WHO's definition of eHealth and committed to abide by resolution WHA58.20 on eHealth, which was adopted in 2005 at the 58th World Health Assembly Resolution (WHO 2005:108–110). The national Department of Health should address the following ten main strategic concerns in order to power eHealth and reinforce healthcare transformation in South Africa:

- Design and guidance;
- Investor appointment;
- Standards and interoperability;
- Governance and regulation;
- Investment, accessibility and feasibility;
- Benefits realisation;
- Ability and workforce;
- eHealth foundations;
- Applications and devices to reinforce healthcare delivery; and
- Monitoring and assessment of the eHealth strategy (RSA DoH 2012:7).

Imaging informatics that functions on a cellular or organ system level, like PHI, is one of the study levels of BMI (Hsu, Markey & Wang 2013:1010). BMI refers to various platforms used in the health environment for storing, retrieving and communicating medical data. The medical data can originate from various sources, such as biological applications, healthcare-related activities, and preclinical or clinical research (Carlton & Adler 2013:363). The different information systems needed in these sources may fall under the same informatics structure as the HIS of the hospital (Huang 2014b:287).

2.4.2 Clinical informatics (eHealth on a personal level)

Clinical informatics, also referred to as health informatics, advocates for accepting, incorporating, and applying IT in the settings of an individual healthcare system. The application of IT assists in ensuring sufficient and eligible support of clinician intentions and healthcare industry best practices (Jidkov, Alexander, Bark, Williams, Kay, Taylor *et al.* 2019:1). Figure 2.3 sets out the relationship of clinical informatics to clinical care, the health system and ICT.

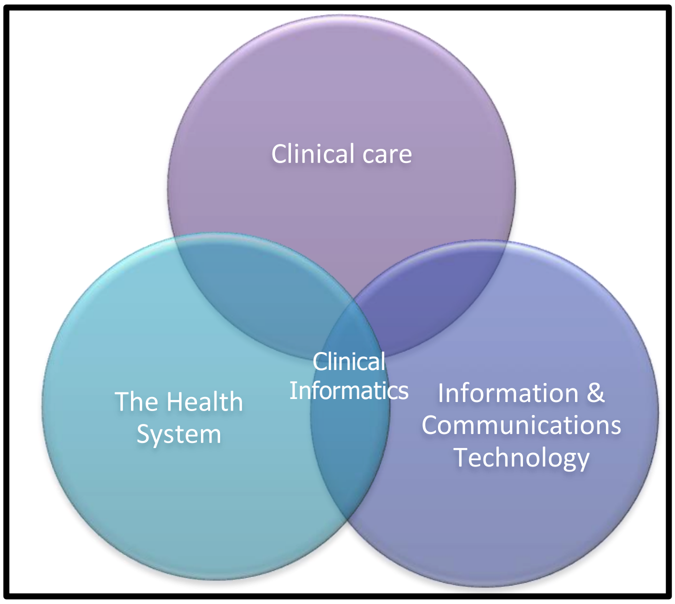


Figure 2.3: Domains of Clinical Informatics (adapted from Gardner, Overhage, Steen, Munger, Holmes, Williamson *et al.* 2009:154)

Figure 2.3 indicates that clinical informatics incorporates three domains: clinical care (delivery of medical services on an individual basis), the health system (the constructions, procedures, and motivations that outline the medical care atmosphere), and ICT (the equipment for effective capture, delivery, conduction, and usage of data, reports, and knowledge for effective application) (Gardner *et al.* 2009:154).

Clinical informatics, in a particular healthcare system, is a subspecialty that includes the following categories that should be mastered: fundamentals, improvement, health information systems and leadership and management for change. Clinical informatics derive information from the bigger field of health and biomedical informatics when they apply informatics concepts, methods and tools in medical practice. Their main goal is to put operational 'decision-making' systems in place, through ICT, to enhance decision-making in clinical care practice (Gardner *et al.* 2009:154). According to Gardner *et al.* clinical informatics professionals must exhibit the expertise of the following:

- The medical field;
- The informatics fields;
- The environment of healthcare, which includes the influence business procedures have on healthcare distribution and the data flow between the main fields in the health system;
- The way information systems and procedures improve or cover the decision-making and engagements of team members in healthcare;
- Redesign of healthcare procedures;
- Essential knowledge of concepts of information systems, which include the life cycle of the information system, continuously developing potentials of IT and healthcare, and technological (non-technical & technical) matters encompassing system implementation;
- The impact that clinical information systems have on patients and users, ways to promote adoption of the system among clinicians, and assisting clinicians as users;
- Appraisal of the information system to submit feedback to improve the system; and
- Leadership in managerial transformation, promoting teamwork, communicating efficiently, and overseeing comprehensive assignments narrated to clinical informatics systems (Gardner *et al.* 2009:154).

Health informatics (clinical informatics) has been evolving resolutions for information systems within an organisation for many years. With the appearance of trans-institutional information systems, a new term, eHealth, was coined to define a new field, which emerged at the intersection of business, public health and medical informatics. eHealth refers to health services with information that is supplied via the internet. In general, eHealth includes more established concepts, such as telemedicine and telemonitoring, but also includes more recent concepts, such as joint EHR or ubiquitous healthcare systems (Ammenwerth, Scheier & Hyan 2010:269).

2.4.3 Bioinformatics

According to Luscombe *et al.* (2001:83), bioinformatics is informatics on a molecular level. Bioinformatics is an elaborated concept of biology, which concerns molecules and the application of informatics procedures to form an understanding and to organise the data connected with these molecules, on a large scale. In summary, bioinformatics is a "management information system for molecular biology" with numerous practical applications (Johnson & Friedman 2006:59).

Traditionally, bioinformatics involves medical laboratory programs for testing specimens, for example, blood tests, urine tests and histology of tumours (Kuznetsov, Lee, Maurer-Stroh, Molnar, Pongor, Eisenhaber *et al.* 2012:2-3). However, bioinformatics has developed into a valuable measurement tool in clinical oncology for theclassification of cancer markers, early indications, prognosis and personalised treatment (Chennubhotla, Clarke, Fedorov, Foran, Harris, Helton *et al.* 2017:110-112; Kuznetsov *et al.* 2012:5-6). The classification of tumour markers is related to a fairly new discipline in bioinformatics, called translation bioinformatics. AMIA defines translational bioinformatics as "the development of storage, analytic, and interpretive methods to optimise the transformation of increasingly voluminous biomedical data, and genomic data, into proactive, predictive, preventive, and participatory health" (Tenenbaum 2016:31).

Friedman, Altman, Kohane, McCormick, Perry, Miller *et al.* (2004:167), state that the suggestion by the American College of Medical Informatics to integrate information and computational sciences with application domains, such as training, healthcare, and biological research, initially produced problems, mainly because of conflicts of the basic and clinical sciences' ethos. A study done by Johnson and Friedman (2006:59-65) relates to experience at Columbia University, where bioinformaticians were trained with a focus on clinical informatics in an attempt to bridge the gap between biology and clinical informatics. In response to the students' dissatisfaction with the new learning programme developing based on clinical informatics, a new curriculum was established. In the new curriculum, bioinformatics and clinical informatics were both recorded as study levels in BMI.

The BMI platforms of PHI, clinical informatics and bioinformatics could include the following operational elements, namely, HIS, EMR or EHR, PACS, imaging modalities, networks, health data standard: DICOM, HL7 or FHIR. The integration of these programs and operational elements have to be monitored constantly to ensure an efficient workflow in HI and imaging informatics, which necessitates the presence of skilled, knowledgeable professional, and, therefore, the need for an imaging informatics teaching model to guide future instructional programme development in this field.

2.4.3.1 *Hospital information systems*

The description of HISs varies according to the settings in which they operate (Matshidze & Hanmer 2007:91). In one of these settings, a HIS is seen as an electronic management system, responsible for fulfilling the following tasks in the healthcare environment:

- Clinical and medical activities in relation to patient care administration of the daily business transactions in a hospital;
- Hospital performance; and
- Long-term projections or goals of the hospital.

A HIS generally computerises patients' organisational (information on patient profile, appointments and billing) and clinical care utilities (e.g., laboratory and digital imaging results, and prescriptions online) and can eliminate the printed document processes within the clinical situation (Cline & Luiz 2013:1). A study by Cline and Luiz (2013:4) indicates that a HIS has the potential to impact positively on optimising workflow and patient care and achieve cost reductions and security of information. The nursing respondents in their study indicated that HIS automation of the patients' administration process benefited their work schedule (Cline & Luiz 2013:1). The majority of the nursing staff (71%) agreed that paper processes require that they devote more time to administrative actions. In contrast, the majority of doctors (55%) suggested that the paper process was not as unproductive as indicated by literature and, thereby, demonstrated their reluctance to adapt to newer processes in the workflow. Nurses, on the other hand, identified the necessity of data duplication, which relates to their paper processes of the past, where they frequently had to record data on different aspects of patients (Cline & Luiz 2013:4).

The information collected through HIS can be grouped into four general classifications, namely, information on the status of health, information related to health, information on health services, and information on health management (Matshidze & Hanmer 2007:91). According to Matshidze and Hanmer (2007:90), in South Africa, HISs developed independently in the public and private sectors, as a result of the initial public-sector emphasis on the maturation and implementation of HISs. The private health sector's HIS was more focused on profitable aspects, for example, compensation and advancement of clinical and administered care intercessions. HISs in the private sector in South Africa are regulated by the Department of Health policies, strategies and legislation, which are applicable to the development of HISs from the 1997 White Paper on Healthcare Reform to the 2004 National Health Act (Act 61 of 2003) (RSA DoH, 2004). The public and private health sectors had to work together to pinpoint the parameters of the individual systems to enable interoperability and to unify the two HIS systems to improve healthcare for all citizens (Matshize & Hanmer 2007:91).

According to Soontornpipit, Taratep, Teerawat, Satitvipawee and Proonrata (2016:254), HIS frequently refers to the front-office section of hospital IT, but it can occasionally refer to the entire IT system of the hospital. Using HIS, EMR, or EHR applications helps with clinical workflows, improves the quality of care through more effective decision-making, and lowers costs (Soontornpipit *et al.* 2016:255). EHRs and HIS are just small pieces of the 'big puzzle' in the healthcare system that are needed to ensure efficient health information exchange.

2.4.3.2 *Electronic medical records and electronic health records*

In the USA, in a debate whether EMR can improve quality of care (Manca 2015:846), 65% of respondents agreed that EMR improved patient care and fewer than 5% were of the opinion that it had a negative impact on the quality of healthcare provided by them. A study by Makoul, Curry and Tang (2001:610) concluded that EMR could improve physicians' ability to perform information-intensive functions, but could impact communication with the patient negatively and, therefore, the quality of patient care. According to Greiver (2015:847), there is little evidence in Canada that EMR improves the quality of care.

As mentioned earlier, EMR and EHR, sometimes used in the same context, are concepts that differed substantially in applications in the past (cf. 1.2.1). EMR includes the longstanding health records of patients' medical history and treatment at individual private or public health institutions (Garrett & Seidman 2011:1; Weeks 2013:137). EMR could only be institution-bound, which left an institutional responsibility to communicate the patient's records with referring physicians via a paper trail (Huang 2014b:403; McEnery, 2013). In contrast to EMR, EHR operates on an all-inclusive patient health basis. EHR programs have interoperability capabilities, which allow sharing of patient healthcare information between service providers (Reisman 2017:572; Garrett & Seidman 2011:2). The interoperability capabilities of EHR ensure access to a patient's healthcare information by all service providers involved in the consumer line. In the USA, the 'meaningful use' incentive was implemented to accelerate the implementation of EHRs (Siddiqui, Nagy, Bonekamp & Dreyer 2014:292-293; USA DoH & HS 2010:467-494), which steered a global awareness. In the USA and Canada, the interoperability and compatible abilities of EHR were seen as an instrument to establish a nationwide integration of EHRs (Tait, Horne, Lo, Evans & Ng 2016:15). Penrod (2017:S14) is of the opinion that the resolution to transition to a new interoperable EHRs system is the result of a realisation that the present circumstances are unsustainable due to costs, especially if the EHR without interoperability capabilities had recently been purchased.

The UK (EHR) and Australia (Personal Controlled Electronic Health Record) made use of a top-down approach to implement a national EHR. However, the program was considered to have been a failure in both countries and was discontinued in 2013 (Greenhalgh & Keen 2013:1; Justinia 2017:2; Tait *et al.* 2016:15). Symons, Ashrafian, Dunscombe and Darzi (2019:1) recognised that siding with a personal (patient) health record (PHR) system can permit enhanced synchronisation of clinical data nationwide and authorise patients to manage their health.

Khalifa (2013:337) reported that several barriers hinder the successful implementation of HIS and EMRs in Saudi Arabian hospitals. The hindrances were identified as human barriers (healthcare professionals' beliefs) and financial barriers (money and funding). A study was done by Cucciniello, Lapsley and Pagliari (2015:295) focused more on the socio-technical features of EMR implementation – this paper highlights technological, organisational, cultural and financial considerations that should be followed when implementing EMRs in hospital venues. In the public sector in Kenya, guidelines and recommendations were developed for the rollout of national EMRs in health facilities, which was tested to conclude the level of compliance in a study done by Kang'a, Puttkammer, Wanyee, Kimanga, Madrano, Muthee *et al.* (2017:68). The results underpinned an intensive use of the resources for the future EMR upgrade.

In South Africa, the majority (71%) of the population's healthcare needs are provided by the public health sector, which is free of charge in the primary section and funded by the national and provincial health departments. The private sector, on an individual, paid medical insurance basis, caters for the remainder (27%) of the population's needs (Nkonki

2019:Online; SAPPF & HealthMan (Pty) Ltd. 2013:16–17). The expectation by the government and citizens was that the application of technology would enhance healthcare services and decrease the disparity between primary healthcare in rural areas, and secondary or tertiary healthcare in urban areas. Notwithstanding the potential benefits of EHR during the early years of this decade, more than 50% of EHRs failed globally on implementation to gain full capacity utilisation (Yogeswaran & Wright 2010:396). The results of the study done by Yogeswaran and Wright are reflected in the results of a study by Cucciniello *et al.* (2015:295), which indicates that EHRs should be seen as a socio-technological issue, where the emphasis is placed on the necessity of amendments to technology, to adjust people's workflow. A systematic literature review by Katurura and Cilliers (2018:1) on EHRs in the government healthcare sector in South Africa, identifies similar barriers to EHR implementation in countries globally. The main barriers are environmental, social and technical in nature (Khalifa 2013:338). For the NHI to work effectively, the interoperability of EHRs will have to work optimally. Currently, the technology barriers include lack of IT infrastructure and implementation costs. The environmental barriers are related to strategy and frameworks, legislation and regulations, and policies and strategies, while the social factors involve training commitment and skills of users (Katurura & Cilliers 2018:3-4). Katurura and Cilliers (2018:3) point out that, according to literature, challenges facing the implementation of EHRs include a lack of ICT skills amongst healthcare personnel, the absence of a recognised profession as a health informatics specialist, and opposition of healthcare personnel, who are of the opinion that these programs will confound their work procedures.

2.4.3.3 *Privacy and confidentiality problems related to EHR*

Bigger privacy and confidentiality issues relating to patient data are resulting from the use of EHR (also known as EMR) programs and their interoperability abilities. Initially, the main concerns of clinicians regarding EHRs were privacy and confidentiality issues relating to patients' private information (AAFP 2018:3). In a LAN or WAN environment of a specific healthcare facility, the personal information of patients is protected by controlling access for healthcare personnel. Controlled access can be regulated by encryption of data through passwords or biometric metric informatics (Keen 2011:2; Pussewalage & Oleshchuk 2016:1168). According to Pussewalage and Oleshchuk (2016:1168), biometric informatics, which denotes biological properties of living people, is unique to each individual, for example, fingerprints, iris, finger veins or palm print scanning; this technology has been embraced extensively to authenticate authorised users of patient health records.

Fernández-Alemán, Señor, Lozoya and Toval (2013:559) found that 11 diverse norms and regulations relating to privacy and security in sharing patient data were in use in different countries globally. Multiple algorithms of data encryption were available for EHR communication and access control. The preferred model for access control was Role-Based Access Control (RBAC). They also observed that an audit is particularly useful for identifying regular and distrustful access procedures. A lack of training in privacy and security was noted. Recognition was granted to the development of proper education training programmes (Fernández-Alemán *et al.* 2013:559). Kruse, Smith, Vanderlinden and Nealand (2017:1) found, in their literature analysis on the security of EHR, that the most commonly mentioned protection techniques and measures can be characterised into three domains: technical (access control to authorised users), administrative (policies and procedures and practices for security checks) and physical (physical limits to access control) securities. Sensitive patient information taken up in the EHRs, and the rapid advancement of technology and superior cyber threads presented over the 'three pillars of healthcare' (cf. 2.3.3.1) – effectiveness, affordability and accessibility, which all have a core of IT – necessitate innovative security measures to address end-users' concerns (Kruse *et al.* 2017:7).

Although HIS, EMR and EHR form the cornerstones of electronic patient information data management (in addition to images) in the hospital setting, they must integrate with the PACS of a healthcare facility to enable access to and sharing of medical images. PACS in the radiology department is part of imaging informatics (Huang 2019:389). PACS (cf. 1.2.1.1) can be hospital or radiology-based, depending on the relationship between the imaging department and the healthcare facility. As mentioned before, in the private sector in South Africa, radiologists privately own the majority of imaging departments (cf. 1.2.1.1).

2.4.4 Imaging informatics

Medical imaging comprises all clinical disciplines that use and interpret images in relation to the patient's health (Aggarwal, Erickson & Kahn 2016:S23). Medical imaging informatics is an interdisciplinary field that interconnects with the health sciences, biological sciences, medical physics, information sciences and engineering (Andriole 2009:202). A combination of situations, and farsighted leaders, made radiology the frontrunners in clinical IT through radiology informatics (now known as imaging informatics), which started in the early 1970s with digital modalities such as computed tomography (CT) (Kohli *et al.* 2015:717). The adoption of IT in radiology departments progressed in the early 1980s with the introduction of RIS, the PACS system in the early 1990s, speech recognition at the start of the 21st century (2000), EHRs by 2010 and clinical decision support, which started in 2017 in the USA (Kohli *et al.* 2015:717). Globally, the first complete digital radiology department was opened in 1980, at the Baltimore VA Hospital in the USA (Kohli *et al.* 2015:718). According to Daniell (2012), the first digital department in South Africa was installed in Pretoria at Little Company of Mary Hospital in 1996.

According to Kohli, Warnock, Daly, Toland, Meenan and Nagy (2014:174), imaging informatics was motivated for 20 years by generally embracing three clinical information systems: RIS, PACS and speech recognition, all three of which imitate the workflow during analogue radiology, which is common knowledge to older radiologists. Since the early 2000s, there was a wave of new inventions in imaging informatics, around EMRs gatherings for statistical purposes, advanced workflow, searches, dashboarding and "analytics tools for quality measures" (Nance, Meenan & Nagy 2013:1065-1067).

Morgan, Meenan, Safdar, Nagy and Flanders (2014:1241) state that the digital computer was and still is at the centre of all the rapid and unavoidable changes in healthcare IT. In the imaging department, computers are essential tools of the diverse imaging modalities, for creating and processing digital images, and for post-processing of imaging data by radiologists and radiographers (Indrajit 2013:17). Scheduling examinations, viewing and analysing images, voice recognition dictations for reporting, and billing and communication with health insurance companies are also done on computers. Computers enable multimedia integration via networking to transmit, store and retrieve electronic patient data and images in and from the PACS and RIS/HIS archive. Image data can also be transmitted and viewed by radiologists via teleradiology, for reporting purposes, or retrieved and viewed on handheld electronic devices by referring physicians at the patient's bedside (Indrajit 2013:17). All role-players in the imaging department should have operational knowledge of computers. Important skills that are essential for radiologists and radiographers are to know the different hardware components within the computer, for example, the central processing unit, the basic input-output system, the random-access memory (RAM) and the internal memory (Indrajit 2013:19).

A clear understanding of the networks in the radiology department is vital for enhancing workflow. A merger of network hardware and software enables smooth workflow in the radiology department. Networks are categorised based on the range of their reach, for example, LAN and WAN. LAN is usually grounded on Ethernet technology, and WAN on the

World Wide Web (Indrajit 2013:20). Communication in a radiology network is only possible with healthcare standards, like DICOM, HL7 and IHE. DICOM delivers protocols for image data integration amongst imaging modalities, while, HL7 provides protocols for the integration and management of administrative and clinical EHRs (Indrajit 2013:18; Mendelson & Rubin 2013:1197).

According to Kansagra, Yu, Chatterjee, Lenchik, Chow, Prater *et al.* (2016:36), workflow in the radiology department started as a rather easy process, from paper-based imaging requests, and ended in paper-based reporting. Radiology workflow expanded rapidly with the introduction of PACS in 1982, into a technologically sophisticated and complex system. In the modern digital imaging department today, the workflow starts as an electronic imaging request from the referring doctor within the EHR/EMR and is pursued by the scheduling in the RIS, digital imaging on the modality and electronic storing in the PACS database, image interpretation and electronic report creation in the RIS/EMR/EHR (Kansagra *et al.* 2016:628).

Globally, and in South Africa, the majority of diagnostic imaging departments are now digitised (paperless and filmless), which, with the engagement of advanced workflow processes, enhanced productivity, quality of work and patient safety (Morgan *et al.* 2014:1241; Mulla in Abbas & Singh 2019:325). The sophisticated workflow processes influence all the facets of radiology practices and role players in the digital imaging department, which include the following activities and role players:

- Ordering (referring clinicians),
- Scheduling (schedulers),
- Order entry (receptionists),
- Decision support, protocol and patient management (radiologists and radiographers),
- Display and review of images (radiographers and radiologists),
- Post-processing (radiographers and radiologists),
- Reporting (radiologists),
- Billing (billing administrator), and
- Communication and critical results reporting (radiologists) (Morgan *et al.* 2014:1241).

All these role players communicate by means of computer software programs, which engage high-tech and conventional interfaces (Morgan *et al.* 2014:1242). According to Morgan *et al.* (2014:1243), in the successful modern radiology department, these interactions are critical and should be managed by highly skilled people and, sometimes, entire teams. Morgan *et al.* are of the opinion that a cross-trained (in informatics) physician (radiologist) should be at the lead of such a team, to overcome the gap between IT resources and clinical requests. Other team members involved in such a team are radiographers and IT technologist, who need to be able to enhance their knowledge and skills regarding imaging informatics. In the absence of a registered imaging informatics course at higher education institutions in South Africa, the development of a teaching model and programme development would benefit these team members, to eventually fulfil their role in the team.

2.4.4.1 *Managing imaging informatics in a digital diagnostic department*

Converting an imaging department from analogue to digital imaging requires good teamwork between management, administration, IT and radiographer role players (Langer, Ramthun & Bender 2012:751). Langer *et al.* (2012:746), list essential information that should be available for the transition to digitising a radiology department as the following:

- Whether all the modalities are 'digital-ready';
- Whether the mandatory infrastructure is available within the healthcare facility and the imaging department;
- The kind of changes that should transpire in the workflow;
- The impact that digitisation will have on other roles in patient practice, for example, orthopaedic and emergency departments;
- Management of the new electronic environment that is, support to users, adjusting incorrect data, archiving of digital images; and
- Data centre omission of the hardware and software of the computers that structure the imaging informatics system.

In the USA, an essential requirement for the purchase of new information systems is complying with Health Insurance Portability and Accountability Act privacy rule (Ness 2007:2164) and ensuring interoperability between all the digital imaging modalities. In South Africa, the function of the Protection of Personal Information Act (PoPIA), the equivalent of the Health Insurance Portability and Accountability Act, is to protect patient data. However, this Act commencement date is only set as 2020, after the information regulator becomes operational, which will probably happen in 2019 (Heyink 2018:9). PoPIA came into effect on 1 July 2020, but enforcement will only start on 1 July 2021.

Langer *et al.* (2012:746), state that imaging modalities need to be 'digital ready' for the transition from analog radiology to digital radiology. Currently, all new, available imaging modalities can be purchased as digital x-ray devices (Carrino 2003:214). Digital-ready indicates the ability of the x-ray modality to integrate with the RIS and the PACS through the modality worklist, and the health standard, DICOM (Mann & Bansal 2014:18).

2.4.4.2 *Imaging modalities*

Digital radiographic images of patients are obtained in the radiology department by the imaging modality. According to Peck (2018:42-43), imaging modalities can be divided into three broad categories according to their imaging output, which is, single image, multi-slice, and hybrid. The imaging modalities should all be integrated into the RIS and PACS workflow of the radiology department, and generally are, *single image acquisition modalities, like* CR, direct digital radiography (DX), US, radio fluoroscopy (RF), mammography (MG), panoramic x-ray (PX), bone densitometry (BMD), and in certain cases x-ray angiography (XA). Nuclear medicine (NM) units were mostly part of the single-slice acquisition modalities in the private and public healthcare sector (Mohd-Nor 2011:91). In other countries like USA, UK and Republic of Ireland, NM imaging departments usually fall under the Radiology Department in the private and public sector. In South Africa, NM imaging departments in the public sector are independents from Radiology Departments, especially in big training hospitals. In the private sector smaller NM imaging departments could be incorporated within the structures of the Radiology Department. Multi-slice modalities include CT and MRI units. From the radiotherapy department, modalities like, radiotherapy images (RTIMAGE) and radiotherapy plan (RTPLAN) are included in the multi-slice modalities (Peck 2018:44). The hybrid modalities are PET and single photon emission computed tomography (SPECT) combined with CT and PET combined with MRI modalities, which then incorporate NM imaging into hybrid modalities, like SPECT/CT, PET/CT and PET/MRI (Mohd-Nor 2011:90; Peck 2018:44; Sanghvi & Harisinhani 2010:85-86). In short, the modality abbreviations listed above are referred to as DICOM modality abbreviation in the imaging informatics environment. These DICOM modality abbreviations are listed in the DICOM standards, which is directed by the Medical Imaging and Technology Alliance. DICOM standards were first published in 1985 and are upgraded every year with new developments (Mendelson & Rubin 2013:1196). The standards are used in the DICOM message structure for communication between the RIS and the modalities through the DICOM modality worklist, and PACS for sorting the images of the different types of modalities in the archives, for an uncomplicated search and retrieval process using DICOM modality abbreviations (DICOM Standards 2018:30).

For older imaging modalities that lack the necessary DICOM standard, a DICOM worklist will not be available on the modality interface. The radiographer has to enter specific details manually on the modality workstation to assure the matching of image data with the patient's information originating from the RIS. IT specialists have to create specific rules to match these images with the relevant RIS information of the patient (Levine, Mun, Benson & Horii 2003:133).

Radiologists and radiographers are required to keep up with newer imaging techniques, which could be on new modalities or additional software programs available on existing modalities, for example, brain perfusion and diffusion imaging in MRI and CT, proton spectroscopy diffusion tensor imaging in MRI, US elastography, tomosynthesis in mammography and cardiac imaging in MRI (Pirimoğlu, Sade, Oğul, Kantarci, Eren & Levent 2016:213). Modalities, such as CT, MRI and tomosynthesis in mammography, produce large volumes of data that could slow down the LAN (Yoshinobu, Abe, Sasaki, Tabei, Tanaka, Takahashi *et al.* 2011:111). According to Kansagra *et al.* (2016:36), modalities generating big data, such as CT, MRI and tomosynthesis in mammography, where the radiologist has access to all the data during the reporting process, and which includes previous examinations and very-thin-slice imaging in CT imaging, enables radiologists to compare image data and provide comprehensive reporting. Unfortunately for the referring physician, these very thin-slice sequences/series contain too much data, and sending it to the archive can cause congestion on the network during the very busy workflow. Some of the information, therefore, does not reach the referring physician, unless it is viewed on the modality. Some patient information is stored in the EMRs or the RIS in the radiology department, and radiologists will look beyond images, at family and personal history, to distinguish between benign and malignant lesions (Kansagra *et al.* 2016:31).

2.4.4.3 ***Radiology information systems***

RISs were developed for the first time in the 1960s, and mainly addressed coding and delivery of reports. RIS continued to evolve under the Radiology Information Systems Consortium, until a proposal by the Digital Equipment Corporation, was accepted to develop new features in RIS (Nance *et al.* 2013:1065). As the years passed, RIS became more reliable and developed from 'isolation island' – managing the radiology operations separately from the hospital – to integration with the PACS into the workflow of the radiology department (Nance *et al.* 2013:1064; Kohli *et al.* 2015:717). RIS is distinctive of radiology by its composition; a department such as pathology has a similar system, namely, LIMS, which is designed for their textual workflow (Peck 2018:62). Although several of the RIS functions, inclusive of electronic patient booking (computerised physicians order entry, CPOE) and registration (enterprise order scheduling and management) have moved to enterprise electronic medical records (EMR or EHR) in hospitals, Nance e*t al.* (2013:1067), are of the opinion that RIS still has a role to play and that radiology practice will carry on evolving "innovative technologies" (Nance *et al*. 2013:1068). Peck (2018:63) explains that some key software companies started including RIS processes in other applications. Traditional RIS processes that are allocated between other systems are reporting to PACS-based; appointments to the scheduling function in EPR worklists to the EPR initiated worklists; and statistics to "business data warehouse's software" (Peck 2018:63). In the imaging environment, the role of the RIS is to capture and process the following:

- Information regarding patient and image records;
- Scheduling of examinations;
- Monitoring of the patient status in the system;
- Creation, formatting, and storage of radiology reports;
- Tracking old soft copy records of patients;
- Timely billing of patient examinations; and
- Statistical analysis of employee workload and patient visiting profiles.

As mentioned before (cf. 1.2.1.1), interfacing the RIS with the PACS is based on the HL7 interface via the TCP/IP through Ethernet. Imaging informatics professionals are responsible for setting up the interfacing between these programmes or monitoring the workflow in the radiology department between the platforms. To ensure that skilled, knowledgeable individuals are available to do the work, an imaging informatics teaching programme in higher education will be beneficial in South Africa.

2.4.4.4 *Picture archiving communication systems*

PACS is an electronic data system for archiving, retrieving, viewing and disseminating digital medical images, which consist of hardware components. The hardware consists of a network for integration of data, digital imaging modalities for creating digital images on a physician referral basis, servers (storage computers) for archiving image data and workstations for viewing and reporting digital images (Schultze, Greyling, Hayes & Andronikou 2007:50). In the 1990s and early 2000s, the clinical effectiveness of PACS depended directly on its integration with various healthcare applications, which included, for example, RIS in the radiology department and HIS in the hospital. The integration process was possible due to compliance of the integration systems with the DICOM and HL7 healthcare standards, and it followed a particular workflow profile. The profile used was similar to the workflow profile of Integrating the Healthcare Enterprise, which enables perfect PACS clinical functions (Huang 2011:163). Some vendors made use of DICOM PACS as their main image storage reserve for more than 15 years prior to 2015. DICOM PACS and Super-PACS store DICOM images – it is just a DICOM archive. In big healthcare companies (hospitals & radiology), Super-PACS is used, which is an established PACS product offering, scaled to operate over a bigger undertaking. The result of a Super-PACS architecture is the possibility of sharing data across a large healthcare establishment on the condition that the enterprise is populated by the vendor's single PACS (DeJarnette 2009:6). The biggest difference between DICOM PACS and Super-PACS DICOM archives, and Vendor Neutral Archives, is the ability of the latter to perform background management tasks. Vendor Neutral Archives are able to store DICOM image data and other data types, for example, scanned documents, non-DICOM images and PDF files (DeJarnette 2009:6).

The PACS scene started to change in 2014, after the arrival of mobile technologies, such as mobile manoeuvre cameras and accessories, and representational state transfer (REST) web services permitted the emergence of a new platform for capturing images and data (Dennison 2014:7). The new platform allowed easier image capturing and improved automated background identifying techniques. Vendor-neutral archiving became customary for storing DICOM-standard interoperability images (Dennison 2014:7). Vendor-neutral archiving, which was a confusing term for end-users in the early stages of its development, was also seen as a Super-PACS by some of the end-users. The notion of vendor-neutral archiving originated from DICOM PACS owners who felt helpless and that they were prisoners of PACS vendors regarding ownership of their patients' digital images and related data. The PACS owners complained that, whatever they chose to do with their PACS data, it always had to involve their vendor at a price (DeJarnette 2009:1). All the logical components of a PACS system, a RIS interface and workflow mechanism and database modality gateway elements, an archive system and an observing system, are usually supplied to a radiology department by the same vendor. Vendors typically used an industry standard that would only allow their images and associated data into their PACS, by doing so, they captured purchasers into their products exclusively (DeJarnette 2009:1). The particular practices of vendors made it very costly and virtually impossible for PACS owners to move to another vendor's product. Traditionally, a medical image storage device or server is a collective resource, which includes the workflow mechanism, RIS and reporting interface, as well as other additional systems needed for recalling highly organised data. Today, the traditional way of storage is doing it at the base of all the medical imaging industry's interoperability complications (DeJarnette 2009:1). Neutrality regarding vendors means that they should meet certain requirements. Two types of vendor neutrality are overriding: 1) functionality with no obvious variance between different manufacturer commodities; and 2) functionality with no obvious variance between comparable imaging applications. The greatest benefit emerges from the second condition, but it also delivers the biggest contest to vendors who are trying to provide an accurate vendor-neutral archiving product (Agarwal & Sanjeev 2012:2-5; DeJarnette 2009:2). According to DeJanette (2009:3), vendor-neutral archiving should meet the following requirements:

- Interface with additional clinical applications and unrelated PACS in order to communicate image data through DICOM should be possible;
- Interface with other information systems in order to communicate results, report and workflow, through HL7 should be possible;
- The ability to archive the entire set of DICOM standard operating procedures classes, which include key imaging notes and performance states;
- All entities should be stored in the state of a non-proprietary setup, recognised generally by the public, for example, in the latest applicable DICOM standard;
- The most comprehensive DICOM 'query/retrieve' identification as a service provider for the data accumulated in the archive store at all levels must be supported;
- Context management must be provided, for example, manipulation ability of DICOM tags for converting demographic and DICOM performance needs of one vendor's PACS to another vendor's PACS prospects, while having an insignificant influence on the operational timeline of the customer; and
- Admission, discharge, transfer (ADT – include most of the HL7 messaging interaction) updates to the DICOM image files stored in the PACS archive must be possible.

With the move to vendor-neutral archiving, connection to the Zero-install Enterprise Viewers, embedded in EHR and health information exchange offered a single, linear view of DICOM images and patient information. Enterprise viewers emerged in the early 2000s and reached its persuading stage in 2015. More users were now using the Enterprise Viewer, operating from within EHR and health information exchange in the place of DICOM

PACS (Dennison 2014:7). The use of Enterprise Viewer required adaptation of the PACS systems of existing PACS vendors, and new vendors with Enterprise imaging PACS programs emerged. Maintenance of Enterprise Viewer proved to be easier, and security was of a higher standard (Dennison 2014:8). Radiologist users started to introduce handheld mobile devices (tablets), to their support of referring physicians and clinicians, which made bedside communication to patients regarding their results much easier (Dennison 2014:8).

In the last two decades, reporting by radiologists in the digital imaging environment has advanced, from Dictaphone voice recordings and typed reports, to voice recognition reporting. According to Ranschaert and Bosmans (2017:99–100), radiologists can secure the value of their contributions by optimising the influence of their reports on value-based care. Structured reporting is developing as a central component of assuring the merit of radiologists’ work and improving their contribution to patient results (ESR 2018:2-3). The radiologist’s contribution will not be possible without skilled imaging informatics professional, who will ensure an efficient workflow for optimum turnaround time and a patient-centred healthcare environment in the radiology department. An imaging informatics instructional course at a higher education institution in South Africa will enhance patient-centred healthcare in radiology departments.

2.5 IMAGING INFORMATICS TEACHING AND LEARNING COURSES

Imaging informatics teaching and learning courses that are suitable for radiographers and IT professionals have different names. Still, they include the same core concepts of PACS and RIS, network requirements and computer operational elements, imaging data standards, imaging acquisition technologies, and clinical modules incorporating anatomical systems and body planes (Oosterwijk 2020:Online). Table 2.2 portrays postgraduate PACS administration or imaging informatics courses in Ireland and the UK, Canada, and the USA.

Table 2.1: Imaging informatics courses

Country	Qualification (Graduate)	Structure	Contents	Delivery modes
Republic of Ireland and the UK	Postgraduate Professional Certificate RIS/PACS Management (10 credits) (4.5 months)	1. RIS/PACS Management I	RIS/PACS Management I • Advanced material on current image acquisition. • Display and storage systems in digital radiology. • RIS and PACS administration is studied, comprising of present regulatory obligations	
Republic of Ireland and the UK	Postgraduate Professional Diploma RIS/PACS Management (20 credits) (9 months)	1. RIS/ PACS Management I 2. RIS/ PACS Management II	RIS/PACS Management I • Advanced material on current image acquisition. • Display and storage systems in digital radiology. • RIS and PACS administration is studied, comprising of present regulatory obligations. RIS/PACS Management II • Acquire expert knowledge and interpretation of the RIS and PACS manager function, and coach the student for complete system administration	
Michener Institution of Education at the University Health Network (UHN) Canada	Postgraduate Imaging Informatics Certificate (12 months – maximum 24 months)	• GEII110 Imaging Informatics: Part I • NTII120 Imaging Informatics: Part II • PLII130 Imaging Informatics: Part III • ENII140 Imaging Informatics: Part IV	• Work and information flow • Networks and infrastructure • Planning the transition • Sustaining the environment	• Four weeks of hands-on practicum • Four online theoretical courses Prepares radiologic technologist for the American Board of Imaging Informatics (ABII) certification exams

Country	Qualification (Graduate)	Structure	Contents	Delivery modes
Clarkson college (2019) in Omaha, Nebraska	Postgraduate Medical Imaging Informatics certificate programme	Four modules	• Technology utilisation for medical imaging informatics; • Operational strategies for medical imaging informatics; • Organisational planning and vision for medical imaging informatics; • Advanced assessment and application for medical imaging informatics	Prepare radiologic technologist for the American Board of Imaging Informatics (ABII) certification exams
OTech, Inc. Dallas, Texas	Postgraduate PACS Certification Clinical (CPAS) PACS Certification IT (CPAS) ABII or PARCA certification	Clinical course IT course	• Clinical anatomy and systems; • Medical imaging technology • Workflow and digital radiography • Healthcare IT fundamentals; and • Healthcare IT infrastructures	Online and face-to-face lectures

The postgraduate PACS administrator courses displayed in Table 2.2 above are available in English-English speaking countries that the researcher targeted during this research study. The course details are displayed according to country of origin, type of graduate qualification, the structure of the course, contents, and delivery modes when available. The courses range from postgraduate, certificates, professional certificates and diplomas. The modules presented, primarily all share the same PACS or imaging informatics principles. The time allocated for completion of these courses ranges from four months to 24 months, mostly done part-time. Several other courses are available, presented over eight days. These courses are either instructor-led or virtual instructor-led for five of the eight days or done through e-learning, which is equivalent to eight days of instructions in the classroom. The courses are dedicated to particular topics in IT and imaging informatics, ranging from entry-level and then associate (CNNA, Cisco certified network associate) to professional (CNNP, Cisco certified network professional) and expert level to become a network architect (Peck 2018:201). Assessments are typical online assessment, which includes multiple-choice questions and 'fill in the blank' test lets (Cisco Training n.d.:Online). The type of courses in the USA and Canada are mostly directed at preparation for radiographers and IT technologist to write the ABII or PARCA certification exams. In the UK, the certification courses are by different companies and involve IT and networks, systems, management and PACS (Peck 2018:202).

2.5.1 Imaging informatics certification courses

Nagy *et al.* (2005:253), led a survey in the USA with IT specialists, radiology administrators, radiologists, radiologic technologists and IT managers to detect the capabilities and skills needed to delineate an effective PACS administrator. The initial job analysis questionnaire consisted of three domains – behavioural sciences, business and technical aspects for PACS administration – with 127 competency statements under the three domains (Raymond & Nagy 2010:242). From the results of this study, the Certification for Imaging Informatics Professionals (CIIP) was designed in 2007, and by 2012 767 professionals in imaging informatics had been certified through the ABII (Kho, Bluth, Meenan & Nagy 2012:678). The CIIP examination has been evaluated through group performance by Babcock and Nagy (2013:378), which indicated that the examination emerged to operate as a high-grade certification assessment method statistically.

The SIIM and the American Registry of Radiologic Technologists via the ABII, support the Certification for Imaging Informatics Professionals (Kho *et al.* 2012:678). ABII does not provide any imaging informatics programmes, only ABII certification exams. The education courses and materials are provided by third parties, such as the SIIM. ABII does not approve any courses or teaching materials (ABII 2018a:Online). ABII tests are scheduled tests that are undertaken at a time and day convenient for the student. Candidates are allowed three attempts or 12 months to pass the test. Individuals passing the test are called certified imaging informatics professionals (ABII 2018b:Online). Candidates can download the certification guide and the learning objectives of sections that need to be covered during studies in order to take the test, from the ABII website (ABII 2019a:Online; ABII 2019b:Online). The contents include sections, such as procurement, project management, operations, communication, training and education, image management, information technology, system management, clinical engineering and medical imaging informatics (ABII 2019a:Online).

The first certification exams for medical imaging and IT professionals were developed by the PACS Administrators Registry and Certification Association (PARCA). These professionals are usually responsible for PACS system administration. PARCA Certification exams comprise four levels, which can all be done online and supervised through webcam. The four levels comprise of an associate, system analyst, interface analyst and manager levels, where each level necessitates a distinct exam (Oosterwijk 2007:Online).

2.5.2 Overview of South African imaging informatics teaching and learning

Globally and in South Africa, students of imaging informatics teaching programmes are mature learners with postgraduate qualifications in one of the 'legs' of imaging informatics, from either an IT section or from a clinical section. The two groups of mature students that could be involved in the field of imaging informatics are radiographers with a radiography qualification as offered by accredited higher education institutions, and IT specialists with either a basic IT qualification or a clinical (health) informatics qualification (Nagy *et al.* 2005:253). In South Africa, most information technologists working in the imaging informatics field have a basic information technologist or health informatics qualification. Most higher education institutions offer health informatics as a specialist area. The institutions that offer postgraduate qualifications are the University of KwaZulu-Natal (medical informatics), University of Cape Town (health informatics and bioinformatics), and University of Pretoria (health informatics). The Nelson Mandela University introduced a three-year degree in IT only in 2019, which offers an elective module for health informatics during the last two years of study. The three-year IT teaching and learning programme's health informatics elective covers healthcare systems, policies and regulation in the first semester, and population-based healthcare in the second semester of the second year of study. In the third year of study, management in healthcare is offered in the electives as a year module. However, the clinical section of imaging informatics is not included (Nelson Mandela University 2019a:122-125). Radiographers, however, undertake comprehensive clinical modules, and also learn physics, imaging technology and basic imaging informatics during their undergraduate four-year professional degree teaching programme (Department of Radiography 2019a). During the radiography teaching programmes, radiographers have to do work-integrated learning in a health institution accredited by the PBRCT at the HPCSA. For the SAQA and HPCSA-accredited radiography diplomas and degrees that are offered at eight higher education institutions, a compulsory component, namely, work-integrated learning weeks, has to be done in each year of their education (SAQA 2015:1). During work-integrated learning, radiography students are exposed to the practical component of imaging informatics as taught in their formal teaching programme at a higher education institution (SAQA 2015:3). Undergraduate IT students do not have to do work-integrated learning in accredited training sites, but the theoretical modules are usually followed by practical modules, during which they use simulated programs on computers at the higher education institution (Nelson Mandela University 2019a:122-125).

Eight higher education institutions offer the radiography programme in South Africa. The transition to the four-year professional degree in radiography started in South Africa in 2014 at two of the higher education institutions and it was phased in at three other institutions in 2015 and 2016 respectively. At the time of writing, the last three institutions were finalising their curricula and obtaining approval for implementation (HPCSA 2016:6). The curricula for the four-year radiography programme of the eight institutions were developed individually by each institution. However, the guidelines (competence levels) for programme development were set by the PBRCT of the HPCSA (HPCSA 2016:4-7).

During their four years of study, undergraduate radiography students are exposed to management principles and strategies, radiographic procedures and clinical radiographic practice, physics, radiation sciences and imaging technology modules, at different levels (Nelson Mandela University 2019b:104-107). Lehrer's study (2008:405) investigated whether education programmes in radiological technology (radiography) in the USA (n=289) were providing an adequate digital-imaging-specific education, and found that the majority (75%) of these programmes had been modified to keep abreast of rapid changes in the digital imaging environment. In South Africa, teaching and learning basic digital imaging and PACS principles formed part of the third-year syllabus of the National Diploma in Radiography, which has been phased out by the eight higher education institutions offering the radiography programme. It also forms a comprehensive part of the postgraduate BTech course in diagnostic radiography during the second year of study. Currently, the BTech course is offered part-time over two years, with four weeks of contact time per year, at most of the eight higher education institutions that offer radiography programmes (Nelson Mandela University 2019b:131). The BTech programme involves mainly assignment writing, independent research and study coursework. The training provided does not qualify graduates to step into a clinical PACS administrator position immediately after completing their BTech course. BTech programmes have been phased out over the last two years, with the Nelson Mandela University planning to phase it out by the end of 2020 (Nelson Mandela University 2019b:131).

2.5.2.1 *Postgraduate qualifications*

In South Africa, MiiTA, a Cape Town-based company, was involved in organising the African PACS and RIS edu-conference. A formal teaching course (coursework and practical work) for South African PACS administrators was discussed at the first (2009) and second (2012) African PACS and RIS edu-conferences. Two questions that were asked by Schultze at the 2009 edu-conference were, "Is there a requirement to establish an African PACS and RIS (Radiology Information System) Administrator Course in South Africa?" and, "Should we create an African Forum to share experiences?" Although the African Forum was created, and a second African PACS and RIS conference took place in 2013, no PACS administrator courses have been discussed or developed by the start of this study. MiiTA was replaced by the company In2PACS Academy, was founded by an independent service provider. The academy offers a PACS administration course in South Africa, which had been created and previously offered abroad in the United Arab Emirates by Mr Teodor Kantchev of Standards and Architecture for Life in the UK. The independent service provider bought the rights to deliver Mr Kantchev's PACS course in South Africa. Students receive continuous units in education on completion of this course, because it is not registered by the SAQA or accredited by the Council on Higher Education (CHE) and the HPCSA, neither is it approved by the Health Education Quality Committee (HEQC) in South Africa (cf. 1.2.3.2).

An imaging informatics course in the South African context is required to fulfil the primary objective of the *National Health Standards Framework for Interoperability in e-Health in South Africa*, which is, "to set a foundational basis for interoperability as articulated in the eHealth Strategy South Africa 2012-2016" (RSA DoH 2012). Another objective is to ensure that properly trained imaging informatics professionals are able to operate the integrated and interoperable BMI and imaging informatics platforms in medical imaging departments (RSA DoH 2014:17).

2.6 IMAGING INFORMATICS TEACHING AND LEARNING PRACTICES

The inquisitive nature of human beings creates a constant desire to advance their present knowledge by adding new information. The process of adding new information to an existing knowledge base is called learning. The experience of education is aimed at assisting individuals to learn (Gravett 2005:18). From an educational context, learning is focused on specific standards and outcome expectations, making the process meaningful to the person, individually, while adding value to the society as well (Garrison & Archer 2000:39). Learning can be divided into two parts: rote learning (repetition and memorising), and meaningful learning (active reasoning and connection to the information) (Brown & Duguid 2000:211). With rote learning, the memorised information soon fades (short-term memory) due to a lack of meaningful, organised arrangement in the brain (Resnick 2016:2). Although memorising also has a specific function in meaningful learning, the learner should have insight and connect with the information to enhance active and adaptable use and structured storage of knowledge in the long-term memory (Perkins 1991:5).

According to Knowles (1970:40), pedagogy, literally, means the "art and science of teaching children". The assumptions of pedagogy regarding learners and learning, which were based, initially, on the teaching of young children, caused adult learners to resist the pedagogical model that focused on drilled, content-loaded lectures and examinations. Adult learners wanted to make more sense of what they were taught. Andragogy assumes that the learning process of the learner should mature from dependency to self-directedness, at different rates for individuals at different life dimensions (Knowles 1970:42).

Education and training concepts are often used as opposite poles, with education focused on theoretical understanding and developing the mind, and training is regarded as the systematic improvement of individuals' skill patterns that they need to acquire to perform at a specific level of proficiency to complete a task. However, education actually refers to an organised process that is focused on acquiring knowledge, which includes both teaching and learning intended for theoretical understanding and developing of the mind, in addition to teaching and learning intended to get learners to reach a specific level of competency to perform certain tasks (Gravett 2005:viii).

A discussion of the learning theories referred to in literature in relation to a biomedical science and BMI education that could be applied for teaching and learning imaging informatics in the digital diagnostic imaging environment will be discussed in the next section.

2.6.1 Imaging informatics learning theories

Learning theories are structured, prepared values explaining how people obtain, recollect and memorise knowledge; in this instance, imaging informatics principles in the medical imaging environment. Through reviewing and recognising diverse learning theories, a better understanding can be established of how learning transpires. The selection of didactic instruments, methods and plans can be guided by the principles of theories to promote learning (Walker & Avant 2019:13-17). The integration of professional knowledge by theories delivers a detailed visualisation for practice, which indicates a dedication to practice grounded on comprehensive and dependable knowledge, which is inherent in the idea of a profession and practice discipline (Walker & Avant 2019:5). Theories serve as conceptual frameworks for practice, isolate elements of knowledge, and could express the objectives and the primary standards of the profession (Walker & Avant 2019:6).

The students involved in the postgraduate learning and teaching of imaging informatics as outlined in the context of this study are adult learners. Knowles' learning theory of andragogy will, therefore, play a leading role in the students' learning process. Knowles reported five assumptions regarding the attributes of adult learners that differ from those of child learners. These assumptions are all based on the maturity changes of a person from childhood to adulthood. They include aspects like autonomy, accumulation of knowledge and skills, developmental responsibilities in society, time management of the learning process, and changes in relation to internal motivation for learning (Knowles 1984:12). Other fundamental learning theories can also play a role in the imaging informatics professional or PACS administrator's learning processes.

Learning theories usually include three 'elementary' styles, namely, constructivism, behaviourism and cognitivism (Stevens-Fulbrook 2019:2–4; Ertmer & Newby 1993:50). According to Patel, Yoskowitz, Arocha and Shortliffe (2009:177), behaviourist theories are mostly dedicated to basic learning, linking stimuli from background circumstances to explicit behaviour, avoiding the cognitive processes of the brain. The authors also indicate that behaviourist theories have little relevance to the type of complex learning associated with biomedicine's knowledge-rich specialities. According to Patel *et al.* (2009:177), the cognitive learning sciences should be included as a basis for BMI and imaging informatics training.

2.6.1.1 *Cognitivism*

John Locke had an empirical view of how people learn. He believed in the theory of 'tabula rasa', which proposes that the mind commences as a blank state and that everything we become is concluded by our experiences (Bates 2019:3). In the historical period between the two world wars, behaviourism formed the foundation of teaching and learning, until psychologists reasoned that thinking and learning was an evolving cognitive procedure in which people generate, rather than receive, knowledge. The concept of generating instead of just receiving knowledge led to the campaign known as cognitivism. In this learning theory, students are active parts of the learning process, and their minds accept, systematise, accumulate, and retrieve knowledge (Bates 2019:43; Ertmer & Newby 1993:58; Ertmer & Newby 2013:51). Learning takes place through the organised storing of information in the memory and is influenced by the student's mental activities, which leads to goal setting and organisation of new knowledge. The transfer of knowledge is connected to the way knowledge is accumulated in the memory. Strategies, like information-processing, problem-solving, and reasoning, are the types of complex learning that are best described by this theory (Ertmer & Newby 1993:59; Ertmer & Newby 2013:52). Patel *et al.* (2009), believe that academic and methodological improvements in the cognitive and education sciences can serve to enlighten curriculum and instruction in teaching and learning programmes for BMI and, therefore, also imaging informatics. It can be done by attending to matters such as the procedures connected to understanding the role of technology in medical imaging informatics, medical information, decision-making and clinical problem-solving.

In teaching and learning programmes internationally, radiographers who wish to become PACS administrators (imaging informatics professionals), have to learn new concepts in imaging informatics, such as computer basics, operating systems, database basics, data representation, network technology and basic security concepts, healthcare standards dealing with medical imaging and patient information, as well as the imaging informatics software platforms (Andriole 2009:15-32; Ralston & Coleman 2009:33-48; Siebert 2009:60-64). They must integrate and apply knowledge of these concepts in the daily workflow of the diagnostic medical imaging department, to enable them to take part in day-to-day troubleshooting. The IT specialist is introduced to new concepts, such as the cycle of medical imaging, basic anatomical planes and landmarks, anatomical body systems, different medical imaging studies and terminology, principles of radiation, imaging equipment, radiation safety, descriptions and measurements of quality assurance and control, and the characteristics of current imaging modalities, as well as the imaging informatics software platforms (Andriole 2009:3-13; Ralston & Coleman 2009:33-48; Siebert 2009:49-64). They must understand all these concepts and apply their knowledge during workflow setup, maintenance, and troubleshooting in the diagnostic medical imaging department. Testing their abilities and applying their knowledge could be done through PACS/RIS/HIS/EPR simulation on the software platforms incorporated in imaging informatics, which could then include system integration too (Huang, Deshpande, Document, Le, Lee, Ma *et al.* 2014:433-435; Law & Zhou 2003:148-140).

2.6.1.2 *Constructivism*

Technically, constructivism can be considered as a branch of cognitivism, because it acknowledges learning as a mental pursuit, that is, generating meaning from experiences. However, constructivists believe the mind filters contributions from the real world to produce its own reality. Student and environmental elements are vital, and learning takes place by contact between the two (Ertmer & Newby 1993:62; Ertmer & Newby 2013:55). Instruction should be designed to ensure that students understand and engage with information. Constructivist theories incorporate social constructivism, connectivism and situated learning. In social constructivism, the construction of knowledge happens within a social setting by communication and interaction with a community that is knowledgeable regarding a specific field (Ertmer & Newby 1993:63-66; Ertmer & Newby 2013:56-59). Students' integration within the knowledgeable community leads to collaborative incorporation and lodging of new knowledge. Students are self-motivated, and they determine their own goals and intentions. However, they are also inspired by the environment of the knowledgeable community. The teacher facilitates and guides collaborative learning and encourages group work (Bates 2015:53-55; Gregory 2016:35). The knowledgeable community for undergraduate and postgraduate radiography students is their peers, PACS administrators, administration staff, IT managers and radiologists in the diagnostic medical imaging department that students interact with, as well as other healthcare professionals in the hospital environment. During interactions in the diagnostic medical imaging department, radiographers learn from the other professionals mentioned above, which enhances their knowledge in the field of these professionals and workers. They also learn to work in teams and to communicate with their peers and superiors.

In an information technology study done by Ammenwerth, Hackl, Felderer, Sauerwein, and Hörbst (2018:196), they report that the online-based Master's programme at the University Massachusetts Institute of Technology, on Health Information Management, is strongly based on the "constructive theory of situated learning". Considered as a key element for effective learning, teamwork and close interaction between students and lecturers in online-based learning and teaching programmes should be reinforced to encourage a community of inquiry amongst all participants. IT undergraduate and postgraduate students who are interested in medical imaging informatics should also be introduced to integrated simulation learning platforms of PACS/RIS/HIS/EPR in imaging informatics and work interactively and cooperatively with fellow students and instructors (Law & Zhou 2003:148-140; Huang 2019:326-329; Huang *et al.* 2014b:433-435) to learn through the knowledgeable community (Ammenwerth *et al.* 2018:197).

2.6.1.3 *Experiential learning theory*

Learning that takes place according to the principles of the experiential learning theory can be defined as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb 1984:41).

Experience gained through education, life and work plays a fundamental role in learning and is regarded as learning by experience or experiential learning (Fry*,* Ketteridge & Marshall 2009:15). Learning from experience is related to Kolb's (1984) theory of experiential learning, which is a "four-stage cyclical theory" that combines cognition, experiences, conduct and reasoning (Fry *et al.* 2009:15; Gregory 2016:51). Work-integrated learning is a learning programme (qualification) that is designed to unite theory and practical (experiential) learning in the form of real-life or computer-based simulation or job surveillance, a practical component. The practical component, which is acquired at the workplace as part of the teaching programme, is called work-based or workplace learning (Zhou & Brown 2015:52-54). Work-integrated learning is seen as an overriding 'umbrella" pedagogy, which includes the part of the student's learning experience at a workplace, work-based or workplace learning (Patrick, Peach, Pocknee, Webb, Fletcher & Pretto, 2008, cited in Larkin & Beatson 2014:9).

Experiential learning for radiography students is compulsory. In each of their study years, they must complete a module, Clinical Radiographic Practice, which involves work-integrated learning. Students have to apply the theoretical knowledge they gained at the higher education institution in practice in real-life scenarios at an accredited healthcare institution during their workplace learning (Nelson Mandela University 2019b:104; SAQA 2015:1, 3). Although Bachelor's degrees in IT have practical modules that follow theoretical modules, which students do at their higher education institutions in computer laboratories on a simulation basis, they do not do work-based learning during their studies. A new three-year degree, Bachelor of Information Technology, which includes an elective module on Health Informatics, during the second and third years of study, was introduced at Nelson Mandela University in 2019 (Nelson Mandela University 2019a:124-125). Undergraduate radiography students may be assisted by computer-based virtual radiography simulation programmes at their place of study, for the development of preclinical skills in a safe learning environment (Shanahan 2016:218). Radiography students must gain experience that relates to the simulated knowledge they acquired at their place of study and workplace observations during real-life scenarios. Similarly, the imaging informatics student (cf. 2.5.1.1; 2.5.1.2), whether a radiographer or an IT specialist, could also train on integrated and interoperable simulation training platforms of PACS/RIS/HIS/EPR (Huang 2019:326-329). However, the simulated knowledge gained should then be applied in real-life scenarios in the medical imaging workplace environment. Work-integrated learning in the form of workplace learning should, therefore, be part of the imaging informatics course, to apply the theoretical knowledge gained at the higher education institution with the skills acquired in the diagnostic medical imaging department. Imaging informatics certification programmes offered in the USA require students to complete a practical component (workplace learning) that needs to be completed within one year. Students on the course must apply the theoretical knowledge gained at the higher education institution in the medical imaging environment to acquire hands-on experience in a real-life scenario (Michener Institute of Education 2019:5).

2.6.1.4 *Andragogy learning theory*

Knowles's theory of andragogy was formulated, in an attempt to develop an approach for adult learning, in particular. Knowles underlined that adults are autonomous and anticipate commitment to choices they make. Four assumptions made from andragogy regarding the design of learning converted into a procedure model for coordinating and providing adult education are (1) adults should be informed about the necessity to learn something; (2)

adults should learn through experience; (3) the approach of adults towards learning is one of problem-solving; and (4) optimised learning for adults take place when the subject is of immediate importance (Qureshi 2004:8–9).

The following section will describe the different instructional strategies for BMI retrieved from the literature that can be used in imaging informatics teaching. The instructional strategies that will be covered are, for example, learning by doing, e-learning, conceptual learning, collaborative learning and problem-based learning.

2.6.2 Teaching strategies

The roles of lecturers who teach at the level of higher education are complicated and multi-layered (Fry *et al.* 2009:3). Academics are contractually obliged to pursue quality in numerous roles in their fields, and teaching knowledge is often seen as the most important role (Guerriero, 2017:29–30). Other activities they have to engage with is research, supervising students, administrative tasks, managing roles and engagement with service providers where their students do experiential learning. To be effective, teaching should be based on consideration of the different ways students learn (multi-intelligences) (Fry *et al.* 2009:3). Best practices in instructional strategies would be to cater for all students by using a variety of teaching methods (Biggs & Tang 2011:30-32).

Different teaching strategies (methods) could be used, including the lecture, which continues to be a strategy that is used extensively in the health sciences. However, the strategy of lectures relies heavily on the expertise of the lecturer and participation and commitment by students (Dent, Harden & Hunt 2017:44). When doing an online query for literature referring to imaging informatics, health informatics and medical informatics, Mantas (2016:96) found that the publications focused on teaching strategies, such as shorter periods of teaching and learning, discipline training programmes, distance and e-learning programmes, continuous learning, career training, and certificate programmes. Teaching and learning programmes in imaging informatics could also make use of these teaching strategies.

The majority of the imaging informatics or PACS administrator's courses delivered worldwide make use of blended teaching strategies. The Griffith Institute for Higher Education adopted blended learning and defines it as a principal means by which ICTs can be used to enhance the teaching and learning activities in a course (Bath & Bourke 2010:1).

Blended learning is used to teach and train a large, diverse group of learners in the classroom and the workplace. This teaching strategy has evolved from a blend of teaching in the classroom and e-learning courses, to a complex mix of integrated teaching strategies that incorporate various learning modalities (Woodall 2012:3), such as e-learning, machine learning and computer-assisted learning (Dias & Diniz 2012:439). E-learning used to be an educational tool that utilised computer-based methods. With the rapid development of online teaching, e-learning is delivered mainly over the internet (Epignosis 2014:5). Other blended teaching strategies include, but are not limited to, scheduled face-to-face classroom teaching, e-learning, machine learning and computer-assisted learning (Sanchez-Mendiola, Martınez-Franco, Rosales-Vega, Villamar-Chulin, Gatica-Lara, Garcıa-Duran *et al.* 2013:381).

Teaching strategies for experiential learning, which include simulation-assisted teaching and role play, and other strategies, like conceptual teaching, collaborative teaching, problem-based teaching, strategy-blended-learning teaching, which includes e-learning and computer-assisted learning and project-based teaching, will be discussed in the next section.

Experiential learning forms a comprehensive 'umbrella' for a broad variety of teaching strategies, which includes apprenticeship, cooperative learning and learning by doing. Learning by doing forms part of Pratt's five instructional methods and is frequently used in higher education to the development of motor skills in radiographers during work-based learning (Bates 2015:86).

Simulation training provides undergraduate and postgraduate students with learning opportunities involving repeated exposure to the skills they need to master, without causing harm to individuals or breaching confidentiality issues (Aggarwal, Mytton, Derbrew, Hananel, Heydenburg, Issenberg *et al.* 2010:157). In simulation for healthcare, training is seen as a team-based strategy to simulate medical service delivery; it includes all the different team players usually involved in the service delivery. It also can be used to monitor team behaviour and communication in healthcare (Beaubien & Baker 2004, cited in Riley, Lownik, Parrotta, Miller & Davis 2011:15). Computer-based simulation programs can also help to prepare students for real-life scenarios in the workplace. As mentioned by Huang (2019:326-329), students in imaging informatics teaching and learning programmes should be trained on integrated simulation learning platforms in imaging informatics of PACS/RIS/HIS/EHR, to experience practical issues in the medical imaging informatics environment.

Conceptual learning is a method of education centred on the comprehension of wider concepts (ideologies and thoughts), for application at a later stage on a diversity of examples. Conceptual teaching strategies promote students' critical thinking ability when they encounter new disciplines, and the situations they encounter within these disciplines (Knutas, Herala, Vanhala & Ikonen 2016:423). Students have to be able to relate facts and examples actively to concepts by completing questions, case studies or problem-solving activities. Effective practical thinking skills during lectures advanced from a lecturer-centred to a student-centred teaching environment, which some educators see as a top-down teaching strategy, or 'flipping the classroom'. In a top-down teaching style, students will be immersed into the overall representation of the module, and then increasingly learn the smaller sections making up the subject (Baron 2017:278–279; Maher, Latulipe, Lipford & Rorrer 2015:218-223). In a flipped classroom, students are required to engage with the theoretical concepts before lectures, and to apply the knowledge in the classroom to achieve interactive learning and reflective thinking (Knutas *et al.* 2016:423).

Undergraduate radiography students need to do compulsory weeks of workplace learning at an accredited healthcare institution during all four years of their undergraduate training programme at a higher education institution in South Africa (Nelson Mandela University 2019b:104; SAQA 2015:1, 3). Experiential learning at an accredited healthcare institution is also called situated learning. The situated learning theory was described by Lave and Wenger (1991), who suggest that "socially situated learning" occurs through people's engagement, through collective learning, in a community of practice (Bates 2019:192). Conceptual learning by radiography students is, therefore, considered to involve participating in the undertakings of communities of practice (Hall & Greeno 2008:212). Learning by radiography students in knowledgeable communities starts from the periphery in the early years and progresses to fuller involvement in the later years of study (Hall & Greeno 2008:213). Postgraduate radiographers are comprehensively involved in activities related to their studies in the diagnostic medical imaging department. However, their imaging informatics knowledge of computers and networks, gained from the higher education institution, is on a basic level (Department of Radiography 2019a), which places them at the periphery of knowledge of computer components and imaging networks. Similarly, for information technologists starting work in the diagnostic medical imaging department, learning occurs through collaborative learning and engagement with the knowledgeable community of practice. Initially, they will start at the periphery of clinical practice in the diagnostic medical imaging department and progress to fuller engagement (Hall & Greeno 2008:213).

Collaborative learning occurs when a group of learners engage in an interactive process of learning to solve problems, create a product or complete a task (Lee & Bonk 2014:11; Laal & Laal 2012:491). Collaborative learning, which can include, for example, case studies, fish-bowl debates, team-based learning and problem-solving in groups, permits students to investigate their interpersonal intelligence (Zhou & Brown 2015:83). To enable collaborative learning in imaging informatics, collaboration engagement platforms such as online chat rooms, discussions boards and web conferencing systems can be used. Collaboration learning in the imaging informatics course could prepare future imaging informatics professionals for collaboration in the workplace with other innovative professionals to ensure high interoperability and integration in the field (Nagy 2018:Online). During collaborative learning students work collectively to solve a problem, simultaneously gaining knowledge of the contents of the subject and experiences with the activity that other professionals, such as imaging informatics professionals, use in their work (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2018:94). The students are participating in actual problem-solving pursuit, one that echoes the way qualified imaging informatics professionals to engage in the same kind of problems (Gauvain 2018:54). Imaging informatics students can then develop their problem-solving strategies (Driska & Gould 2014:227). The lecturer uses a student-centred approach, and students must apply their problem-solving abilities during group work (Linaker 2015:10).

In project-based learning, students gain knowledge and skills by investigating and responding to a complex problem, on which they work together as a team over an extended period. The seven essentials for project-based learning are, a need to know; a driving question; student voice and choice; 21^{st}-century skills; inquiry and innovation, feedback and revision; and a publicly presented product (Larmer & Mergendoller 2010:34). The lecturer uses project-based learning aspects during lectures, which will allow students to develop their planning, creating and processing (reflection) skills, and also promotes integrating activities that teach to the different intelligences (Zhou & Brown 2015:83). Complex problem scenarios can occur in the imaging informatics environment, such as the rising drive in healthcare informatics to integrate and interoperate systems from different departments and institutions to enhance service delivery to patients (Peck 2018:70). Medical imaging informatics and ICT professionals work together collaboratively on the DICOM standards to solve the integration problems in the healthcare enterprise (Pearson

2017:Online; Nagy 2018:Online).

Computer-assisted learning and greater availability of the internet plays a significant role in radiography education (Howlett, Vincent, Watson, Owens, Webb, Gainsborough *et al.* 2011:234). In the undergraduate education programme for diagnostic radiography, teaching trends are moving towards blended learning programmes that accommodate all the different learning styles of students (inclusive education). The majority of respondents (91%) in a study on postgraduate academic education for radiographers in specialised fields in diagnostic radiography, indicated that they preferred blended learning programmes and part-time study as the preferred method of study (Du Plessis, Friederich-Nel & Van Tonder 2012:115).

Combining blended learning with conventional face-to-face contact in the lecture hall reduces the cost of higher education and makes life-long learning more accessible. With online teaching and learning platforms, students can study anywhere and at any time. Also, blended learning provides novelty, flexibility, interest and collaboration in the teaching-learning procedure (Soomro, Soomro, Bhatti & Imtiaz 2018:259). Postgraduate radiographers and imaging informatics specialists who have already entered the workforce could prefer blended learning strategies for imaging informatics courses in South Africa, due to the flexibility of the teaching and learning environment – as found by the study of radiographers by Du Plessis *et al.* (2012:115). Therefore, it is important to include different teaching strategies to enable professionals in the workforce to enhance their careers through postgraduate studies.

2.6.2.1 ***Assessment***

Evaluation is a comprehensive phrase that describes the process of establishing assessment, importance and attribute. In higher education programmes, summative assessment is conducted to determine student outcome attainment (Billings & Halsted 2016:172). Assessments are used for student feedback on their progress, to enhance education, and to guide students to become skilled and knowledgeable individuals (Billings & Halsted 2016:385). The goal of summative assessment is to measure student learning after the completion of a study unit by contrasting it against established standards (Macartney-Clark 2018:2). These assessments are usually done to advance a student to a next study unit or year. Summative assessments can be done in a written or online format where questions can take on forms, such as multiple-choice single answer, multiple-choice multiple answers, one-word answers, true and false, drag-and-drop or essay type questions. Summative assessments during workplace learning could include a portfolio of evidence for tasks that need to be observed or performed.

Formative assessment differs from summative assessment in that the former assists lecturers to evaluate students' progress towards reaching the outcomes regularly (Billings & Halsted 2016:172). It is employed as a "problem-solving learning tool" to determine the weaknesses and strengths of a student (Gaberson, Oermann & Shellenbarger 2015:323). The lecturer can lead the formative assessment, or it can be peer or self-regulated. Formative assessment is heavily reliant on feedback (Macartney-Clark 2018:2). Formative assessment can take on forms, such as worksheets, presentations, unprepared mini-tests, and online quizzes.

2.6.3 Teaching models

Teaching models are conceptualised ways of organising a process and intend to generalise a lecturer's strategy to resolve similar difficulties in other fields. Models are descriptive in character, and they are not testable. Model types for research are developed from a researcher's higher cognitive processes regarding research dependents relating to the research questions (Eggen & Kauchak 2012:7-8). Models provide practical direction for comprehending theories; theories are commonly descriptive of structures. However, models are only descriptive in a specific context. Models of teaching have three characteristics: goals that promote students' critical-thinking skills and a profound understanding of precise contents; phases that are planned to aid students to reach specific learning outcomes; and foundations, which are supported by principles and research on education and motivation (Joyce *et al.* 2015:5; Eggen & Kauchak 2012:5-6).

Although several previous eras generated many methods for improving learning circumstances, the most outstanding teaching models from former times are still thriving today. Various education models attract students into specific kinds of content (knowledge, skills, values) and amplify their capability to develop in individual, social, and academic fields. Common attributes across teaching models are assisting students to become responsible learners, supporting them in their attempts; and helping them gain areas of needed knowledge, competencies, and cognisance (Joyce *et al.* 2015:5–6). Models of teaching can be categorised into four families, where the participants share orientation regarding people and how they learn. These families are information-processing, social, personal, and behavioural systems (Joyce *et al.* 2015:9).

Learner focused models is a type of conceptual models (instructional design models) where the instructions accentuate the learner (Reigeluth 1999:5). Two different categories of learner-focused models exist, namely, Knowles' (1978) developmental model based on adult learning, and Snow's (1977) model based on the interactions occurring between specific learner attributes and a bestowed instructional approach (Qureshi 2004:8). Knowles' (1913–1997) adult (andragogy) learning theory for constructing a teaching model for imaging informatics was considered suitable for the teaching model's development. Knowles constructed five (1980; 1984) assumptions regarding the attributes of adult learners that differ from assumptions concerning child learners (Kurt 2020:Online). These assumptions are self-concept, adult learning experience, readiness to learn, orientation to learning, and motivation to learn. The five assumptions are outlined as follows: 1) *Self-conception*, as a person matures, he/she moves from a dependent nature to one of autonomy; 2) *Adult learner experience*, as a person develops, it leads to a build-up in the pool of knowledge that develops into a cumulative resource for learning; 3) *Readiness to learn*, as a person matures, the person becomes progressively more concerned with the developmental responsibilities of his/her societal roles; 4) *Orientation to learning,* with growth, causes a person's time stance to change from a deferred application of knowledge to instantaneous application. The result is an orientation towards learning that realigns to problem centeredness; 5) *Motivation to learn* changes with maturation to an internal one (Knowles 1984:12).

Reigeluth's elaboration model of instruction was used in the construction process of the teaching model (Reigeluth & Darwazeh 1982:22). Reigeluth's elaboration theory of instruction (Reigeluth *et al.* 1980:195), is used for sequencing, synthesising, and summarising the subject matter and standards for a teaching model in a structured and systematic way. By using the instructions from Reigeluths theory, sufficient sequencing of the contents can be done to enhance students' understanding through the scaffolding of the subject matter and assist them in achieving the learning outcomes. Researchers should look for similarities and differences between the summarised findings. The synthesis of the subject matter should then enable researchers to make inclusive deductions. During the development of a teaching model, summarising the contents and standards, in a systematic and structured way, will be underpinned by Reigeluth's elaboration theory of instruction, during the development of a teaching model (Chapter 2, cf. 2.6.3). The theory is a cognitive prescriptive theory, grounded on the spiralling curriculum of Bruner, the web teaching of

Norman, the cumulative learning theory of Gagné, and the subsumptive sequencing of Ausubel. The main concepts in each of these learning theories were incorporated into the teaching model and could be used in the proposed curriculum.

Bruner's spiral curriculum is defined by repeated visits to known topics. Repeated engagement with known subject matter enables students to strengthen former learning in their recollection, and accumulate new knowledge on it over time. The three fundamental principles that outline the spiral learning approach are that it is (1) *Cyclical*: Students need to revisit the same subject matter numerous times during their education career; (2) *Increasing in depth*: With every review of the same subject matter, a deeper level of learning should take place, and more complexity should be explored; (3) Dependent on *prior knowledge*: Prior knowledge should be developed when students return to the same subject matter, to allow them to build on their foundational learning (Drew 2020:Online).

Norman defined seven principles of interaction that could make web teaching successful. These principles are(1) *Visibility,* of which enhancement of operations will improve a user's ability to operate the programme; (2) *Feedback* refers to the communication to the student regarding actions done, and accomplishments, which will allow the person to persist with the learning; (3) *Constraints* refer to decision-making on ways of limiting specific user communication that can occur at any one time; (4) *Mapping* refers to the association amongst controls and their outcomes in the world, like the interaction between the up and down arrows and the cursor movements on the computer keyboard; (5) *Consistency* relates to creating interfaces with similar operations and using similar factors for attaining similar tasks, like always using the left mouse button for specific tasks; (6) *Affordance* is a term utilised to point out the quality of an article that gives individuals the information on how to use it, for example, a mouse button (Preece, Rogers & Sharp 2002:21; Neal 2002:Online)

According to *Gagné's cumulative learning theory* (Qureshi 2004:7)*,* there exist various kinds of learning that exist, and distinctive instructional methods are necessary to maximise each student's objectives to succeed. The focus of Gagné theory is on the memorising and refining of academic skills. Gagné's cumulative learning theory suggests that there are "nine essential steps of instruction", (1) *Gain attention* – reception of instruction should be ensured by presenting a stimulus; (2) *State the learning objective* - what the student will gain from the teaching; (3) *Stimulate recall of prior learning* – ask students to recollect current applicable knowledge; (4) *Present the stimulus* by displaying the content; (5) *Supply learning supervision*; (6) *Elicit performance* – the response by students demonstrating understanding; (7) *Provide feedback* – present the student with enlightening feedback regarding performance; (8) *Assess performance* – to reinforce knowledge, further performance and feedback is needed; and (9) Augment remembering and assigning to other circumstances (Khadjooi Rostami & Ishaq 2011:117; Qureshi 2004:8).

Ausubel's *subsumptive sequencing* is an advanced organising information-processing model that improves the student's capability to engage with knowledge and organise it during the learning process, through lecture presentation and reading interpretation. Ausubel also called the process intellectual scaffolding, which refers to structuring the concepts and particulars students come across during a lecture (Joyce *et al.* 2015:198; Weibell 2011:122).

Reigeluth's theory suggests seven main strategy elements: an elaborative sequence, followed by learning requirement sequences, a summary phase, synthesis, comparisons, reasoning strategies, and student control (Qureshi 2004:14).

Instructional design results are 'blueprints' of the instruction that will be created. Having a collection of models can be beneficial to the instructional designer. Each of the models will be employed as a 'standard blueprint' to encounter different learning methods or teaching contents (Merriënboer 2017:182; Reigeluth & Darwazeh 1982:22). According to Reigeluth and Stein (1983: 370), the first step in instructional design is to select the organisation method, which, in this study, is conceptual. In elaboration theory instructional design, the instructions should be organised in increasing difficulty (Reigeluth & Darwazeh 1982:22).

2.6.3.1 *Legislation underpinning Higher Education*

Awareness of and knowledge regarding the Higher Education Qualifications Sub-Framework (HEQSF) (revised 2013) as approved by the then Minister of Higher Education and Training (DHET) (now known as the Department of Education, Science and Information) with regard to the National Qualifications Act, 2008 (Act No. 67 of 2008) and as meditated by the Higher Education Act, 101 of 1997, which regulates and provide a more united higher education system in South Africa, is necessary when developing a teaching model.

2.6.3.2 *Regulations underpinning Higher Education*

Student qualifications from all higher education institutions should now be compliant and aligned with the HEQSF, which provide for "a single qualification framework for higher education to facilitate the development of a single national co-ordinated higher education system" (RSA DHET 2013:9). The HEQSF is an intact portion of the National Qualifications Framework (NQF) that involves the integrity of complete qualifications, comprehended to include at least 120 credits. SAQA is the body responsible for policy and standards development for registration of qualifications on the NQF (RSA DoE 2009:7). Level descriptors are declarations delineating learning successes at a specific level of the NQF and specify the exit-level outcomes of the teaching and learning programmes on the individual levels of the NQF or HEQSF. NQF level descriptors for *postgraduate qualifications* at higher education institutions range from Exit Level 7 to 10.

2.6.4 CURRICULUM MODELS

A curriculum development model is an instrument that facilitates individuals in education who wish to compile and develop curriculum guidelines. Curriculum guidelines provide motives for options made in education. A model for curriculum development is necessary for formulating a conceptual framework for planning a specific appraisal, depending on the particular purpose of the teaching, learning and assessment processes. Several curriculum development models exist, for instance, Stake's, Roger's, Scriven's and Kirkpatrick's models. Tyler's objective-centred model could be used to evaluate curriculum programme development from the teaching model in imaging informatics created by this study (Glatthorn, Boschee, Whitehead & Boschee 2015:379).

Tyler's model is known for the detailed attention rendered in the planning phases. It is a deductive process, as it progresses from the general (analysing the requirements of stakeholders first) to specifics (stipulating instructional objectives). Tyler placed the merit on the association the objectives have with the instruction of the knowledge and the evaluation (Glatthorn *et al.* 2015:360). Tyler not only targeted the students' feelings and views, but also their intelligence. Tyler's reasoning includes a four-step approach, which comprises a statement of the objectives, the selection of learning competencies, structuring learning experiences, and assessing the curriculum, which is an explanation of these steps. A developer could make use of the four-step approach to construct a future curriculum for imaging informatics.

2.6.4.1 *Image informatics curriculums*

Patel *et al*. (2009:176) state that BMI is becoming part of biomedical curricula and will, in time, fulfil a more significant role in health professional and biomedical education. Curriculum development in BMI could also involve curriculum adjustments in medical and nursing curricula, including BMI, imaging informatics or medical imaging informatics. Biomedical informatics competencies are considered to be essential educational requirements for the healthcare professional (Sanchez-Mendiola *et al.* 2013:381).

Aiyer *et al.* conducted a study (2009, cited in Burnette, De Groote & Dorsch 2012:1), to establish the status of medical informatics training in medical education. Just more than half the medical education institutions involved in the study reported that they had implemented some form of medical informatics training in their curricula. According to the study, demands on faculty time and rising costs were reported as major barriers to complying with the curricular add-ons.

After PACS implementation in the USA, the Society for Computer Applications in Radiology (SCAR) realised that IT-trained personnel could handle advanced technological features, but greater advantages would come from 'bridging' individuals who had received training in radiology and IT. SCAR's education committee identified the need for a standardised curriculum and started developing a curriculum that outlined radiology informatics (imaging informatics). The programme was initially developed to train radiology residents in radiology informatics (Branstetter *et al.* 2004:245). The SCAR document was organised into four subject areas, as shown in Table 2.2. The first part was written with IT terminology applicable to radiology. The second part refers to clinical informatics and is of great interest to the radiologist who lacks proper informatics training. The third part addresses PACS administration, which is usually done by a dedicated PACS administrator, though radiologist informatics professionals also need to understand these skills, as it will empower them with critical decision-making skills in the digital radiology department.

Table 2.2: Outline of SCAR radiology informatics curriculum (Branstetter *et al.* 2004:246)

Outline of SCAR Radiology Informatics Curriculum	
1. Information Technology	• Servers and databases • Networks • Mission-critical infrastructure • Storage and archiving • Security

Outline of SCAR Radiology Informatics Curriculum	
2. Clinical Informatics	• Information systems • Workflow and integrated healthcare enterprise • PACS • Image processing • Image display • Reporting systems • Communication modes
3. PACS Administration	• Systems management and integration • Technology assessment • Business models and economics • User management and training • Productivity and efficiency • Facility design and ergonomics • Quality control and data integrity
4. Academics	• Research and statistics • Education • Management and leadership

Radiologists, as imaging informatics professionals, need to liaise with PACS administrators and vendors, as well as other radiologists. Academic research issues, the fourth subject area, was specifically added for radiologists so that they could assist other medical specialists in research (finding images). Part of the curriculum applied to IT specialists' daily responsibilities. Radiological technologists (radiographers) could learn more about their role-play changes and the workflow changes brought about by the implementation and integration of PACS and RIS and the interoperability with modalities in the new digital environment in the radiology department. PACS administrators could gain an understanding of all the imaging informatics concepts and what their effects are in a radiology department. PACS administrators gain an understanding of the complexity of the systems (the four components of PACS and their mutual integration) and the impact of the technology on the practice of radiology (how the technology changes the workflow). Therefore, radiographers (radiological technologists), PACS administrators and IT specialists also benefited from the teaching (Branstetter *et al.* 2004:247).

In 2016, the SCAR's imaging informatics curriculum for radiology fellowship graduates, developed in 2001, was reported as needing additional formalisation and standardisation. Vey, Cook, Nagy, Bruce, Filice, Wang *et al.* (2019:91) surveyed existing fellowship directors across the USA to assess the current curriculum. The topic covered in the curriculum at that stage included business and management, technical informatics, and in some instances, safety and quality. This need initiated a National Imaging Informatics Course – Radiology (NIIC-RAD), offered in the USA (SIIM 2020:Online), developed through a partnership between the RSNA and SIIM. The course designed for fourth-year residents in radiology is open to all healthcare professionals. The curriculum for this course involves the following sections: introduction to imaging informatics; standards; computers and networking; PACS and archiving; the life cycle of radiology exam; radiology as seen from outside the department; privacy and security; data and data plumbing; algorithms for image and non-image analytics; the business of informatics and beyond imaging informatics. Learning strategies incorporated are live lectures, flipped classrooms, recorded classes, recommended readings and pre-and post-tests (SIIM 2020:Online).

2.7 CONCLUSION

Chapter 2 presented a literature review and a conceptual framework for the development of an instructional model for the teaching and learning of imaging informatics – a platform in BMI in a future integrated NHI system in South Africa. The framework investigated NHSs globally and in South Africa; integrating and interoperability standards in health data; BMI platforms with the emphasis on imaging informatics; learning theories and teaching strategies that could be applied in imaging informatics; teaching model development; teaching and learning programmes in other countries and South Africa, and a short overview of curriculum development.

In Chapter 3, ***Research design and methodology***, the selected research design and the applicable methods used during the study will be discussed.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

As mentioned in Chapter 1 (cf. 1.6), the study aimed to develop a model for the teaching and learning of imaging informatics in a future integrated NHI system in South Africa. It is anticipated that this model would address current shortcomings in higher education institutions' teaching and learning programmes for PACS administrators and imaging informatics professionals in the digital imaging environment. Chapter 2 provided the background to imaging informatics concepts, teaching and learning theories, and strategies that could be applied in teaching and learning programmes in imaging informatics.

Chapter 3 will provide a theoretical foundation for the research methods and design that was used during this research study. Thereafter, a detailed explanation of the research process and instruments used for data collection will follow. The research instrument included self-administered questionnaires for three distinct target groups, as well as a Delphi study with a panel (expert group) of imaging informatics professionals. The statistical test used to analyse the data will also be explained. The chapter will conclude with a discussion on the ethical considerations and the notions of validity and reliability that were relevant to this study.

Figure 3.1 presents a schematic representation of the conceptualisation of terms in this chapter. The concepts that will be addressed include the research assumptions (cf. 3.2; also see 1.10), theoretical perspectives, methodology, and research methods (Scotland 2012:9).

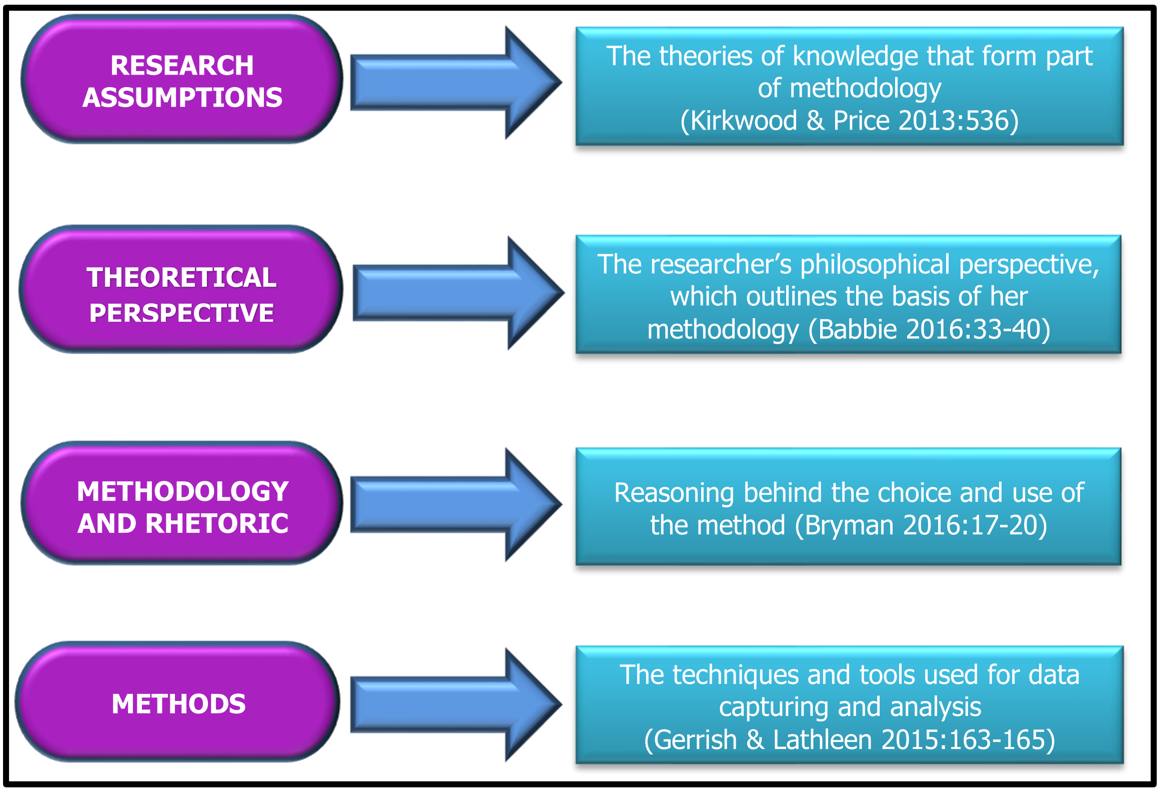


Figure 3.1: Schematic representation of the conceptualisation of the study

3.2 PHILOSOPHICAL ASSUMPTIONS

Research assumptions or paradigm in Figure 3.1 refer to a complete collection of the beliefs, values and techniques that are shared by representatives of a specific population, in this case, imaging informatics professionals. It is also called a theoretical approach or a 'lens', which the researcher uses to view and gather knowledge to address her research topic (Kuhn 1970:175). The particular theoretical approach that is used includes its views on ontology and epistemology (Matthew & Ross 2010:34). The researcher's philosophical stance or worldview (Creswell 2014, 5; Lincoln & Guba 1985:7) influenced the way she scrutinised and interpreted knowledge (Denscombe 2010:130-132).

Epistemological assumptions signify the researcher's view of how to obtain knowledge and involve the question of what is considered appropriate learning, in a specific subject (Bryman 2016:24; Mack 2010:5; Neuman 2014:95-97). The researcher's relationship with what is observed is objective. In this study, epistemological assumptions were addressed by informed decisions made concerning the structured questionnaires and Delphi study.

Ontological assumptions involve the researcher's view of actuality and existence. Ontology is usually the starting position that is likely to advance the researcher to her theoretical framework (Bryman 2016:28; Mack 2010:5). The researcher's ontological assumption is embedded in a pragmatic approach, according to which she believes that efficient resolutions in education, which usually involve students and teachers, should also develop the changing perspective of a digital age. However, the resolutions should also engage with evolving perceptions of the human brain and people's conduct.

Although the researcher believes that learning by doing is significant, she also realises that learning solely by doing is not conducive to building comprehensive knowledge on imaging informatics. The IT specialist and radiographer imaging informatics professional (PACS administrator) originate from two different undergraduate backgrounds. They need some formal academic education in each other's fields to become valued members of the imaging informatics professionals team (PACS administration). The model, as envisaged by the researcher and informed by the research, may assist the imaging informatics professionals team to overcome their knowledge shortcomings.

Methodology and rhetoric (Aliyu, Singhry, Adamu *et al.* 2015:21) in Figure 3.1 represents the third assumption of the research study, or construct in the paradigm. Methodological assumptions concentrate on the breakdown of the methods that are used to acquire data and points to the epistemological assumptions inferred from specific research methods, which embrace our entire approach to the research. Rhetoric relates to the mutual comprehension of research language, the use of specific definitions, and formal language. Our approaches include our suppositions about the 'nature of knowledge' and the methods applied to obtain and analyse data statistically (Assalahi 2015:312).

Axiology assumptions relate to beliefs about the function of ethics (values and morals) in research or, more sufficiently, what we believe to be true or what the researcher values in her research (Kaushik & Walsh 2019:1; Dudovskiy 2018:35). According to Dudovskiy (2018:35), axiology applies primarily to the intentions of the research. The researcher believes that her research should be relevant, and the axiology of the research must be unbiased.

3.3 THEORETICAL PERSPECTIVES ON THE RESEARCH METHODOLOGY

Perspectives are our viewpoints or the way we regard something. Theoretical perspectives in Figure 3.1 refer to our philosophical stance, which informs the methodology, provides a background to the process, and supports the reasoning and beliefs (MacIntyre 2006:11). During the completion of this research study, the researcher was guided by the pragmatist paradigm (philosophical worldview) (cf. 1.10), which emphasised an evolving educational system that was evolving, to keep up with a rapidly changing digital revolution. Pragmatists are usually individualists and experimentalists, who assign greater value to change than to ideas. Pragmatists believe that reality is continually transformed, discussed, and interpreted, considering its efficiency in new inconsistent settings; therefore, the most suitable method to use is the problem-solving one; discovering is the means, transformation is the aim (Makombe 2017:3367–3368; Patel 2015:3). The pragmatism paradigm was deemed appropriate for this study, due to the philosophical assumptions (cf. 3.2) of the researcher on the education process (Educational System 2019:2) and the qualitative data collected through the quantitative methods used by this study. The quantitative approach highlights generalisable findings and statistical analysis of the data (Mack 2010:5-6).

The choices in research are often influenced by three main components: worldviews (paradigm), methodology and methods (Chilisa & Kawulich 2012:52). The paradigm, consequently, directs us to ask specific questions and make use of suitable approaches towards systematic investigation, which is recognised as a methodology. The distinction between research design or the strategies or approaches that the researcher pursues to investigate the research problem is represented by quantitative and qualitative methods (Makombe 2017:3364). The approach refers to the procedure that a researcher will follow to collect the data. Specific paradigms are sometimes linked to particular methods – the positivist paradigm is typically associated with quantitative research, interpretivism with qualitative, and pragmatism with mixed methods approaches (Botma *et al.* 2010:42). This is not the rule; in this study, the researcher pursued a pragmatism paradigm using a method in which quantitative and qualitative data were collected.

3.3.1 Theory building

Research is an organised, systematic process, that is used to find answers to relevant questions, to solve problems. In research, an organised, planned structure can enable a researcher to conclude. Without questions and the acknowledgement of gaps in the body of knowledge, research is not possible (Levin 2013:5).

According to Levin (2013:2), "to know is not enough": Research knowledge should be used too. Philosophers tend to divide knowledge into three groups: knowledge of the individual

– personal knowledge; knowledge of procedures – procedural knowledge; and knowledge of facts – propositional knowledge. The theory of knowledge (epistemology) is primarily involved with propositional knowledge.

Bhattacherjee (2012:17) states that a theory is a group of interconnected constructs that are developed to clarify and envisage a particular phenomenon or conduct within specific threshold conditions and suppositions. Lynham (2002:223) describes good theory building as a continuous cycle by which well-structured narratives, clarifications, and understandings of "observed or experienced phenomena are generated, verified, and refined" (Lynham 2000:161). Rigour and relevance, also called validity and utility, are two essential qualities that should be reflected by good theory building (Siegler, Fazio & Pyke 2011:190; Van de Ven 1989:486). The result of good theory building should be two types of knowledge, namely, outcome and process knowledge. Outcome knowledge is mostly explanatory and predictive, and process knowledge is more related to increasing understanding of operations and their meaning (Dubin 1976:309). The two types of knowledge can be seen as two parts (cycles) in the theory-building process, where the first part is theoretical and the second part of an operational nature. The theoretical part includes the identification, interaction and relations of the theoretical concepts, which are representations of the variables whose concerns involve the core of the theory —completing the first part of the process involved the theoretical framework. The theoretical framework of this study relies on the literature discussed in Chapter 2. The second part (operational) includes empirical research, the results and an explanation of the data.

3.3.2 The strategy of inquiry and research approach

In contrast to inductive reasoning, which progresses from fragmented specifics to a connective view of circumstances, deductive reasoning starts with a general statement and works towards specifics (Gray 2018:18). The researcher used deductive reasoning, which denotes the most familiar view of the kind of correlation that exists between social research and the theory (Bryman 2016:21). The researcher drew from the known (general) about radiography, imaging informatics, and BMI system operational concepts, teaching and learning programmes and academic concepts. She then moved to more specific detail regarding imaging informatics teaching and learning, and she developed conceptual and theoretical structures that were tested by empirical observation (Gray 2018:19). Deductive reasoning is also sometimes called, the 'top-down' approach (Bryman 2016:21).

The strategies of inquiry comprised contextual, descriptive, exploratory and non-experimental designs.

3.3.3 The research design of this study

Selection of research design, as part of the methodology or rhetoric, is a critical factor in the research process. Research design is referred to as a blueprint for experiential research that is expected to resolve the research questions or to lead to gaining new knowledge (Bryman 2016: 400). To achieve the goal of the study the design was underpinned by the use of questionnaires and a Lockean inquiry system through a Delphi study. The research design of this study was mainly quantitative, while the Delphi study had qualitative elements. In the structured questionnaire survey, open-ended qualitative questions were used to enable respondents to make suggestions, which allowed the researcher to add possible themes, sub-themes and categories to the first-round questionnaire in the Delphi study.

Quantitative research strategies of inquiry are usually formal and objective. It involves a rigorous, systematic collection of data, which is used to describe new concepts or situations. There are several different strategies in quantitative research, which can be classified as experimental or non-experimental, namely, descriptive, exploratory, sequential, correlation, and quasi-experimental. The current knowledge available on a research problem will influence the type of quantitative research that is conducted (Burns *et al.* 2011:34; Brink *et al.* 2013:103).

In this research study, the quantitative design was applicable due to the cross-sectional survey design that was implemented, by which the researcher collected data through different structured questionnaires and a Delphi survey from four distinct respondent groups:

- Registered, qualified radiographers;
- Lecturers in the physics of digital diagnostic imaging and PACS;
- Biomedical informatics or e-Health informatics specialists, imaging informatics professional (PACS administrators) and system managers working in biomedical informatics or the imaging informatics environment in digital imaging departments of private or public hospitals, vendor IT imaging informatics professionals and application specialists; and

- An expert panel in imaging and health informatics.

In survey research, the method comprises using standardised questionnaires. The data collection is done systematically and involves people's preferences, beliefs and activities regarding a certain phenomenon (Bhattacherjee 2012:74). Collecting quantitative data involves moderately large samples of the population under investigation (Bhattacherjee 2012:74; De Leeuw, Hox & Dillman 2008:2). According to Dillman, Smyth and Christian (2014:3), the four cornerstones of survey research, namely, sampling, coverage, measurement and nonresponse error, can cause surveys to fail to achieve their objectives.

To minimise *sampling error*, sample sizes should be increased, appropriate sampling methods should be used, and statistics can be used to estimate sampling errors (Pflughoeft 2019:2). In this study, the population size for each of the four distinct respondent groups for the three structured questionnaires and Delphi survey were optimised and purposively selected to sufficiently represent the characteristics of the rest of the population of radiographers, lecturers, IT specialists, and imaging informatics professionals, in order to eliminate sampling errors. *Coverage error* can occur when an incomplete or inaccurate list of the population is used for sampling (Pflughoeft 2019:1). The lists for the different respondent populations were updated versions provided by professional bodies. The researcher sorted the list before purposive sampling commenced to ensure equal chances for inclusion in the research samples for all population members. *Measurement errors* can occur when respondents are unwilling or unable to convey their authentic answers in a survey (Pflughoeft 2019:3–4). The researcher avoided questions that prohibited respondents from expressing their truthful views; avoided asking unclear questions and tried to eliminate question order effects. *Nonresponse errors* can occur when the non-respondents from the sample group differ systematically from the responsive group (Pflughoeft 2019:3–4). Nonresponse errors in this research study were addressed by the researcher's thorough knowledge of the different target populations and acknowledgement of differences within the individual populations that could affect different subsets' willingness or ability to respond.

Collecting data through self-administered questionnaires was done over a period of six months. The data collection process included the initial sending of the questionnaire through the online QuestionPro® Survey program, sending reminders after six weeks and three months, and, finally, download the data for statistical analysis.

The research designs that can be used in qualitative research are based on phenomenology, ground theory and ethnography, and a historical approach. Focus groups, field observation, in-depth interviews or documents and analysis can be used. Furthermore, supplementary techniques, such as nominal groups and interviews (open-ended questions), informal conversations, the interview guide approach, or standardised open interviews, can be used (Burns *et al.* 2011:76; Polit & Beck 2018:203-208). Open-ended questions in the structured questionnaire survey and the Delphi study added qualitative elements to the research methods used in this study.

Contextual research is involved in detecting what exists in the social world, and the method through which it exhibits itself (Isaksen, Murdock, Firestein & Treffinger 1993:255; Ritchie, Lewis, McNaughton Nicholls & Ormston 2014:31). In this study, data was collected from participants whose work involved (or who had worked in the past), servicing or teaching in a medical imaging informatics environment.

Descriptive research examines a situation exactly as it is and does not intend to change or modify situations (Babbie 2016:135). A series of questions posed by the researcher to respondents can be summarised and processed statistically to draw inferences from the population under investigation (Babbie 2016:136; Bless *et al.* 2013:61; Polit & Beck 2018:11-12). In this research study, group-applicable questionnaires were sent to the respondents in the different target groups. The responses were used to compile the descriptions (themes, sub-themes and categories) for the first-round Delphi study questionnaire, which was sent to an imaging informatics expert group regarded as knowledgeable in the field of imaging informatics.

The main aim of explanatory research is to provide insight into and understanding of the problem that the researcher has identified and to discover concepts and opinions (Polit & Beck 2018:12). In this research study, a Delphi study involving an expert panel of imaging informatics professionals was used to explore the themes, subthemes and categories that should be included in a model for teaching imaging informatics.

This research study used a non-experimental approach, because, in non-experimental research, independent variables are neither controlled nor manipulated. Non-experimental research is used mainly to describe phenomena and to explore and explain the relationships between variables. Although the absence of experimental control affects the researcher's ability to determine cause and effect, non-experimental research is useful for generating knowledge (Kumar 2019:236; LoBiondo-Wood & Haber 2018:181-183).

3.4 DESCRIPTION OF THE RESEARCH METHODS

Research methods define the data collection process the researcher used for collecting data in order to answer the research questions; also, it provides details about the statistical procedures in quantitative research (Kumar 2019:400). A detailed presentation of the methods used in a research project and the way it was implemented will enable other researchers to verify the results if they repeat the study.

Three research methods were used to create the foundation of the study. The research methods involved a literature review for the empirical research phase, three structured questionnaires that were sent to three distinct samples of respondents, and a Delphi study, which was done with a group of imaging informatics experts.

The description of the methods includes an explanation of the population, sampling method and sample size. Data collection involved the research instruments, research processes and pilot studies conducted, whereas the analysis of the data involved statistical processing. The research process had to comply with ethical considerations as set out in the Belmont Report. The data collected, and the research instruments were tested for reliability and validity.

Figure 3.2 provides a schematic outline of the sequence of the research methods used in this study.

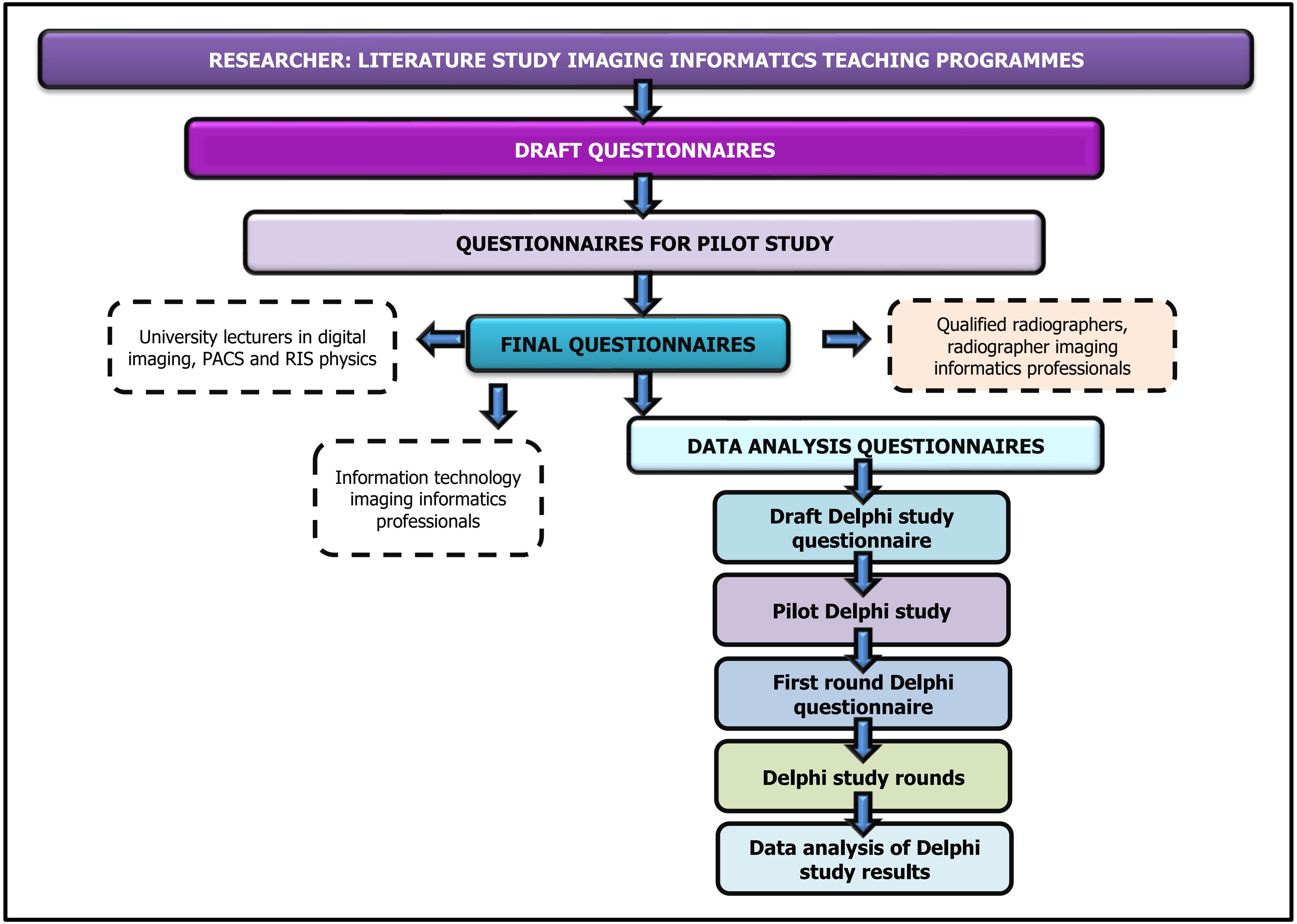


Figure 3.2: Schematic outline of the sequence of the research methods

3.4.1 Literature review

The purpose of a literature review is to do a critical appraisal of the improvement of knowledge in the research domain to identify the gaps in the literature that led to the study. Additionally, it involves the interpretation of literature related to a particular topic or problem, to place the problem in the context of related research and theory (Walliman 2020:220; Aveyard 2014:2). A literature review was done to contextualise the problem that had been identified in relation to associated research and theory. Conceptualising a study occurs when a researcher integrates a study into a larger framework of research done in a certain field of study (Mouton 2014:119). The literature review also ensures that a researcher is adequately informed regarding the discipline of study.

Researchers can make use of several methods to gain insight into their research topic. One way is to use the title of the research to map or guide the researcher into the domain of the study. A literature review serves to establish whether a research topic is viable and assists the researcher to narrow the scope in the specific area of research (Walliman 2020:220; Mouton 2014:120). The researcher stated the research topic as a question, detected the main concepts in the question, and tested the concepts in the topic by using them as search terms in suitable background sources or journal databases. A review of education websites, articles and books were done during the literature review, to establish the status, trends, contents or facilitation methods of formal academic imaging informatics teaching and learning programmes in other countries and South Africa. These countries are on different continents, including the USA, UK, Europe, Asia and Australasia. The contents of imaging informatics courses at different higher education institutions were investigated. In addition, the literature review served to compare the current situation in South Africa with that in the rest of the world. To do this, teaching and learning programmes in radiography and information technology at higher education institutions in South Africa were reviewed, to enable the researcher to determine the teaching and learning backgrounds of the respondents of the research study – this information guided the construction of the first questionnaire.

As mentioned in Chapter 2 (cf. 2.1), various databases on the Nelson Mandela University and University of the Free State's library platform were utilised to search for articles on the topic of this research study. Books and articles on education with titles related to the following topics were consulted: learning theories and teaching strategies and curriculum design, operational components and teaching and learning programmes of BMI platforms, imaging informatics, bioinformatics, clinical informatics (eHealth on a personal level) and PHI (eHealth on a population level). Phrases used during the searches included imaging informatics; biomedical or medical informatics teaching and learning or education; learning theories and teaching strategies in higher education; interoperability and integration in BMI platforms and imaging informatics; national health system or national health insurance systems internationally or in South Africa; health data standards in imaging informatics, integrating the health enterprise, imaging informatics hardware, and software operational elements for effective digital imaging services. Although more recent articles in peer-reviewed journals, nationally and internationally, were preferred, recent book publications on the research topic and problem were also consulted. The information from the literature review, radiography and IT teaching and learning programmes at higher education institutions in South Africa enabled the researcher to construct and sequence the questions of the three structured questionnaires in a clear way to enable respondents to follow and understand the questions easily.

3.4.2 Development of structured questionnaires

A questionnaire is an important data collection instrument in quantitative and qualitative research. Qualitative research methodologies make use of unstructured or semi-structured questionnaires, whereas quantitative research mostly uses structured questionnaires with closed-ended questions. The advantages of using structured questionnaires include the low cost in time and money; quick data inflow; the ability to complete questionnaires at convenient times and places; that anonymity can be insured; and that data coding is quick (Gray 2018:342-343; WHO 2000). In this research study, the researcher made use of three structured questionnaires and a three-round Delphi study.

After completing the literature review on imaging informatics, three draft questionnaires were created for the first round of data collection. The self-administered, structured questionnaire survey consisted of open (qualitative) and closed-ended (quantitative) questions. According to Artino, La Rochelle, Dezee, and Gehlbach (2014:463), a seven-step design process should be followed to develop a structured questionnaire in the medical field. The steps used by this study included a literature review and synthesis of previous literature studies. However, in this study, a six-step literature review model was followed, namely: 1) select a topic; 2) develop tools for argumentation; 3) search the literature; 4) survey the literature; 5. critique the literature; and write the review, as described by Machi and McEvoy (2016:25–26). The questions of the questionnaires were developed according to the information reviewed and then tested through pilot studies to ensure validity and reliability and to determine the time needed for completion. The data were collected by means of a web-based electronic questionnaire program. The department of Biostatistics at the University of the Free State and a biostatistician from Nelson Mandela University assisted with quantitative data analysis.

3.4.2.1 *Three structured questionnaires*

The first structured questionnaire, entitled *Assessment of the teaching and learning of radiographers and PACS administrators in imaging informatics*, was divided into four categories, which were (A) Biographical information and education, (B) Formal academic training (undergraduate and postgraduate) in digital imaging, PACS and RIS (imaging informatics) at a higher education institution, (C) Professional (workplace) training and experience in digital imaging, PACS and RIS, and (D) Rating candidate imaging informatics topics. Each category was divided into subcategories. Questions in categories B and C were guided by the learning outcomes of modules for radiographic imaging technology in the second, third and/or fourth year of study of the four-year professional degree in radiography at higher education institutions that offer the radiography programme in South Africa. Questions were based on all the topics covered in the learning units on digital imaging, PACS, RIS, HIS, networks and workflow components, computer hardware, imaging data standards, image display and storage and quality control in PACS.

The questionnaire was developed in Microsoft Excel then incorporated into QuestionPro®, a web-based survey program licensed under the higher education institution where the researcher worked. Responses for most of the questions were constructed in various Likert scale formats. The types of variables measured were dichotomous (offering only two value possibilities), nominal (categories or names), and continuous (actual number range, including values between numbers) (Gray, Grove & Sutherland 2017:109). A number of open-ended questions were also included and provided respondents with the opportunity to comment; these comments were used to create the themes, subthemes and categories of the Delphi study questionnaires (Allen & Seaman 2007:64).

The second self-administered questionnaire, entitled *Assessment of radiographers' formal education in digital imaging PACS and RIS at higher education institutions in South Africa*, was also divided into three categories, namely, (A) Biographical information and education, (B) Imaging informatics principles covered during undergraduate radiography programmes, and (C) Imaging informatics principles covered during postgraduate radiography programme at a higher education institution. Each category was divided into subcategories. The questionnaire was developed in a similar way as the first questionnaire.

The third self-administered questionnaire, entitled *Imaging informatics professional practice analysis*, was adapted for the South African context from a questionnaire used by the ABII for defining the job role of imaging informatics professionals (ABII 2013). Permission was obtained from Dr Babcock of ABII to use the questionnaire (cf. Appendix AE). The purpose of the ABII survey was to enable the ABII to revise the exam content conditions of the CIIP course (Babcock 2014). The questionnaire is divided into several categories, namely, (A) Work-related biographical information and education, (B) Procurement, (C) Operations, (D) Imaging informatics, (E) Clinical informatics, (F) Information technology operations, (G) Imaging informatics software component maintenance, (H) System management, and (I) Clinical engineering informatics support, interaction and management. A six-point Likert scale was used to rank the intervals at which the tasks were performed. The intervals for most of the tasks performed were either daily, weekly, monthly, quarterly, yearly or less, and not responsible.

Based on the findings of the three structured questionnaires, a first-round Delphi study questionnaire was compiled with the relevant data (themes, subthemes and categories) that had been derived, and the first-round Delphi study questionnaire was sent to a respondent group of experts in imaging informatics.

3.4.2.2 *Delphi study questionnaires*

A Delphi study questionnaire involves an iterative process that uses a series of data collection and analysis techniques. In this study, the Delphi study questionnaires were used to extract the essential meaning or most important aspects of data gathered from the questionnaire sent to the survey sample, using the anonymous judgement of a group of experts in the specific field of imaging informatics in this study. The Delphi questionnaires consisted of a series of data collection and analysis techniques, which necessitated several rounds of feedback until data saturation had been reached (Garrod 2012:2; Skulmoski, Hartman & Krahn 2007:1;).

The data collected from the different sample groups using the three structured, self-administered questionnaires were used to compile the first-round questionnaire of the

Delphi study (cf. 5.2.1.1), also known as a Lockean Inquiry System (Boggs & Hammer 2010:201). Respondents were asked to indicate which data sets – different categories included in specific sub-themes in the Delphi study questionnaire – are essential and should be included, are not essential, but could be included with some editing provided by the respondents in the comment section after each subtheme, or not needed and should be excluded. The responses of the respondents on the different categories or statements enabled the researcher to establish, on a consensus level of 80%, what to keep, add to or exclude from the following round of the Delphi study questionnaires (Botma *et al.* 2010:253). The layout of the first Delphi questionnaire will be discussed in Chapter 5 under the data collection instrument (cf. 5.2.1.1).

From the original set of data sent to the respondents for the first round, data were added or removed through the experts' consensus in each subsequent round, until no more information was added or removed (data saturation). Consensus was considered to have been achieved at 80% agreement on the essential selection in the Delphi questionnaire. The number of rounds was determined by data saturation, though at least two to three rounds should be done. In this Delphi study, questionnaires were sent to the respondents for three rounds, and all the topics on which consensus had not been achieved after the third round, are reported as such. The Delphi research process for this study is depicted in Figure 3.3.

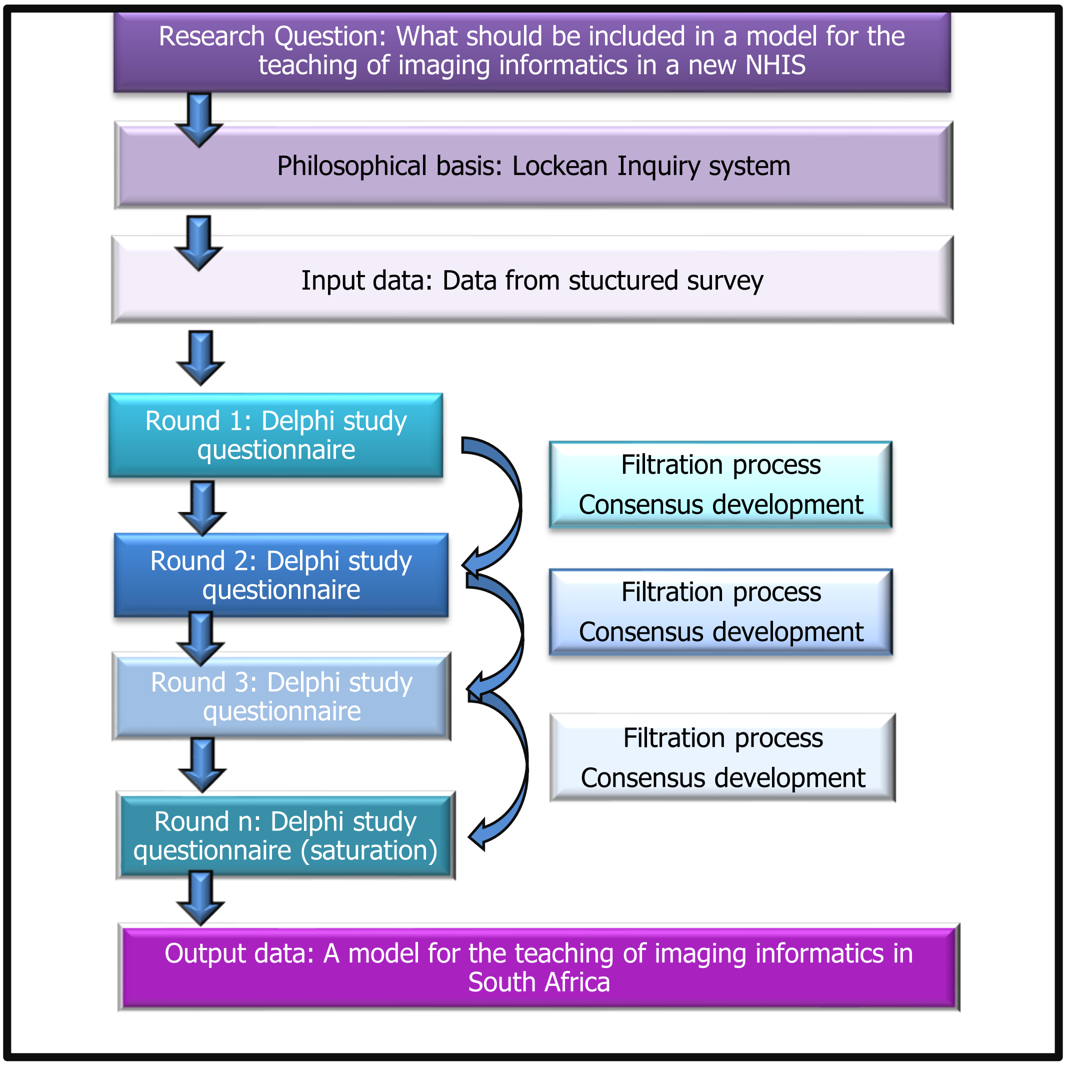


Figure 3.3: The Delphi process for developing a model for teaching biomedical informatics

3.4.3 Piloting the structured questionnaires

Questionnaires, especially if they are employed for large surveys, are seen as a 'one-stop' endeavour to collect data. Therefore, it is imperative to ensure that the questionnaire is straightforward to complete, explicit and accurate (Gray 2018:368). The main purpose of piloting a structured questionnaire is to test certain elements, such as the sample frame (the representation of the population under study), questions, to determine face and content validity (for self-administered questionnaires), and the instrument itself, for length and time needed for completion.

3.4.3.1 *Three structured questionnaires*

After the questionnaires had been modified on the basis of statisticians' feedback, a pilot study was conducted for each questionnaire. A small group of respondents with characteristics similar to those of the different sample groups (cf. 3.4.3.3) were used to pilot the three questionnaires (O'Leary 2017:311). The pilot studies were conducted in the Nelson Mandela Bay health district and involved the following sample respondents.

Questionnaire 1: Assessment of the teaching and learning of radiographers and PACS administrators in imaging informatics

- Eight radiographers who had trained to be PACS 'champions' (trained in the workplace on PACS component, workflow and troubleshooting); and
- Eight radiographers without any dedicated PACS training, who worked in diagnostic radiography departments.

Questionnaire 2: Assessment of radiographers' formal education in digital imaging PACS and RIS at higher education institutions in South Africa

- One lecturer in digital imaging and PACS physics at one of the eight higher education institution that offered the radiography programme in South Africa.

Questionnaire 3: Imaging informatics professional practice analysis

- Two IT imaging informatics professionals, who worked in an imaging informatics environment, in a public or private hospital's digital imaging department; and
- One vendor applications specialist involved in professional training after installations in the imaging informatics environment in private or public hospitals' digital imaging departments.

3.4.3.2 *Delphi study questionnaire*

The Delphi study questionnaire constructed for the first round was discussed with a statistician to ensure validity. A pilot study involving a group of four experts in imaging informatics was conducted in the Nelson Mandela Bay Health district:

- One imaging informatics manager;
- One IT specialist working in an imaging informatics environment;
- One vendor imaging informatics professional; and
- One imaging informatics professional involved in teaching and learning programmes for imaging informatics.

Prior to conducting the pilot studies for the structured questionnaires, ethical clearance and approval to do the research study were received from all the relevant gatekeepers, as explained under 3.7.1.

The questionnaires were delivered personally by the researcher to the respondents who had indicated that they were willing to participate by means of signing an informed consent letter. The respondents were asked to make comments and suggestions regarding the questionnaires' structure, whether they understood the questions, and how long it took them to complete them. The researcher collected the completed questionnaires after one week. After analysing the comments, the researcher made minor adjustments before populating the questionnaires on the online survey program, QuestionPro®. The data gathered from the completed questionnaires of the pilot studies were not included in the main research study, neither were the participants in the pilot study included in the main study data collection process.

3.4.4 Data collection

The selection of a data collection method depends on the aim of the study, the resources obtainable and the abilities of the researcher (Bless *et al.* 2013:184-185). Quantitative research studies favour structured data collection methods and instruments to obtain answers underpinning the research study (Kumar 2019:214).

Data collection includes three steps: the construction of the data collection instruments (cf. 3.4.2), piloting the instruments (cf. 3.4.2.1) and describing the data collection process. Before data can be collected and data processing is done, the target population will be described and sampling, sample size and recruitment of the respondents will be discussed.

3.4.4.1 *Target population for the structured questionnaires*

Before sampling can be done and sample size determined, the target population of the research study should be established. The population (target) represents the total set of research subjects that relates to the field of interest in the researcher's study (Houser 2018:158). The target population used for the three self-administered questionnaires will be discussed below.

The target population for Questionnaire 1

- All qualified radiographers (±6500) registered with the Professional Board of Radiography and Clinical Technology of the HPCSA in terms of the Health Professions Act, 56 of 1957.
- All vendors' (businesses selling and servicing imaging informatics technology) radiographer applications specialists and IT and radiographer imaging informatics professionals (±10) involved in professional training after PACS installation in an imaging informatics environment in private or public hospitals' digital imaging departments.

The target population for Questionnaire 2

- All lecturers of imaging informatics and digital imaging physics at the eight higher education institutions offering the radiography programme in South Africa (±8).

The target population for Questionnaire 3

- All imaging informatics or BMI professionals, or e-Health specialists working in an imaging informatics environment in private or public hospitals' digital diagnostic imaging departments (±130).
- All vendors (people selling and servicing biomedical informatics and imaging informatics technology), IT specialists or imaging informatics professionals (±130) involved in after-sales service support rendered after installation of equipment in imaging informatics environments in private or public hospitals' digital imaging departments.

3.4.4.2 *The target population for the Delphi study questionnaires*

The target population for the Delphi study questionnaires comprised professionals who are regarded as experts in the field of imaging informatics in South Africa and other countries, among whom of the following groups:

- Radiologists involved in planning, implementation and management during the transition process from analogue radiography to a digital imaging informatics environment;

- Radiographers with imaging informatics qualifications obtained in countries other than South Africa;
- IT specialists in the health sector, working in private and public hospitals in imaging informatics environments;
- Vendor application specialists involved in training after installation and implementation as part of the transition to a digital imaging informatics environment;
- Imaging informatics system managers, who were involved in imaging informatics management, installations, training and administration;
- Imaging informatics professionals involved in teaching and learning programmes for imaging informatics; and
- Professionals in countries other than South Africa, involved in imaging informatics or medical imaging informatics fields.

From these target population groups, samples were selected by purposive sampling.

3.4.4.3 *Sampling method and sizes for structured and Delphi questionnaires*

Sampling should be representative of the population under study, in order to avoid biased and unsystematic sampling, and to enable the generalisation of the study's results to the defined population (Houser 2018:159; Mouton 2014:133). Purposive sampling was done for all the groups in the population and will be explained further under the headings below. Purposive sampling also referred to as "purposeful, judgemental, or selective sampling", is used when researchers need rich information from knowledgeable individuals in order to learn more about the fundamental goal of the study (Gray *et al.* 2017:345). Purposive sampling was deemed appropriate for this research study, due to the nature of the fairly new domain and specialised information regarding imaging informatics in South Africa, the lack of imaging informatics training in the undergraduate education for an older population of radiographers and IT specialists in South Africa, and because the older population of radiographers and IT specialists in South Africa was unlikely to have undergone imaging informatics training during their undergraduate education. The sample groups and sample sizes of respondents for the three structured questionnaires were the following.

<u>Sample size for Questionnaire 1</u>

- *Sample 1:* A selection of 400 qualified radiographers registered with the HPCSA in terms of the Health Professions Act, 56 of 1957. Qualified, registered radiographers from all disciplines in radiography – diagnostic and ultrasonography, therapeutic and nuclear medicine – were included in this sample, because of their involvement in a digital imaging environment.

- *Sample 2:* A selection of ±10 qualified radiographers and IT specialists who were applications specialists or PACS administrators from vendors in South Africa, and who were involved in training and guidance after PACS installations in imaging informatics environments in private or public hospitals' digital imaging departments (cf. 3.4.4.1).

A second sample was included for Questionnaire 1 to target radiographers and IT PACS administrators, considered to be knowledgeable in PACS and RIS, as described in sample 2 above, to enhance the feedback on possible additional categories for inclusion in the teaching model for imaging informatics.

Sample size for Questionnaire 2

- *Sample 3*: A selection of eight imaging informatics and digital imaging physics lecturers at higher education institutions that offered radiography programmes in South Africa.

Sample size for Questionnaire 3

- *Sample 4*: A selection of 20 imaging informatics or BMI professionals, or e-Health specialists working in imaging informatics environments in public or private hospitals' digital imaging departments.
- *Sample 5*: A selection of four IT specialist or imaging informatics professionals, involved in after-sales service support after installations in imaging informatics environments in private or public hospitals' digital imaging departments.

Sample size for the Delphi study questionnaires

The Delphi study sample population (15) had disparate knowledge of the imaging informatics platform of BMI, and represented the following groups:

- Four radiologists;
- Two radiographers who were PACS administrators;
- Two vendor application specialists;
- One vendor IT specialist/PACS administrator;
- One imaging informatics system manager;

- Three imaging informatics professionals;
- One imaging informatics software consultant; and
- One health informatics director.

Five of the respondents in the sample for the Delphi study questionnaires were from continents other than Africa. The researcher targeted English-speaking counties, namely, the USA, UK and Canada, and two respondents were from the UK, and three from the USA.

3.4.4.4 ***Recruitment of respondents for structured and Delphi questionnaires***

Three structured questionnaires

Qualified radiographers (400 – Sample 1), imaging informatics or BMI professionals, or e-Health specialists working in an imaging informatics environment in public or private hospitals' digital imaging departments (20 – Sample 4), were recruited from large digital diagnostic imaging departments at one private and one public hospital in each of the nine provinces of South Africa. The public digital imaging departments were selected according to suggestions and approval by the nine provincial Departments of Health, which had provided ethical clearance to do the study. The private digital imaging departments were randomly selected from a list of private radiology practices in South Africa, which had been downloaded from the Radiologic Society of South Africa website. The practice managers were contacted by email to obtain approval from the directors to target their radiography and IT personnel. Poor response rates by public and private digital diagnostic imaging departments necessitated the researcher to divert to snowball sampling. Snowball sampling involves using a network of knowledgeable respondents that had been recruited during the study (Kumar 2019:308) to recruit more respondents in the field of radiography, imaging informatics and BMI. Application specialists (10 – Sample 2) and IT specialists or imaging informatics professionals (4 – Sample 5) were recruited from five major vendors in South Africa by convenient sampling. Those who were willing to participate, accepted after reading the online information letter, and attempted and completed the questionnaire(s) on QuestionPro®. Ethical approval was obtained from all eight higher education institutions offering the radiography programme, to recruit their postgraduate BTech. student groups and the imaging informatics or digital imaging physics lecturers (8 – Sample 3).

Delphi questionnaires

The researcher recruited 25 experts with disparate knowledge on the imaging informatics platform of BMI through personal telephone conversations and email messages. They were then selected to represent the groups mentioned (cf. 3.4.4.3) under the sample size for the Delphi study questionnaire.

Before data collection could commence, ethical clearance or approval was obtained from all the relevant gatekeepers, as described in 3.7.1.

3.4.4.5 *Collecting data with the structured questionnaires*

Collecting data in quantitative research is generally the most time-consuming part of the research study. In this study, it involved sending the questionnaires through the online questionnaire program, QuestionPro®, to all the respondent groups, constantly monitoring the responses, and sending reminders at specific time intervals. Finally, the data were downloaded in Excel spreadsheet format and dispatched to the statisticians.

Three structured questionnaires

Data collection transpired when the researcher used the measuring instruments (in this data collection method, the three structured questionnaires (cf. Addenda A, B, C), to investigate the five selected samples (Kumar 2019:2010-2011). QuestionPro®, a web-based survey program for creating and distributing surveys, was used to gather data for the three questionnaires. The questionnaires generated in Microsoft Excel were incorporated into the QuestionPro® program by the researcher. A survey link to the specific questionnaire was sent via email from QuestionPro® to the individual sample respondents, as stated in 3.4.4.3 Radiography managers in digital imaging departments at public and private hospitals in the nine provinces were recruited to distribute the survey link to the relevant respondents. A hard copy of a questionnaire (cf. Appendix A) was only distributed if a respondent did not have access to email or requested a hard copy. The researcher created email addresses on QuestionPro® for the different respondent groups before sending them the link to the relevant questionnaires. The researcher constantly monitored responses to the online survey program. After six weeks, reminders were sent via QuestionPro® to encourage respondents who had not yet done so, to complete the questionnaire. After another six weeks, a second reminder was sent. After two months from the start of data collection, the researcher noticed that the response rate from certain groups of respondents was lower than anticipated. The researcher then shared the link of the first questionnaire with qualified radiographer members of two radiography societies, the Society of Radiographers South African (SORSA) and Association of Radiographers in South Africa (ARSA). The researcher also shared the questionnaire on social media with radiographers of all disciplines. All BTech. radiography students at the eight higher education institutions in South Africa offering the radiography programme were also targeted through their individual radiography departments. The BTech students were part of the sample group of qualified radiographers in South Africa.

During the construction of the questionnaires, an invitation to participate in the research study, and an information letter, were created in the online survey program, QuestionPro®, to inform the respondents in the different sample groups about the research topic, the researcher, the goal of the study, what respondents will be required to do, and the risks or benefits involved in participating (cf. Addenda A, B or C). The information letter also informed potential respondents that participation would be voluntary, that respondents could withdraw at any time, and that participation would be anonymous and confidential. The researcher provided her contact details and invited the respondent to contact her with questions regarding the research study. They were also informed about the approximate time needed to complete the questionnaires. After reading the information letters, respondents were asked to click to accept and start the survey. Informed consent was considered to have been obtained after the completion and submission of responses to the questionnaire. Respondents were also able to save their completed answers if they were interrupted before completion, which enabled them to return to the questionnaire to complete it, instead of starting over.

The data were available immediately after completion and submission by the respondents. The data were downloaded after six months from the QuestionPro® online survey program, in an Excel spreadsheet format, and sent for statistical analysis by a statistician at the Nelson Mandela University. The researcher and the statisticians arranged a meeting before the analysis started, to ensure that the statistician understood the terminology of imaging informatics and that the correct statistical tests would be performed.

<u>Data collection with the Delphi study questionnaires</u>

The researcher incorporated the Delphi study questionnaires into the QuestionPro® online survey program. A survey link to the questionnaire was sent to each respondent for each of the rounds in the Delphi study (number of rounds depended on data saturation). The information letter (cf. Addenda E, F & G), which explained the research process and the ethical issues that were addressed during the study, was incorporated on the first page of each of the three questionnaires. Respondents who accepted the information and were willing to respond had to click the 'start survey' box. Informed consent was assumed by the action of starting the questionnaires, and the final submission. Due to the length of the questionnaires and the time needed to complete them, respondents could save their completed answers, and return to the questionnaire at a later stage to respond to the remaining statements before submission.

Each Delphi study questionnaire round was allocated 12 weeks for completion, to consider respondents' workload and the limited amount of free time available to attend to the questionnaires. After six weeks, a reminder was sent to the respondents through the QuestionPro® survey program; this reminder was repeated after 10 weeks. The data were available immediately on QuestionPro® after respondents had submitted their completed questionnaires. The quantitative and qualitative data for each round of the Delphi study questionnaires were downloaded in Excel spreadsheet format and sent to the statistician for statistical analysis. The qualitative data were presented in tables according to the categories where the panellists made comments or suggested editing. After each round, the researcher and the statistician met to discuss the statistical tests required for analysing the quantitative data.

3.4.5 Data processing of the structured questionnaires

Processing raw data in quantitative research studies involves, firstly, ensuring that the data are 'clean', which means that it must be complete and not contain discrepancies. The cleaning process is generally referred to as editing (Kumar 2019:376).

3.4.5.1 *Three structured questionnaires*

The researcher scrutinised the data from the three completed questionnaires downloaded from QuestionPro® to detect and reduce, where possible, incompleteness, misfiled information and gaps in the data from the respondents. Data editing can be done in two ways: 1) Scrutinise all the responses to one question (variable) at a time, or 2) Scrutinise all the answers given by one respondent to all the questions at a time (Kumar 2019:377).

According to Kumar (2019:376), even the best researchers can make mistakes while constructing measuring instruments. The researcher tried to reduce mistakes in the questionnaires by scrutinising the themes and topics for completeness and by reviewing the answers for internal consistency.

The next step in the data processing involves coding, which is the process of allocating numerical values to individual categories of answers to analyse them (Babbie 2016:413; Kumar 2019:379). For the first and second structured questionnaires, similar responses were grouped and assigned codes. These groups formed the basis of the different topics to create statements for the Delphi study questionnaire. The data from the open-ended question in Questionnaires 1 and 2, *Please list other candidate topic(s) that you regard as important below*, were interpreted into themes, subthemes and categories or statements. These themes and categories were integrated with the grouped data derived from the data of the three structured questionnaires and used to compile the first round Delphi study questionnaire.

3.4.5.2 *Delphi study questionnaires*

Data from the first round Delphi study questionnaire were presented in a table format, in order to colour-code all the themes and topics on which consensus (80%) had been reached (cf. Appendix E). The feedback of the results that were sent to panellists after Round 1 of the questionnaire included quantitative data and qualitative data. The comments by the respondents on the statement were considered qualitative data, whereas the basic statistical summations demonstrating the combined selections (e.g. frequency distributions) of the group members, were considered as quantitative data (Boulkedid, Abdoul, Loustau, Sibony & Alberti 2011:2; Hsu & Sandford 2007:4). Feedback on the results of the first two rounds of the Delphi study questionnaires was sent to the respondents before they were provided with the link to the next questionnaire round of the Delphi study. For the second and third round questionnaires of the Delphi study, questions on the topics were presented one by one, and the questionnaire included the results of the previous round and anonymous comments by other respondents.

3.4.6 Data analysis

The data analysis process included summarising and categorising the information that had been collected and presenting it in meaningful terms, to address the research aim (Bless *et* *al.* 2013:246; Kumar 2019:375).

3.4.6.1 *Analysing the data of the three structured questionnaires*

All the data were downloaded from QuestionPro® in Microsoft Excel format for analysis by a statistician at the Nelson Mandela University. The data were then edited by the researcher and a statistician to eliminate incompleteness and inconsistencies of the contents that remained (Kumar 2019:376). The statistician used a self-constructed Excel statistical analysis program for the data analysis. The data analysis process in this research study used two general classes of statistical techniques, namely, descriptive and inferential statistics.

Descriptive statistics were used to organise, simplify and summarise the sample statistics (Gravetter & Wallnau 2014:6). Descriptive statistics consisted of frequency distributions and seven measures of central tendency and dispersion. Data from the three structured questionnaires completed by the five sample groups (cf. 3.4.2.2) were summarised using frequency distributions and percentages for categorical data. Categorical data were recorded in data order (1st column), along with the frequency *(f)* at which each appeared (2nd column) in the tables. Frequency distributions in the first questionnaire were done for demographical data, teaching and learning in imaging informatics topics during undergraduate radiography studies, respondents' ratings of the importance of candidate topics for imaging informatics, and their rating of training received in the workplace. In the second structured questionnaire, frequency distributions were done for imaging informatics principles covered in undergraduate and postgraduate radiography syllabi. For the third structured questionnaire, the only descriptive statistics done were frequency distributions.

The measures of central tendency delineate the average value, which gives a common description of the sample data. Measures of central tendency of continuous data include the mode (a data item score occurring the most often in a data group), median (the midpoint value of scores arranged in a certain order) and mean (average score in a data set) (Bless *et al.* 2013:254-256; Gravetter & Wallnau 2014:72; Plichta & Garzon 2009:24-25). For structured Questionnaires 2, the continuous data were summarised using ranges, means and medians. To calculate a mean, all the scores in a distribution are used, which makes it the most correct degree of central tendency (Bless *et al.* 2013:254-258). The dispersion of a variable refers to the spread of variation in the data set. The measures of dispersion used predominantly include the coefficient of variance, variance, standard deviation, interquartile range and range (Plichta & Garzon 2009:40). The formula for standard deviation equals the square root of variance. The quartiles in descriptive statistics are denoted by quartile one (Q1), quartile two (median) and quartile three (Q3) and quartile four (maximum), which split data sets into four equivalent groups of equivalent size. In Chapter 4, for the second structured questionnaire, the central tendency and dispersion of the theme scores were done for the level of inclusion of imaging informatics principles in the undergraduate and postgraduate radiography syllabi and is displayed by means of seven statistical measures: mean, standard deviation, minimum, Q1, median, Q3 and maximum.

The confidence interval of Cronbach's alpha was used to test for reliability of the summated scores derived from questionnaire one and two. Cronbach's alpha reliability is the measure of reliability used most commonly in organisational and social sciences. In measurement representing multiple questionnaire items, which is also the prevalent use, Cronbach's alpha is indicated as the degree of reliability (internal consistency) (Bonett & Wright 2015:3). The interpretation intervals for Cronbach's alpha in this study were as follows: unacceptable if less than 0.50; acceptable if between 0.50 and 0.69; good if between 0.70 and 0.79 and excellent if greater or equal to 0.80.

3.4.6.2 *Analysing the data of the Delphi study questionnaires*

The data from the Delphi study questionnaires included qualitative and quantitative data. Respondents' opinions were achieved by asking open-ended questions on the different topics under the themes.

Data from the three questionnaire rounds of the Delphi study were summarised according to consensus, which was considered to be reached if 80% of respondents agreed. Descriptive statistics included frequency distributions and percentages for the demographical data and individual agreement level on each topic or statement. Central tendency was used to calculate the mean (arithmetic average) and median (midpoint) of the data sets statistically. Level of dispersion was used as a measure of the standard variation between the values in the data sets and their associated rankings.

Various statistical measurements can be used for interrater reliability in Delphi study rounds. These tests include, for example, percentage agreement, weighted and unweighted Kappa test values, and the contingency coefficient (McHugh 2012:278). Three statistical measures for testing for interrater reliability were calculated for the study: Kendall's coefficient of concordance (Kendall's CC) (weighted); Fleiss' Kappa (unweighted) and Cohen's Kappa (weighted). Kendall’s CC (weighted) statistics were processed on the agreement levels of the subthemes within the four themes between the consecutive Delphi study rounds. The CC value did not calculate interrater agreement levels between respondents. Statistica, an advanced analytic software program, was used to calculate Kendall’s CC (weighted) test values. The interpretation intervals for Kendell's CC (W) can range from minus one to plus one (-1 to +1), similar to the majority correlation statistics (McHugh 2012:278; Holey, Feeley, Dixon & Whittaker 2007:54).

The Delphi study questionnaires represent the first phase in the development of the model for teaching imaging informatics and will address mainly the contents of this teaching model. The structure of the teaching model will be discussed in Chapter 6.

3.5 TEACHING MODEL FOR IMAGING INFORMATICS

A model can be described as a representation, replica or copy of an existing thing or proposed structure. It is usually symbolic of a particular style or design. A model in the social sciences involves mainly words – an account of the most noticeable facets of a phenomenon (Brynard, Hanekom & Brynard 2014:5)

When an imaging informatics teaching model is being designed, it is important for the researcher to, first, acquire a thorough understanding of existing teaching models through the literature review (MacKellar 2012:146). In the second phase of the teaching model's development, the researcher investigated several teaching models in countries other than South Africa, especially those relating to imaging informatics and BMI, by doing an extensive literature review. The data gathered through the Delphi study questionnaire (consensus) were used to compare the content of these models, to analyse similarities and differences, before compiling the contents of this study's teaching model.

The researcher used the conceptual elaboration model of Reigeluth to construct the teaching and learning model for imaging informatics. The procedure of model generation for a teaching and learning programme in imaging informatics was piloted according to six of the nine conceptual elaboration sequence steps suggested in the elaboration theory (Reigeluth, Merrill, Wilson & Spiller 1980:199-206). The stages used are the following:

- Step 1. Decision to make use of conceptual organisation.

- Step 2. Select all the concepts to be included in the model and organise them into types and elements conceptual structures.
- Step 3. Decide which of the conceptual structures to use as the ordering structure for the course.
- Step 4. Allocate all concepts in the ordering structure to the degrees of detail.
- Step 5. Identify the reinforcing content for each systematising content idea.
- Step 6. Assign all content on each level to instructions and order them (Reigeluth & Darwazeh 1982:24).

3.6 VERIFICATION OF THE DATA

The methods used by researchers to determine the trustworthiness of qualitative and quantitative research vary in many ways. In qualitative research, trustworthiness can be established by confirmability, transferability, credibility and dependability (Kumar 2019:276). In quantitative research, establishing trustworthiness involves ensuring reliability and validity. Several kinds of validity are listed by Cohen, Manion and Morrison (2007:132). According to Oluwatayo (2012:392), only four kinds of validity are of importance in educational research, namely, face, content, construct and criterion-related validity.

3.6.1 Validity

Validity in quantitative research denotes the truth value or credibility of the findings (Altheide & Johnson, 1994, as cited in Mohajan 2017:1). The criteria for truth and value in quantitative research are measured by how well the risks to internal validity have been regulated and by the validity of the research instrument (Kumar 2019:271; Noble & Smith 2015:34). The criteria for applicability or generalisation were demonstrated by means of external validity (Noble & Smith 2015:34). The large sample size and the national representation of the population of radiographers enabled the researcher to make realistic and truthful statements and to generalise from the sample to a larger population in questionnaire one.

Establishing that all the questions or statements on the questionnaires are logically linked to an objective indicates the research instruments' face validity. Content validity is judged by the research instruments' coverage of all the features of the issues at hand; and the extent to which the statements or questions measure what they are supposed to measure

(Heale & Twycross 2015:66; Kumar 2019:273). Content and face validity was ensured by selecting the topics for the first and second questionnaire from the literature review on imaging informatics and BMI, and the aspects of imaging informatics included in the modules concerning radiographic imaging technology for the four-year professional degree programme in radiography at the higher education institution where the researcher worked. Her experience of research as a PACS administrator and her knowledge regarding digital imaging and PACS also played a role in ensuring content and face validity. The third questionnaire was a pretested questionnaire used by the ABII to define imaging informatics professionals' job role in the USA (cf. 3.4.2). As the questionnaire was modified to engage with the context of imaging informatics in South Africa, it was tested for content and face validity through doing a pilot study (cf. 3.4.3.2). Minor adjustment to the questionnaire was needed after the pilot study. The data from the pilot study were not included in the main study data.

The validity of the structured questionnaires and the Delphi study questionnaires was enhanced by each one being tested in a pilot study and amended appropriately before being utilised in the main study. The qualified diagnostic radiographers, BMI/imaging informatics/IT specialists, and digital imaging physics lecturers were considered knowledgeable on the topic of imaging informatics. The Delphi study respondents were considered as individuals with disparate knowledge in the imaging informatics field. Therefore, the feedback from the Delphi study questionnaires contributed to the content validity of the structured questionnaires as measuring instruments.

3.6.2 Reliability

Reliability in quantitative research is related to the stability of the results (Altheide & Johnson, 1994 as cited in Mohajan 2017:1). The reliability (internal consistency) of a measurement procedure refers to measuring the same variable under the same conditions and obtaining the same results every time (Heale & Twycross 2015:66-67). According to De Vos, Strydom, Fouché and Delport (2012:177), perfect reliability is rare. However, Neuman (2014:213) suggests following a specific procedure to increase a measure's reliability. He suggests four measures to improve reliability: distinctly conceptualise all concepts; increase measurement level; use numerous values of a variable, and use pilot studies (Neuman 2014:214).

The structured questionnaires and Delphi study questionnaires were tested for reliability by conducting pilot studies. Only minor adjustments were necessary before the questionnaires were used to collect data for the main study. Involving knowledgeable respondents in the field of imaging informatics also added to the reliability of the data collected. The Delphi study panellists were individuals with disparate knowledge in the imaging informatics and BMI fields.

Cronbach's alpha confidence intervals were used to test the reliability (internal consistency) of the theme scores derived from structured questionnaires 1 and 2 statistically. In the Delphi study survey, the reliability of the results was tested with Cohen's k (weighted) statistics, which were processed on the agreement levels of the subthemes between the successive Delphi rounds.

3.7 ETHICAL CONSIDERATIONS

Ethics in research is important at all levels of research. The aim of ethics in research is always to ensure that no harm or evil purposes are embedded in the research process (Gray 2018:70-71; Wisker 2009:205). According to the Belmont Report (USA DoH, E & W 1978), the three basic ethical principles are respect for persons, beneficence and justice. Application of these three general ethical principles when carrying out research steers researchers to consider other requirements, such as informed consent, selecting respondents, and risk or benefit assessment. During this research study, the researcher ensured that all the ethical principles as contained in the Belmont report were considered, by gaining permission from all the relevant gatekeepers.

3.7.1 Gaining ethical approval to do the research

Ethical clearance for the research project was obtained from the Ethics Committee of the Faculty of Health Sciences at the UFS (ECUFS NR 185/2015) (cf. Appendix J). Ethical clearance was also obtained from the deans of the Faculties of Health Sciences at the eight higher education institutions in South Africa that offer the radiography programme (cf. Appendices T–Z & AA). Approval to do the research was acquired from the Department of Health (DoH) in each of the nine provinces (cf. Appendices K–S). After obtaining ethical clearance from the relevant provincial health departments, who also indicated the digital diagnostic department where the research should be done, the researcher gained permission from the research ethics committee or chief executive officer of the hospital, and the radiology manager, to do the research (cf. Appendices AB–AD). Verbal approval was received from two vendors, where voluntary respondents – imaging informatics/BMI and IT specialist, PACS administrators and application specialists – were asked to take part in the research. These individuals gave informed consent by reading the information letter, agreeing to complete, and submitting the completed online questionnaire.

3.7.2 Respect for persons

Respect for persons includes at least two ethical certitudes: individuals taking part in the research should be acknowledged as autonomous representatives, and vulnerable individuals should be safeguarded (Doody & Noonan 2016:803; USA DoH, E & W 1978). Respondents in this research study were treated as autonomous people who have the right to make their own choices and manage their doubts. The respondents were not coerced to take part in the study and they were told that they were free to withdraw from the study at any time. To avoid respondents being deceived, they were provided with a comprehensive information letter regarding the research study. They had adequate time to make informed decisions about their participation, and they could contact the researcher if they had any queries regarding the research study.

Confidentiality and privacy were insured by the anonymity of participants in the online questionnaire, and the distribution of the link to the questionnaire by the relevant gatekeepers. Each respondent was assigned a code by the online program, which could not be linked to their identity. The information (data) downloaded from the online program were only reported in the different groups, with no link to the personal information of the respondents. The only personal information of respondents known to the researcher was the demographic and education details of the panellists in the Delphi study survey. The information from these respondents was not shared with any other people involved in the study, and are kept in a secure, password-protected folder on the researcher's computer. Access to the data in the QuestionPro® online program was restricted to the researcher only.

3.7.3 Beneficence

Beneficence strives to do good and secure the wellbeing of individuals taking part in research studies, thereby, also benefiting the society from where the respondents were recruited as a whole (Doody & Noonan 2016:804). The information letter on the online questionnaire program informed the respondents that the benefit of this study would not be on an individual level, but would benefit the radiographer and imaging informatics community as a whole. The respondents were all above the age of 21 years, part of the radiography and imaging informatics workforce, and able to make an informed decision to participate. The researcher assured the respondents that they would not be harmed by any action during the research process.

3.7.4 Justice

The principle of justice states that all human subjects recruited to take part in a research study should be treated equally. The researcher should ensure privacy, anonymity and fair treatment of all respondents (Doody & Noonan 2016:805). All individuals in the relevant population groups were given an equal chance to participate in the research study. The links to the online questionnaires were shared with radiography and imaging informatics communities through social media as well. None of the respondents received any financial benefits for their participation. Participation was treated as anonymous, and individuals' information was handled in a privately and confidentially by the researcher.

3.7.5 Informed consent

According to Section 49 of the Consumer Protection Act (2008), informed consent means that persons must have full prior knowledge of the nature and consequences of risks, whether actual or potential, that they may suffer or experience as a result of their participation in a particular activity. This consent is the acceptance of any harm or damages that may result, and a waiver of his or her rights to claim in the event of their participation in the activity. If any harm or economic loss for a respondent is foreseen, then full disclosure of the nature of their role as respondents should be made (RSA DOJ & CD 2009:98). Full disclosure about the research study, its purpose and procedures, were provided to the respondents, with an explanation of what was required of them. Participation was totally voluntary, respondents remained anonymous, and the results were reported on in a group.

Informed consent, in a legal sense, was, thus, not imperative, due to the nature of the research and study, since no harm or loss was contemplated to result to a respondent by the respondent voluntarily answering the questionnaires. However, informed consent, in an ethical sense, remained imperative and, therefore, all the voluntary respondents had to accept the information in the online information letters before they started, completed and submitted their responses.

3.8 CONCLUDING SUMMARY

In Chapter 3, the theoretical perspectives underpinning the research design, strategies of inquiry, research approaches and design used were discussed in detail. The research methods, which included the research instruments, populations, sampling methods, sample sizes, data collection and processing, analysis, validity and reliability, and the ethical considerations applied during the research study, were presented to provide the reader with an inclusive perspective regarding the research study.

In the next chapter, Chapter 4, entitled, ***Results and discussion for the structured questionnaire survey study,*** the statistically analysed data gathered from the three structured questionnaires will be presented and discussed.

CHAPTER 4

RESULTS AND DISCUSSION FOR THE STRUCTURED QUESTIONNAIRE SURVEY STUDY

4.1 INTRODUCTION

In Chapter 3, a theoretical outlook on the research methods and design that were used during this research study were given. A detailed explanation of the research process and instruments was also offered. The three self-administered questionnaires that were sent to the three different target groups, as well as a Delphi questionnaire, which was sent to a panel (expert group) of imaging informatics professionals were also explained. The chapter concluded with ethical considerations and validity and reliability notions applicable to the study.

In Chapter 4, the results and discussion of the structured questionnaire survey will be discussed in three sections as follows: Section 1, *assessment of radiographers' teaching and learning in imaging informatics*; Section 2, *assessment of radiographers' formal education in imaging informatics (digital imaging, RIS and PACS) at higher education institutions in South Africa*; and Section 3, *imaging informatics professional practice analysis*. The three sections include the three structured questionnaires with the same titles. The presentation and discussion of the results of the three sections are followed by a collective summative discussion of all three questionnaires' results.

During the first empirical phase of the study, the three questionnaires were sent to three distinct respondent groups. The data collection process for the three questionnaires in the structured questionnaire survey was done over nine months. The second empirical phase (cf. Chapter 5) involved the different rounds (three) of the Delphi questionnaire survey.

4.2 QUESTIONNAIRE 1: RADIOGRAPHERS' TEACHING AND LEARNING IN IMAGING INFORMATICS

The discussion of the results of the assessment of radiographers' teaching and learning in imaging informatics includes explanations of the response rate to the questionnaire, demographic and educational data of the respondents, as well as the professional work and formal educational contexts in the imaging informatics field, as mentioned before (cf.

Section 3.4.2).

The questionnaire was viewed by 809 people (radiographers) on QuestionPro, though only 149 attempted and completed the questionnaire. The average time for completion of the questionnaire was 12 minutes. From the sample size of 400, the response rate was therefore only 37%. A slow response rate and time limitation contributed to the small sample size.

4.2.1 Demographic information and education of the respondents

In Figures 4.1 to 4.6 the demographic profiles of the respondents are reported.

4.2.1.1 *Gender of respondents*

Figure 4.1 demonstrates the gender distribution of the respondents by means of a pie diagram.

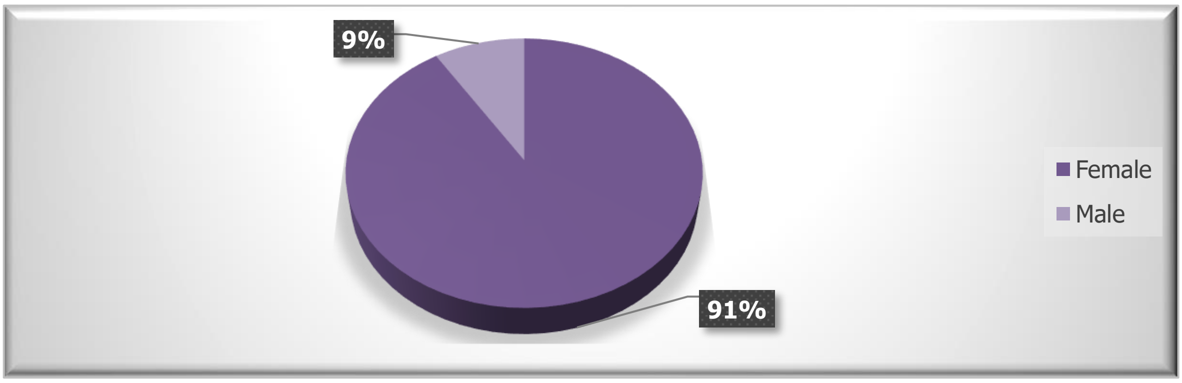


Figure 4.1: Frequency distribution of respondents' gender (n=149)

The majority (91%) of the respondents were women. In a study done by the Society and College of Radiographers (2009:Online), 84% of the respondents – diagnostic radiographers – were female, which is an indication that women are the dominant gender in the radiography profession. According to Strudwick (2011:57) and Yielder (2006:311), like in other allied health professions, more women study radiography than men do.

4.2.1.2 *Age of respondents*

Figure 4.2 displays the frequency distribution of the age per category of the respondents with a bar diagram. The ages of the respondents were analysed according to five age groups between 20 and 69 years.

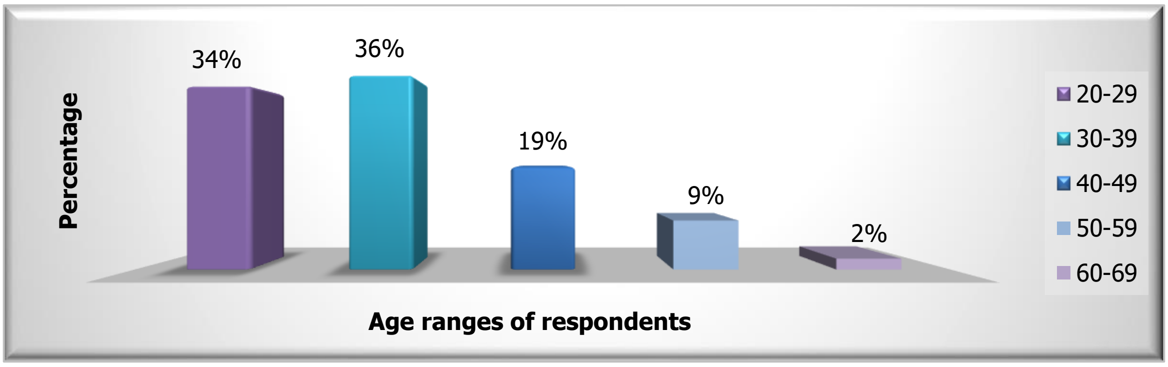


Figure 4.2: Frequency distribution of age per category

The majority (70%) of the respondents were between 20 and 39 years old. In a study done on stress in the workplace among South African diagnostic radiographers, Gam, Naidoo and Puckree (2015:18) found that more than half (51%) of the respondents were in the age group 20 to 29.

4.2.1.3 *Respondents' nature of current employment*

The respondents were asked to indicate the nature of their current employment, which is indicated in the legend of Figure 4.3.

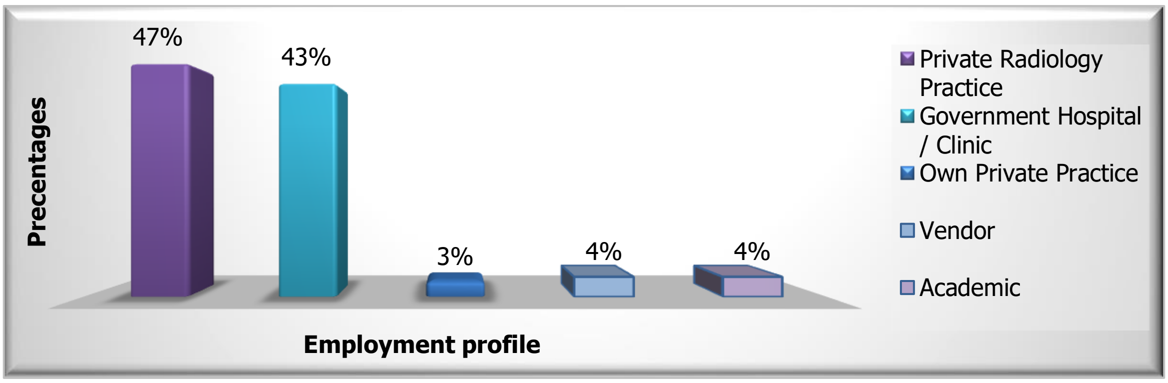


Figure 4.3: Frequency distribution of the nature of current employment

In one of the questionnaires, this question was not completed. Of the 148 respondents who answered the question, 47% (69) were employed in private radiology practices and 43% (63) worked in public hospitals or clinics. Statistics in South Africa show that more radiographers work in the private sector (70.4%) than the public sector (29.6%). In this research study, the distribution between private and public sector respondents was nearly equal, similar to the results in the research study by Khoza, Pieterse and Motto

(2018:Online). The next section relates to the respondents' position.

4.2.1.4 *Respondents' current position*

Table 4.1 displays the frequency distribution of respondents' positions in radiography or imaging informatics at the time of the survey. The current positions indicated on the questionnaire referenced all the post levels in radiography, including radiographers involved in teaching and learning, and radiographers in IT or imaging informatics professionals.

Table 4.1: Frequency distribution of current position in radiography or imaging informatics

Position in radiography or imaging informatics	*f*	%
Radiographer	63	42%
Senior radiographer	33	22%
Chief radiographer	17	11%
Line manager	1	1%
Clinical specialist (Modalities)	2	1%
Radiography manager	8	5%
Position in radiography or imaging informatics	***f***	**%**
Human resources manager	1	1%
Clinical tutor in work integrated learning (Hospitals)	3	2%
Lecturer	4	3%
Own private practice	2	1%
PACS administrator	6	4%
Application specialist	6	4%
Vendor IT specialist	1	1%
Ultrasonographer	2	1%
Total	**149**	**100%**

The majority of the respondents were either in radiographer (42%) or senior radiographer (22%) positions. Only six responses (4%) were recorded for the PACS administrator position. A reason why there are so few PACS administrators among this sample group may be because formal teaching and learning opportunities and programmes in South Africa was scarce at the time of data collection. The next section presents the qualifications of the respondents.

4.2.1.5 *Qualifications of the respondents*

The respondents were *allowed to select all the institutions* where they had studied, which means the total is more than n=149 (100%), therefore, only n is displayed and not percentage. Figure 4.2 depicts the number of higher education institutions where respondents obtained academic qualifications.

Table 4.2: Frequency distribution of higher education institutions where studied

Higher education institutions	*f*
Nelson Mandela Metropolitan University	62
Cape Peninsula University of Technology	57
University of Johannesburg	16
Durban University of Technology	14
Central University of Technology	12
University of Pretoria	11
Other universities	5
Tshwane University of Technology	4
University of the Free State	3
University of Cape Town	2

At the time of data collection, the current Nelson Mandela University was still called Nelson Mandela Metropolitan University, hence, the previous name used during data collection is reflected in the results. Most of the respondents had studied at Cape Peninsula University of Technology (38%) and or Nelson Mandela Metropolitan University (42%). Students who had completed their undergraduate studies at one of the other seven higher education institutions offering the radiography programme could have done the postgraduate BTech degree at Nelson Mandela Metropolitan University. Table 4.3 illustrates the higher education institution qualifications obtained by the respondents.

The respondents were additionally allowed to select *all the qualifications* that they obtained. The qualifications ranged from undergraduate IT, radiography certificates or diplomas to postgraduate BTech, MTech and PhD degrees.

Table 4.3: Higher education institution qualifications obtained

Qualification	*f*
Certificate	17
NDip2	4
NDip3	123
B Rad	11
B Tech/Hons	52
HDip	1
PGDip EH	1
PGDip IT	1
M Tech	5

The majority (123) of the respondents indicated that they had three-year National Diplomas. The three-year National Diploma in radiography (diagnostics) was the undergraduate programme for radiographers at seven of the eight higher education institutions in South Africa that offered radiography teaching and learning programmes. The four-year professional Bachelor's Radiography in Diagnostics (BRad) degree had been phased in at the eight higher education institutions from 2014 to 2019. Furthermore, 52% of respondents indicated that they also had either a BTech degree or an Honours degree in radiography.

The researcher wished to establish whether radiographers in South Africa had completed any international PACS administration courses. Two of the respondents indicated that they had done a PACS administration course. The PACS administration course presented in South Africa is a course developed in the UK by Kantchev (IBISEdu 2019) and is *not* registered with SAQA. The course facilitator had applied for continuous professional development accreditation and provided continuous education units (one hour of learning) to radiographers or IT professionals who had engaged in the course. The topics of imaging informatics teaching and learning in undergraduate radiography programmes in South Africa will be discussed in Section 4.2.2.

4.2.2 Imaging informatics teaching and learning in undergraduate studies

Exit-level outcomes can be defined as the learning, abilities and mindsets that should have been mastered by a student upon receipt of a qualification, which the student will be evaluated against for competence. Exit-level outcomes are based on the NQF's "policy and criteria for the registration of qualifications and part-qualifications" (SANQF 2016:42). According to the policy and criteria, all radiography teaching and learning programmes in South Africa should comply with the registered exit-level outcomes of SAQA, even if the degree names and subject titles differ. Under information technology, the SAQA exit-level outcomes for radiography are as follows:

- *Access, organise and present information applicable to the radiography context in order to record, retrieve and communicate patient data.*
- *Data are compiled, and information is scientifically presented.*
- *Information technology is effectively communicated/used within the radiographic context.*
- *Relevant information is selected and critically evaluated (SAQA 2018).*

A Critical Cross-Field Outcomes is as follows:

- *Communicate effectively in the learning and health care environment by demonstrating competency and skills necessary for use of technology and associated accessories necessary for transfer or sharing of information among healthcare workers and other stakeholders so as to deliver quality patient care and facilitate management processes*

(SAQA 2018).

Two of the major subjects of the radiography programmes are medical radiographic physics and equipment engineering. Undergraduate student radiographers in diagnostics are engaged in radiographic imaging technology (RIT) modules in each of their four years of study for the professional Bachelor of Radiography in Diagnostics degree (Department of Radiography 2019a; Department of Radiography 2019b). The topics in Table 4.4 were retrieved from the study guides for RIT210 and RIT310 (Department of Radiography. 2019a; Department of Radiography. 2019c) at the institution where the researcher worked as a lecturer (cf., 2.5.2; 3.4.1), and the chapters regarding digital imaging, PACS, RIS, and networks in the prescribed books by Carlton and Adler (2013:323–369; Carlton *et al.* 2020:273–337). The respondents had to indicate whether these topics on imaging informatics and digital imaging had been included in their undergraduate teaching and learning programmes. Table 4.4 portrays teaching and learning in imaging informatics topics during undergraduate radiography studies. The topics are listed according to the frequencies obtained from questionnaire 1

Table 4.4: Teaching and learning in imaging informatics topics during undergraduate radiography studies (n=149)

Teaching and Learning Topics during undergraduate studies	*f* Yes
Digital imaging equipment	73
PACS components	68
Digital imaging processing and manipulation	64
None of the topics covered	62
RIS workflow concepts	58
PACS workflow concepts	56
Image storage and archiving	53
RIS workstations	52
Standards used: DICOM, a standard for handling, storing, printing, and transmitting information in medical imaging	48
Image display	48
Quality assurance and quality control in PACS and RIS	44
Modality worklist	43
PACS and RIS troubleshooting	22
HL7 – interface or integration engine built specifically for the healthcare industry and connects legacy systems by using a standard messaging protocol	20
IT concepts in PACS (e.g. image size)	16
Adding components/modalities to the network	12
Network basics and communication speed	11
TCP/IP concepts	9

In total, 62 (42%) of the respondents indicated that they had not been exposed to any of the topics in Table 4.4 during their undergraduate studies. The topics most respondents indicated as having been included in their undergraduate teaching and learning programmes can be summarised as digital imaging equipment, processing and manipulation, PACS and RIS components and workflow concepts, modality worklist and DICOM standards, image display storage and archiving, and quality assurance and quality control in PACS, RIS and digital imaging. Digital imaging equipment was indicated by the 49% of respondense (*ƒ*=73) as a topic covered by undergraduate studies. Digital imaging and PACS were included in the radiography programmes at higher education institutions where the programme has been offered from 2007 onwards, as indicated by the lecturers of physics of digital imaging, PACS and RIS at these institutions (cf. 4.7). Therefore, the respondents (*ƒ*=62) who indicated that they had received no formal teaching and learning on the topics displayed in Table 4.4 during undergraduate studies, could be radiographers who had obtained their radiography qualifications before 2007.

The imaging informatics topics included in the diagnostic radiography undergraduate and postgraduate programmes since 2007, as displayed in Table 4.4, are all included in PACS administrator courses in countries such as the USA, Canada and UK, and in the middle east (Oosterwijk 2018; IBISEdu 2019; Michener Institute of Education 2019).

However, for most of these topics, only a basic level of knowledge and understanding is required by the radiography programme, whereas the PACS administrator course requires in-depth knowledge and is at a higher level of understanding. According to Peck (2018:196), radiographers moving into the imaging informatics speciality are not only involved in managing digital imaging equipment, digital image processing, manipulation, display, storing and archiving, typically through RIS and PACS; the radiographer PACS administrator also has IT-related tasks, such as PACS, RIS and workflow-related troubleshooting. They can also be involved with computer, printer, compact disc robot and document scanning problem-solving (Peck 2018:197). Section 4.2.3 will present information about radiographers who had trained in PACS, RIS and digital workflow in the workplace after new PACS installations.

4.2.3 Training of imaging informatics in the workplace

According to Hughes and Poletti (2016:696), imaging informatics or PACS administration professional originate from varied backgrounds, including having been IT specialists and radiographers. At the time of their research, there were very few imaging informatics training programmes in Australasia, and the radiographers and IT specialists had obtained most of their imaging informatics knowledge from the vendor IT or imaging informatics specialist, in the workplace. Training in the workplace is usually done by application specialists from the company or vendor from which the PACS and RIS system was purchased (Seikh 2016:111; Diagnostic Imaging 2003:1). According to a service-level agreement contract, the company is responsible for post-installation support and training of personnel and referring specialist on the PACS during working hours. A vendor will, therefore, provide training during and after installation, but it is unlikely that they will train numerous PACS users continuously (Yousem & Beauchamp 2008:225; Diagnostic Imaging 2003:2). Also, not all personnel will be able to attend the training sessions during regular working hours. Therefore, the PACS administrator, in collaboration with the IT team involved in the department, will then train radiographers and other personnel who were unable to attend the vendor training sessions. Senior radiographers will also be involved in workplace training of students on the PACS system (Huang 2019:560; Seikh 2016:111). Table 4.5 indicates the professional persons who respondents reported trained radiographers in PACS, RIS and digital workflow in the workplace after PACS installation.

Table 4.5: Professionals who trained respondents in imaging informatics in the workplace

Professional involved in imaging informatics training	*f* *Yes*
A peer (fellow radiographer, PACS administrator or IT specialist)	84
Vendor PACS application specialist	54
Your radiology department/practice PACS administrator	48
Your radiology department/practice IT specialist or manager	22
Vendor IT specialist	20
Sent to another radiology department/practice for training	2

The majority (*f*=84) of respondents indicated that most of the PACS and RIS training was presented by a peer; a fellow radiographer or radiographer PACS administrator. Other high-frequency responses were training by vendor PACS application specialists, and by the departments' PACS administrator. In a study done in Australia, Floyd, Trepp, Ipaki, and Ng (2015:316) indicate that 46.1% of the respondents learned about PACS in the workplace informally from their peers. The finding of the Australian study corresponds with the results of this study. Participant 104 said, *'It is hands-on training in practice, very much practical training'* (P104). According to Sapci and Sapci (2017:1186), students were consistently requesting additional opportunities for hands-on experience in health information technology and imaging informatics. The next section will display ratings of workplace learning by radiography and IT professionals.

4.2.3.1 *Rating of workplace training received*

The same topics used for teaching and learning in imaging informatics during undergraduate radiography studies (cf. Table 4.4) were used to rate the informal training the respondents received in the workplace during and after installation of digital radiology modalities, PACS and RIS. Table 4.6 displays the rating of workplace learning by radiography and IT professionals.

Table 4.6: Rating of the level of training received in the workplace (n = 149)

Topics	No Training	Some Training	Fair Training	Good Training	Excellent Training
	f	***f***	***f***	***f***	***f***
Digital imaging equipment	17	27	36	53	16
Digital imaging processing and manipulation	15	31	35	48	20
PACS components	18	37	38	42	14
PACS workflow concepts	31	36	32	38	12
RIS workflow concepts	34	38	30	36	11
Modality worklist	34	29	31	43	12
RIS workstations	31	34	32	40	12
Standards used: DICOM - a standard for handling, storing, printing, and transmitting information in medical imaging.	35	46	30	30	8
HL7 - interface or integration engine built specifically for the healthcare industry, which connects legacy systems by using a standard messaging protocol	100	15	24	8	2
TCP/IP concepts	103	17	18	9	2
Network basics and communication speed	88	33	9	14	5
IT concepts in PACS (e.g. image size)	71	34	19	20	5
Image display	29	47	31	32	10
Image storage and archiving	27	42	35	33	12
Quality assurance and quality control in PACS and RIS	54	34	29	22	10
Adding components/modalities to the network	87	25	18	13	6
PACS and RIS troubleshooting	60	38	23	19	9

HL7 standard messaging system (f=100) and TCP/IP (f=103) training was not covered in the workplace, as indicated by the high 'no training' response from the respondents. As stated before (cf. 4.2.2), formal radiography teaching and learning programmes of radiographers who qualified before 2007 did not include digital imaging, RIS and PACS concepts. Good training had been provided in digital imaging equipment (f=53), and digital imaging processing and manipulation (f=48). These topics were included in the formal radiography teaching and learning programmes in South Africa from 2007 to 2010 (cf. 4.2.2).

The next section reports the feedback by respondents on whether radiographers and IT professionals would benefit from formal postgraduate imaging informatics programmes in South Africa.

4.2.3.2 *Benefit of formal postgraduate imaging informatics programmes in South Africa*

Respondents were asked whether formal postgraduate PACS administration programmes (imaging informatics) in South Africa would be beneficial to radiographers and IT PACS administrators (imaging informatics professionals). Figure 4.6 displays the feedback of respondents on whether radiographers and IT professionals would benefit from formal postgraduate imaging informatics programmes in South Africa.

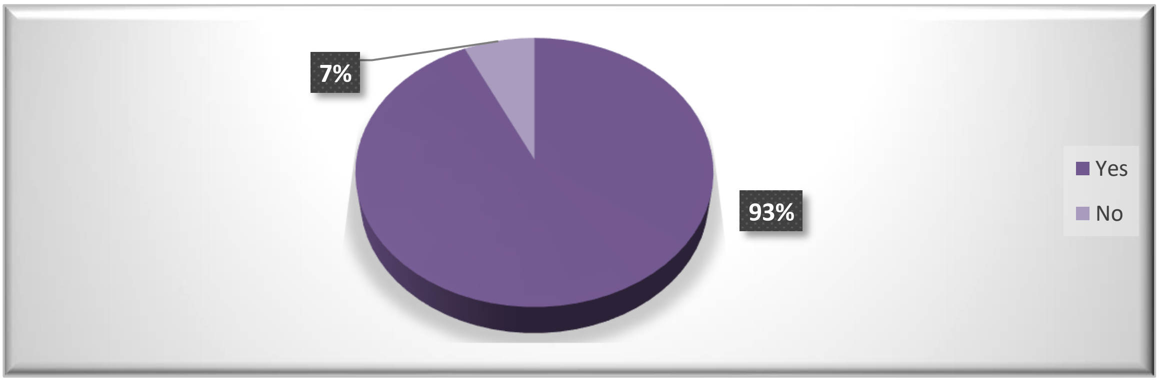


Figure 4.4: Benefit of PACS administration courses in South Africa

The majority (93%) of the respondents indicated that radiographer and IT PACS administrators (imaging informatics professionals) would benefit from a South African PACS administration course.

In an open question, respondents were asked to indicate why they believed a postgraduate course in imaging informatics could or would not be beneficial to radiographer and IT PACS administrators in South Africa. One respondent of the 97% who reacted positively about a postgraduate course in imaging informatics being beneficial, gave a reason for why it could be beneficial:

> *I do not think radiographers who have studied prior to the introduction of digital radiography has all the knowledge they need to know about it'*(P37).

Of the ten respondents who indicated it would not be beneficial, respondents 44 and 34 reacted as follows:

> *We have service providers who come and train radiographers* (P44).

> *All systems are different – in house training* (P34).

A SAQA and HPCSA accreditation qualification will enhance radiographers' skills and provide a new field in which they can specialise. Patient care will be enhanced, because healthcare professionals will be more knowledgeable about the imaging informatics field, which will ensure a better workflow in the radiology department (cf. 1.9.1; cf. 1.9.2). The next section will display the respondents' (n=149) rating of the importance of candidate topics for an imaging informatics teaching and learning course.

4.2.3.3 *Rating importance of candidate topics for imaging informatics*

The respondents were asked to rate the importance of candidate topics in imaging informatics, which are displayed in Tables 4.4 (undergraduate topics covered at higher education institutions) and 4.6 (training in the workplace). Table 4.7 displays the respondents' (n=149) rating of importance of candidate topics for an imaging informatics teaching and learning course.

Table 4.7: Rating importance of candidate topics for imaging informatics training

Topics	Not important		Important		Very important	
	f	%	*f*	%	*f*	%
Digital imaging equipment	3	2%	59	40%	87	58%
Digital imaging processing and manipulation	0	0%	62	42%	87	58%
PACS components	1	1%	59	40%	89	60%
PACS workflow concepts	1	1%	64	43%	84	56%
RIS workflow concepts	4	3%	64	43%	81	54%

Topics	Not important		Important		Very important	
	f	%	*f*	%	*f*	%
Modality worklist	6	4%	79	53%	64	43%
RIS workstations	5	3%	71	48%	73	49%
Standards used: DICOM - a standard for handling, storing, printing, and transmitting information in medical imaging.	4	3%	79	53%	66	44%
HL7 - interface or integration engine built specifically for the healthcare industry and connects legacy systems by using a standard messaging protocol.	15	10%	88	59%	46	31%
TCP/IP concepts.	18	12%	85	57%	46	31%
Network basics and communication speed	12	8%	84	56%	53	36%
IT concepts in PACS (e.g. image size)	6	4%	88	59%	55	37%
Image Display	0	0%	61	41%	88	59%
Image storage and archiving	2	1%	58	39%	89	60%
Quality assurance and quality control in PACS and RIS	1	1%	47	32%	101	68%
Adding components/modalities to the network	8	5%	87	58%	54	36%
PACS and RIS troubleshooting	1	1%	46	31%	102	68%

All the topics in Table 4.7 were rated by the respondents as either important or very important for the proposed imaging informatics teaching and learning model. According to NEMA MITA (2020:Online), medical imaging informatics involves digital imaging equipment; digital imaging processing, manipulation, distribution, archiving and storage; communication via networks and telecommunications; communication standards, such as DICOM and HL7; management of the information workflow in the digital imaging department; and integration of the information on the digital images with other relevant information in digital imaging departments. All the functions mentioned above are used in the radiology department in applications such as PACS, RIS, HIS, computer-aided diagnosis (CAD) and teleradiology (NEMA MITA 2020:Online), which is in agreement with the topics rated in Table 4.7.

Under 4.2.3.4, topics on imaging informatics principles that were suggested by the respondents for addition to the purposed instructional model for the teaching and learning of imaging informatics will be presented and discussed.

4.2.3.4 *Suggested important topics*

In an open-ended question, respondents were asked to suggest other topics that could be included in the teaching and learning model for imaging informatics in South Africa. The researcher sorted the topics suggested by the respondents under headings related to imaging informatics topics derived from the literature review (cf. 2.4.4; cf. 2.5; cf. 4.2.3.3) and stated by NEMA MITA (2020:Online). Table 4.8 displays the sorted candidate topics that were suggested by the respondents for inclusion in the purposed instructional model for teaching and learning imaging informatics.

Table 4.8: Other important candidate topic suggested by respondents

NETWORK and PACS TROUBLESHOOTING
PACS troubleshooting Downtime procedures for PACS General network and computer troubleshooting Network infrastructure
PACS
Training on PACS PACS in the rural hospital Specifications for PACS Link between HIS, RIS and PACS Image storage How to merge studies Troubleshooting to be done by all senior radiographers, not by PACS administration people only
IT
IT troubleshooting Computer basics General computer IT networks/information
RIS
RIS management Patient reports
HIS
HIS
WORKFLOW
How to ensure smooth workflow Training a multi-generational workforce Pathway of images and reports between radiologists and typist and where problems may arise Troubleshooting printers, networks and hardware
DIGITAL IMAGING AND QC FOR IMAGING EQUIPMENT
Relevance of centring/collimation in digital imaging Image manipulation Image printing Quality control of digital plates How to work with digital imaging equipment and the effects on radiographic technique Digital image quality evaluation criteria Image manipulation technique Multimodality processing and system limitations
QUALITY ASSURANCE AND QUALITY CONTROL IN PACS
Quality assurance and quality control Patient confidentiality and safe record keeping Confidentially Ethics and confidentiality Access, security, ethics and indemnity
CLINICAL
Short courses, for example, pattern recognition Role extension – pattern recognition Clinical experience

MANAGEMENT
Managing a department Project management General management
EDUCATION
Physics on digital imaging systems
INTEROPERABILITY
Network infrastructure needs to be coordinated with the hospital IT manager Needs someone with full computer sciences or related degree to ensure network stability HIS and RIS should be blended or work hand in hand Integration of all medical imaging modalities (ultrasound, nuclear medicine, radiotherapy, CT, MRI) with PACS and manipulation thereof Digital integration Quality/phantom tests mammography for PACS
DICOM CONCEPTS
Create an app for on the go viewing
EVOLVING IMAGING INFORMATICS
Future trends

Mendelson and Rubin (2013:1197) state that IT and informatics tools are the ultimate elements for creating radiology resolutions. The universal reception of the DICOM 3 standard initiated the PACS era (Mendelson & Rubin 2013:1197). IT tools are also involved in the solutions for quality measurements and delivery enhancement in the radiology department (Mendelson & Rubin 2013:1208). Management forms an integral part of a radiology department before, during and after the installation of a new PACS system. The PACS committee should be organised and managed well, to ensure that predicted outcomes will be achieved (Reed & Reed 2001:18), which indicate that management skills are a core component of imaging informatics teaching programmes. The relevant candidate topics that were suggested, were included under appropriate subthemes and themes in the first round of the Delphi questionnaire. The preferences of the respondents for formal education in imaging informatics will be presented and discussed below.

4.2.3.5 *Preference for formal education in imaging informatics*

Respondents were asked to rank their preferences for formal education in imaging informatics courses according to five teaching strategies. The ranking was made according to five options: 1 indicated their first, and 5 their fifth choice of preference. Table 4.9 presents the frequency distribution of the respondents' preferences regarding formal education in imaging informatics.

Table 4.9: Respondents' preference for formal education in imaging informatics

	1st		2nd		3rd		4th		5th	
	n	%	n	%	n	%	n	%	n	%
Full time lecturing	22	15%	14	9%	16	11%	13	9%	84	56%
Part time lecturing	53	36%	39	26%	14	9.3%	35	23.4%	8	5.3%
Distance learning	14	9%	34	23%	52	35%	23	15%	26	17%
eLearning	31	21%	32	21%	33	22%	36	24%	17	11%
Blended learning (Contact time and distance learning)	47	32%	37	25%	24	16%	18	12%	23	15%

More than half, 56%, of the respondents indicated full-time learning as their fifth option, which shows that it is their least preferred method of instruction; the reason could be that they work full time as qualified healthcare professionals. Part-time (36%) and blended learning (32%) were indicated as the most preferred methods of instruction. Blended learning has two 'legs', contact time and distance learning, which provides students with face-to-face contact sessions during which they can voice their questions and concerns (Kintu, Zhu & Kagambe 2017:1). The different summated theme scores emerging from questionnaire 1 will be presented and discussed next.

4.2.4 DESCRIPTIVE STATISTICS OF THE SUMMATED THEME SCORES

Theme scores were derived from undergraduate teaching and learning (cf. 4.2.2, Table 4.4) and workplace training topics (cf. 4.2.3.1, Table 4.6). Table 4.10 indicates the different themes that emerged from questionnaire 1.

Table 4.10: Summated theme scores from training in the workplace

Theme names	Theme codes
Digital imaging or Digital Radiography	DR_TW
Standards for interoperability in imaging informatics	II_TW
Networking in imaging informatics	NII_TW
Picture archiving communication systems	PACS_TW
Quality assurance and quality control	QAQC_TW
Radiology information systems	RIS_TW

Six summated themes scores emerged from training in the workplace (TW), which were included in the first-round Delphi questionnaire. The DR_TW theme comprises digital imaging equipment, image processing and manipulation. II_TW theme contains the standards HL7 and DICOM for interoperability in medical imaging informatics. NII_TW encompasses TCP/IP concepts, network basics and communication speed. PACS_TW includes PACS components and workflow concepts, IT concepts in PACS (e.g. image size), and image storage and archiving. QAQC_TW involves quality assurance and quality control in PACS and RIS troubleshooting. RIS_TW consists of RIS workstations, modality worklists and workflow concepts in RIS (cf. Table 4.4).

The theme scores for the level of training received in the workplace, as indicated in Table 4.11, show that fair training (neutral) was received for DR_TW (2.60 to 3.40), very little training for II_TW, NII_TW, and QAQC_TW (1.00 to 1.79), little training for PACS_TW (1.80 to 2.59), and good training for RIS_TW (3.41 to 4.20).

Table 4.11: Frequency distributions: Theme scores for the level of training received in the workplace (n = 149)

Themes	Very little training 1.00 to 1.79		Little training 1.80 to 2.59		Fair training 2.60 to 3.40		Good training 3.41 to 4.20		Excellent training 4.21 to 5.00	
DR_TW	23	15%	29	19%	**45**	**30%**	31	21%	21	14%
II_TW	**72**	**48%**	42	28%	14	9%	18	12%	3	2%
NII_TW	**100**	**67%**	21	14%	16	11%	6	4%	6	4%
PACS_TW	39	26%	**47**	**32%**	23	15%	28	19%	12	8%
QAQC_TW	**64**	**43%**	37	25%	16	11%	24	16%	8	5%
RIS_TW	35	23%	32	21%	31	21%	**37**	**25%**	14	9%

Cronbach's alpha coefficients for the reliability of the summated theme scores from questionnaire 1 will be presented in 4.2.5

4.2.5 Reliability of summated theme scores from Questionnaire 1

The reliability of the summated scores derived from the surveys was tested using a confidence interval of Cronbach's alpha. Cronbach's alpha is used to test for internal consistency or reliability of the measuring ability of the research instrument and, therefore, the results obtained. The interpretation intervals for Cronbach's alpha that were used are as follows: smaller than 0.50 equals unacceptable; between 0.50 and 0.69 equals acceptable; between 0.70 and 0.79 equals good; greater or equal to 0.80 equals excellent (cf. 3.4.5.1). Table 4.11 displays Cronbach's alpha coefficients for the reliability of the summated theme scores.

Table 4.12: Cronbach's alpha coefficients for the theme scores

Summated themes	Training received in the workplace (TW)		Importance of topics (Imp)	
Digital imaging or digital radiography	DR_TW	0.89	DR_Imp	0.82
Standards for interoperability in imaging informatics	II_TW	0.73	II_Imp	0.77

Summated themes	Training received in the workplace (TW)		Importance of topics (Imp)	
Networking in imaging informatics	NII_TW	0.85	NII_Imp	0.81
Picture archiving communication systems	PACS_TW	0.87	PACS_IMP	0.79
Quality assurance and quality control	QAQS_TW	0.76	QAQS_Imp	0.71
Radiology Information Systems	RIS_TW	0.95	RIS_Imp	0.89

All six themes scored a confidence interval of Cronbach's alpha higher than 0,70, which is an indication of a good to excellent reliability or internal consistency of the results for the theme scores for training received in the workplace and the importance of the topics.

4.2.6 Summary of questionnaire 1

From questionnaire 1, *assessment of radiographers' teaching and learning in imaging informatics,* six summated theme scores were derived. The topics making up each of the six themes were included in the first Delphi questionnaire (cf. Table 4.4). The topics are the following:

- Digital imaging equipment, image processing and manipulation;
- HL7 and DICOM standards in medical imaging;
- TCP/IP concepts, network basics and communication speed;
- PACS components and workflow concepts;
- IT concepts in PACS (e.g. image size) and image storage and archiving;
- Quality assurance and quality control in PACS, and RIS troubleshooting; and
- RIS workstations, modality worklists and workflow concepts.

The topics suggested by the respondents (Table 4.7) were grouped with the topics in the six summated themes derived from questionnaire 1 (cf. Table 4.10), for inclusion in the first-round Delphi questionnaire. The topics from Table 4.7 are the following,

- General network (IT) and computer basic, infrastructure and troubleshooting;
- Links between HIS, RIS and PACS and interaction with hospital IT manager
- PACS in rural hospitals;
- PACS and RIS specifications, troubleshooting and downtime procedures
- RIS management and tracking of patient reports in the workflow;
- Troubleshooting hardware components like DICOM digital printers, document scanners and CD robots;
- Digital imaging storage and retrieving;

- Digital imaging modality workflow, image quality evaluation and manipulation criteria;
- Multimodality processing and system limitations;
- Ethics, confidentiality and safe record keeping;
- Access, security and indemnity;
- Quality assurance and control of PACS related equipment;
- Project and general management in imaging informatics;
- Interoperability and digital integration in medical imaging informatics;
- Digital integration of all medical imaging modalities (e.g. US, nuclear medicine, RT, CT, MR) with PACS and manipulation thereof;
- Basic physics of digital imaging modalities and image formation;
- Application for PACS viewing on handheld devices (cf. Table 4.4);
- Future trends in imaging informatics;

In the next section, the findings of questionnaire 2 will be displayed and discussed.

4.3 QUESTIONNAIRE 2: IMAGING INFORMATICS EDUCATION IN SOUTH AFRICA

The discussion of the results of questionnaire 2, Assessment of radiographers' formal education in imaging informatics at higher (digital imaging, RIS and PACS) education institutions in South Africa, contains descriptions of questionnaire response rate, biographic and educational data of the respondents, as well as the imaging informatics principles covered during undergraduate and postgraduate qualifications in radiography programmes in South Africa (cf. 3.4.2).

After piloting Questionnaire 2, no changes were needed after the feedback from the respondents. As discussed in Chapter 3 (cf. 3.4.4.1), the target population was eight lecturers. The link to the questionnaire was sent to the head of the radiography departments of the eight higher education institutions, for distribution to the relevant lecturers; this procedure was followed to ensure optimal anonymity and confidentiality. The questionnaire was viewed 34 times on QuestionPro, of which only six attempts were completed and submitted. The low response rate can be contributed to only eight higher education institutions in South Africa offering the radiography programme, and only the lecturers in radiographic imaging technology and physics were recruited.

4.5.1 Demographic information and education of respondents

The six respondents of questionnaire 2 were two men (33%) and four women (67%). One respondent represented each of the age groups 20 to 29 and 40 to 49 and two each the age groups 30 to 39 and 50 to 59. The current employment status for the respondents included one junior and one senior lecturer and four lecturers. The respondents had studied at the following higher education institutions in South Africa: one each at Cape Peninsula University of Technology and Durban University of Technology, and two each at Nelson Mandela Metropolitan University (now known as Nelson Mandela University) and University of Pretoria. The education qualifications of the respondents were BTech degrees (33%), Diploma in Higher Education (17%), Master's degrees (33%) or PhD degree (17%). The respondents were also requested to provide feedback on the extent to which imaging informatics principles were covered in the undergraduate radiography syllabus, which will be reported in the next section.

4.3.1 Imaging informatics in radiography programmes

The researcher needed to make sense of the responses in Questionnaire 1 regarding undergraduate teaching and learning of imaging informatics principles (cf. Table 4.4). Therefore, the respondents of questionnaire 2 were asked to indicate the year when imaging informatics principles had been introduced into their curriculum for undergraduate and postgraduate radiography programmes. In order to ensure anonymity and confidentiality of the respondents, no questions were included that could identify the respondents or the higher education institution where they worked. Two respondents indicated 2007, three indicated 2008, and one indicated 2010 as the year imaging informatics principles had been introduced into their syllabi for undergraduate radiography programmes. For the postgraduate curriculum in radiography, two respondents specified 2005, two respondents revealed 2008, and one respondent signified 2010 as the year of the inclusion of imaging informatics principles. One respondent indicated that imaging informatics principles had not been included in their postgraduate radiography programme by the beginning of 2017.

4.3.2 Imaging informatics principles covered in undergraduate syllabus

The imaging informatics principles used in questionnaire 1 (cf. Table 4.4), where the respondents had to indicate whether the topics had been included in their undergraduate radiography studies, were also used in questionnaire 2. The lecturers had to show the extent to which these imaging informatics principles were covered in the undergraduate (cf. Table 4.18) and postgraduate (cf. Table 4.19) syllabi for radiographers. The five-point Likert scale used in these two tables consisted of the following categories; not included, basic principles, more than basic principles, advanced and comprehensive. Table 4.18 portrays the extent to which imaging informatics principles were covered in the undergraduate radiography syllabus.

Table 4.13: Imaging informatics principles covered in undergraduate syllabus

Imaging informatics principles	Not included		Basic principles		More than basic principles		Advanced		Comprehensive		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Digital imaging equipment	0	0	**2**	**33**	**3**	**50**	0	0	1	17	6	100
Digital imaging processing and manipulation	0	0	**2**	**33**	**3**	**50**	0	0	1	17	6	100
PACS components	0	0	**4**	**67**	**1**	**17**	0	0	1	17	6	100
PACS workflow concepts	1	17	**4**	**67**	**1**	**17**	0	0	0	0	6	100
RIS workflow concepts	1	17	**3**	**50**	**1**	**17**	0	0	1	17	6	100
Modality worklist	1	17	**3**	**50**	**1**	**17**	0	0	1	17	6	100
RIS workstations	1	17	**3**	**50**	**1**	**17**	0	0	1	17	6	100
Standards used: DICOM – a standard for handling, storing, printing, and transmitting information in medical imaging	0	0	**4**	**67**	**1**	**17**	0	0	1	17	6	100
HL7 - interface or integration engine built specifically for the healthcare industry and connects legacy systems by using a standard messaging protocol	**4**	**67**	2	33	0	0	0	0	0	0	6	100
TCP/IP concepts	**3**	**50**	**3**	**50**	0	0	0	0	0	0	6	100
Network basics and communication speed	1	17	**2**	**33**	**3**	**50**	0	0	0	0	6	100
IT concepts in PACS (e.g. image size)	1	17	0	0	**3**	**50**	**1**	**17**	1	17	6	100
Image display	0	0	**2**	**33**	**2**	**33**	**1**	**17**	1	17	6	100
Image storage and archiving	1	17	**2**	**33**	**1**	**17**	**1**	**17**	1	17	6	100
QA and QC in PACS and RIS	1	17	**3**	**50**	**1**	**17**	**1**	**17**	0	0	6	100
Adding components/modalities to the network	2	33	**4**	**67**	0	0	0	0	0	0	6	100
PACS and RIS troubleshooting	1	20	**4**	**80**	0	0	0	0	0	0	5	100

The majority (≥67%) of the respondents indicated that they covered imaging informatics principles on a basic to advanced level in the undergraduate syllabus. These principles were digital imaging equipment, processing and manipulation; PACS and RIS components, workstations, workflow concepts, troubleshooting, QA and QC and modality worklists; DICOM standards for interoperability in medical image informatics; network components, communication speed, image display, storage and archiving and adding components or modalities to the network. However, the majority (67%) of the respondents indicated that basic HL7 information was not included in the undergraduate training programme. The concept of TCP/IP was indicated as basics included in (50%) and excluded (50%) from the syllabus, by the respondents. Additionally, the extent to which imaging informatics principles were covered in the postgraduate training programme was investigated.

4.3.3 Imaging informatics principles covered in postgraduate syllabus

The respondents had to indicate the extent to which the imaging informatics principles displayed in Table 4.14 were covered during the postgraduate training programme. Table 4.14 displays the extent to which imaging informatics principles were covered in the postgraduate training programme.

Table 4.14: Imaging informatics principles covered in postgraduate syllabus

Imaging informatics principles	Not included		Basic principles		More than basic principles		Advanced		Comprehensive		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Digital imaging equipment	1	17	0	0	**2**	**33**	**3**	**50**	0	0	6	100
Digital imaging processing and manipulation	1	17	0	0	**1**	**17**	**4**	**67**	0	0	6	100
PACS components	1	17	0	0	**2**	**33**	**3**	**50**	0	0	6	100
PACS workflow concepts	1	17	0	0	**3**	**50**	**2**	**33**	0	0	6	100
RIS workflow concepts	1	17	0	0	**3**	**50**	**2**	**33**	0	0	6	100
Modality worklist	1	17	1	17	**2**	**33**	**2**	**33**	0	0	6	100
RIS workstations	1	17	0	0	**3**	**50**	**2**	**33**	0	0	6	100
Standards used: DICOM - a standard for handling, storing, printing, and transmitting information in medical imaging	1	17	**1**	**17**	**3**	**50**	0	0	1	17	6	100
HL7 - interface or integration engine built specifically for the healthcare industry and connects legacy systems by using a standard messaging protocol	2	33	**1**	**17**	**2**	**33**	0	0	1	17	6	100
TCP/IP concepts	1	17	**2**	**33**	**2**	**33**	1	17	0	0	6	100
Network basics and communication speed	1	17	0	0	**3**	**50**	**1**	**17**	1	17	6	100
IT concepts in PACS (e.g. image size)	1	17	0	0	1	17	**3**	**50**	**1**	**17**	6	100
Image display	1	17	0	0	1	17	**3**	**50**	**1**	**17**	6	100
Image storage and archiving	1	17	1	17	0	0	**3**	**50**	**1**	**17**	6	100
Quality assurance and quality control in PACS and RIS	1	17	1	17	**1**	**17**	**2**	**33**	**1**	**17**	6	100
Adding components/modalities to the network	1	17	**2**	**33**	**1**	**17**	**1**	**17**	1	17	6	100
PACS and RIS troubleshooting	1	20	**1**	**20**	**1**	**20**	**1**	**20**	**1**	**20**	5	100

The majority (≥67%) of the respondents indicated that some of the imaging informatics principles were covered on a more than basic to advanced level in the postgraduate syllabus. These imaging informatics principles were digital imaging equipment, image processing and manipulation, PACS and RIS components, and workflow concepts, modality worklist, RIS workstations and network basics and communication speed. Image display, storage and archiving, and IT concepts in PACS (e.g. image size) was indicated as covered at an advanced to comprehensive level in the postgraduate training programme. More than 50% of the respondents reported that HL7, DICOM standards, the concept of TCP/IP and adding components or modalities to the network, were covered at a basic to more than a basic level. Quality assurance, quality control and troubleshooting in PACS and RIS were indicated as receiving basic to advanced coverage during postgraduate training programmes.

Methodological triangulation is used to verify proposed results; however, it can also be used to conclude the comprehensiveness of data (Dźwigoł 2018:63). Methodological triangulation was used to validate the summated data derived from questionnaire 1, by using the same imaging informatics principles in questionnaire 2. The respondents to questionnaire 2 – lecturers – were asked to rate the level of coverage of the same imaging informatics principles during the undergraduate and postgraduate radiography programmes. The identical summated scores or themes as in questionnaire 1 were, therefore, derived from the findings of questionnaire 2. The next section will portray the reliability of the summated scores.

4.3.4 Descriptive statistics of the theme scores

A summary of the summated themes and topics derived from questionnaire 2 is displayed in Appendix AF.

4.3.4.1 *Reliability of summated theme scores derived from the survey*

As mentioned before (cf. 4.3.1), Cronbach's alpha confidence intervals were used to test the reliability of the summated themes scores derived from questionnaire 1. The same imaging informatics principles from questionnaire 1 were rated by the respondents in questionnaire 2 regarding the level of inclusion in undergraduate and postgraduate studies. Therefore, the same summated theme scores were tested for internal consistency. Table 4.15 indicates the Cronbach's alpha coefficients for the reliability of the summated theme scores derived from questionnaire 2 for the level of coverage of imaging informatics principles during undergraduate and postgraduate radiography study programmes.

Table 4.15: Cronbach's alpha coefficients for theme scores (n = 6)

Theme	Imaging Informatics principles covered in:			
	Undergraduate Syllabus		Postgraduate Syllabus	
Digital imaging (digital radiography)	DR_UG	**0,98**	DR_PG	**0,96**
Standards for interoperability in imaging informatics	II_UG	0,56	II_PG	**0,97**
Networking in imaging informatics	NII_UG	**0,81**	NII_PG	**0,97**
Picture archiving communication systems	PACS_UG	**0,87**	PACS_PG	**0,96**
Quality assurance and quality control	QAQC_UG	0,64	QAQS_PG	**0,91**
Radiology information systems	RIS_UG	**1,00**	RIS_PG	**0,98**

All six themes of the postgraduate syllabus scored above 0.90, which is in the Cronbach's alpha interval (≥0.80) that indicates an excellent internal consistency or reliability of the results obtained. Also, in the undergraduate syllabus, digital radiography, NII, PACS and RIS scored in the excellent interval. However, II_UG and QAQC_UG scored in the acceptable range for the undergraduate programme. The next section will portray the completeness and correctness scores of the theme scores for the level of inclusion in undergraduate programmes.

4.3.5 Completeness and correctness scores for inclusion level in undergraduate programmes

As mentioned before (cf. 4.3.2), descriptive statistics and inferential statistics for correctness and completeness of the summated scores derived from the survey (Appendix B), were measured to quantify the theme scores (cf. Table 4.15), for the level of inclusion in undergraduate (cf. Table 4.16) and postgraduate radiography programmes (cf. Table 4.18). The intervals of the theme scores for the level of inclusion of imaging informatics principles (topics) into the undergraduate (cf. Table 4.17) and postgraduate (cf. Table 4.19) radiography syllabi were reported under the following headings: not included, 1.00–1.79; basic principles, 1.80–2.59; more than basic principles, 2.60–3.40; advanced, 3.41–4.20; and comprehensive, 4.21–5.00. Table 4.16 displays the central tendency (mean) and dispersion or variability [standard deviation (SD)] of the theme scores for the level of inclusion of imaging informatics principles in the undergraduate syllabus.

Table 4.16: Measures of central tendency for theme scores in undergraduate syllabus

(n = 6)

	Mean	S.D.	Min.	Quartile 1	Median	Quartile 3	Max.
DR_UG	3,06	1,10	2,00	2,25	3,00	3,25	5,00
II_UG	2,00	0,77	1,50	1,50	1,75	2,00	3,50
NII_UG	1,83	0,55	1,00	1,50	2,00	2,25	2,33
PACS_UG	2,67	1,02	1,50	2,06	2,38	3,25	4,25
QAQS_UG	2,08	0,66	1,00	2,00	2,00	2,38	3,00
RIS_UG	2,50	1,38	1,00	2,00	2,00	2,75	5,00

The mean scores of NII_TW (M=1.83), II_TW (M=2.00), QAQC (M=2.08) and RIS_TW (2.50) fall into the 'basic principles' interval. The average scores for DR_TW (M=3.06) and PACS_TW (M=2.67) are in the 'more than basic principles' interval. Table 4.17 displays the intervals of the scores for the imaging informatics principles part of the undergraduate syllabus.

Table 4.17: Theme scores for topic part of undergraduate syllabus (n = 6)

	Not included [1.00 to 1.79)		Basic principles [1.80 to 2.59)		More than basics [2.60 to 3.40]		Advanced (3.41 to 4.20]		Comprehensive (4.21 to 5.00]	
DR_UG	0	0%	2	33%	3	50%	0	0%	1	17%
II_UG	3	50%	2	33%	0	0%	1	17%	0	0%
NII_UG	2	33%	4	67%	0	0%	0	0%	0	0%
PACS_UG	1	17%	3	50%	0	0%	1	17%	1	17%
QAQC_UG	1	17%	4	67%	1	17%	0	0%	0	0%
RIS_UG	1	17%	3	50%	1	17%	0	0%	1	17%

Three respondents (50%) indicated that the theme, standards for interoperability in imaging informatics (II_UG), was not included in the undergraduate syllabus. The majority (67%) responded that, for NII_UG and QAQC_UG, only the basic principles were covered. For DR_UG, PACS_UG and RIS_UG, the respondents indicated that basic to more than basic principles were covered. One of the respondents (17%) indicated that DR_UG, PACS_UG and RIS_UG were covered at a comprehensive level. The next section will indicate the central tendency and dispersion of the theme scores for the level of inclusion of imaging informatics principles in the postgraduate programmes.

4.3.6 Completeness and correctness scores of the theme scores for level of inclusion in postgraduate programmes

The intervals of the theme scores for the level of inclusion of imaging informatics principles or topics into the postgraduate radiography syllabus in Table 4.19 were reported under the same headings as for the undergraduate radiography syllabus (cf. Table 4.17). Table 4.18

indicates the central tendency and dispersion of the theme scores for the level of inclusion of imaging informatics principles in the postgraduate programme.

Table 4.18: Measures of central tendency for theme scores in postgraduate syllabus (n = 6)

Codes	Mean	S.D.	Minimum	Quartile 1	Median	Quartile 3	Maximum
DR_PG	3,33	1,21	1,00	3,33	3,67	4,00	4,33
II_PG	2,67	1,40	1,00	1,75	2,75	3,00	5,00
NII_PG	2,83	1,26	1,00	2,33	2,67	3,50	4,67
PACS_PG	3,25	1,22	1,00	3,06	3,50	3,94	4,50
QAQS_PG	3,00	1,41	1,00	2,25	3,00	3,75	5,00
RIS_PG	2,94	1,10	1,00	2,75	3,00	3,75	4,00

The mean scores of all six themes fall into the more than basic principles interval for the level of inclusion into the postgraduate radiography syllabus. Table 4.19 displays the intervals of the theme scores for the imaging informatics principles part of the postgraduate syllabus.

Table 4.19: Theme scores for topics part of postgraduate syllabi (n = 6)

	Not included [1.00 - 1.79)		Basic principles [1.80 - 2.59)		More than basics [2.60 - 3.40]		Advanced (3.41 - 4.20]		Comprehensive (4.21 to 5.00]	
DR_PG	1	17%	0	0%	2	33%	2	33%	1	17%
II_PG	2	33%	1	17%	2	33%	0	0%	1	17%
NII_PG	1	17%	2	33%	1	17%	1	17%	1	17%
PACS_PG	1	17%	0	0%	2	33%	2	33%	1	17%
QAQC_PG	1	17%	1	17%	2	33%	1	17%	1	17%
RIS_PG	1	17%	0	0%	3	50%	2	33%	0	0%

Four respondents (66%) reported that the theme II_PG was covered on a basic to comprehensive level during the postgraduate syllabus. However, two respondents signified that II_PG was not covered during postgraduate programmes. For the other five summated themes, the majority (>80%) of the respondents indicated basic principles to comprehensive coverage of imaging informatics principles during the postgraduate radiography syllabus.

4.3.7 Summary of questionnaire 2

The findings of questionnaire 2 were presented and discussed in Chapter 4 (cf. Section 4.3). The results report on undergraduate and postgraduate imaging informatics teaching and learning at South African higher education institutions that offer radiography programmes. These principles were similar to the ones investigated by questionnaire 1. From questionnaire 2, the same six summated theme scores were derived. Methodological triangulation was used to confirm findings suggested by questionnaire one, by using the same imaging informatics principles in questionnaire 2. Only eight higher education institutions in South Africa offer radiography programmes, which is the reason for the small sample group in questionnaire 2. The findings of questionnaire 3 will be displayed and discussed next.

4.4 QUESTIONNAIRE 3: IMAGING INFORMATICS PROFESSIONAL PRACTICE ANALYSIS

4.4.1 Introduction

Questionnaire 3 is a validated questionnaire used by the ABII to revise the contents and specifications for CIIP examination (cf. 3.4.2). Permission was obtained from the American Registry of Radiologic Technologists (cf. Addendum AE) to use the Imaging Informatics Professional Practice Analysis questionnaire (cf. Addendum C). After piloting structured questionnaire 3 (cf. 3.4.3.1), no changes were made to the questionnaire. The link to the questionnaire in the online survey programme, QuestionPro, was then sent to 25 imaging informatics or BMI professionals working in imaging informatics environments in private or public hospitals in South Africa, as discussed in Chapter 3 (cf. 3.4.3.3).

The questionnaire was viewed by 138 people (imaging or medical imaging informatics professionals) on the QuestionPro link, of whom 17 attempted, completed and submitted the questionnaire. The demographic information of the respondents will be discussed next. The possible reason for the small sample size could be that

4.4.2 Demographic information of the respondents

The demographic profiles of the respondents reported in the next section include employment, experience and education (Tables 4.20 to 4.23).

4.4.3 Primary job role, employment and experience

Table 4.20 depicts the respondents' primary job roles.

Table 4.20: Title of primary job

Primary job role	n	%
Imaging informaticist	3	18%
PACS administrator	3	18%
System analysts	1	6%
IT network engineer/IT staff	5	29%
Radiographer	1	6%
IT manager	2	12%
Computed radiography manager	1	6%
Clinical engineer	1	6%
Total	**17**	**100%**

The majority of the respondents were IT network engineers/IT staff (29%). System analysts, radiographer, computed radiography manager and clinical engineer were all represented by only one respondent. Table 4.21 represents the place of employment of the respondents.

Table 4.21: Place of employment

Place of employment	n	%
Hospital (single site)	8	47%
Healthcare system (multiple sites)	4	24%
Government agency	3	18%
University/education	2	12%
Total	**17**	**100%**

The majority (47%) of the respondents are employed at a single site hospital. Only two (12%) respondents are employed at a university (higher education institution). Table 4.22 portrays the experience of the respondents in imaging informatics.

Table 4.22: Experience in imaging informatics

Year ranges	n	%
< 2 years	3	18%
2 to 5 years	4	24%
5 to 9 years	4	24%
> 10 years	6	35%
Total	**17**	**100%**

The majority (35%) of the respondents have more than 10 years' experience in imaging informatics. Only three respondents have less than two years' experience in imaging informatics. The next section relates to the education of the respondents.

4.4.4 Education of respondents

Table 4.23 represent the highest qualification of the respondents.

Table 4.23: Highest qualification

Qualification	n	%
Certificate	4	24%
Diploma	5	29%
Postgraduate Diploma	2	12%
Bachelor's Degree	1	6%
Master's Degree	4	24%
Doctoral Degree or higher	1	6%
Total	**17**	**100%**

Four (29%) respondents had obtained diplomas at higher education institutions. One respondent had obtained a doctoral degree. Table 4.24 displays the responses of the respondents in response to being asked to indicate any shortfalls in the training they had received in imaging informatics at the higher education institutions where they had obtained their IT qualifications.

Table 4.24: Shortfalls in education programme regarding imaging informatics

Comments	n	%
Medical imaging formats and protocols were never mentioned or discussed. DICOM/HL7/etc. only became known 'on the job.'	1	6%
Formal PACS and RIS administration training	1	6%
Not applicable	3	18%
Not covered in standard IT syllabus No knowledge of it	2	12%
No formal programmes in South Africa	1	6%
Funds to obtain these devices and the skills to use them	1	6%
Clinical interpretation Not enough information related to illnesses and diseases	2	12%
I did not receive any education on this. This is not the field I work in	1	6%
Practical exposure Students do not receive enough exposure and troubleshooting of imaging informatics is not discussed in-depth, which I feel is something that must form part of the education programme.	2	12%
Integration of ICT with healthcare	1	6%
None, since software training by the vendor, is sufficient.	2	12%
Total	**17**	**100%**

Shortfalls highlighted in education programmes for imaging informatics by some of the respondents were as follows:

- Two respondents (12%) indicated a lack of practical exposure — '*students do not receive enough exposure and troubleshooting of imaging informatics is not discussed in-depth, which I feel is something that must form part of the education programme.*' (P17 and P18, Q2).
- One respondent (6%) signified a lack of '*formal PACS and RIS training*' (P2, Q2).
- Two respondents (12%) implied that not enough '*clinical interpretation*' and that '*information related to illnesses and diseases*' is not covered. (P7 & P11, Q2).
- One respondent (6%) denoted that '*medical imaging formats and protocols were never mentioned or discussed. DICOM/HL7/ etc. only became known on the job*' (P1, Q2).

However, two respondents (12%) believed that imaging informatics was not needed in their course,

'None, *since software training by the vendor is sufficient*' (P15, Q2).

The shortfalls regarding imaging informatics principles indicated by the respondents in their education programmes, as listed in Table 4.24, could be due to the small number of higher education institutions in South Africa offering health informatics as a specialist area in a postgraduate programme at the time of data collection (cf. 2.5). Respondents who indicated that training by vendors in the workplace is sufficient, also stated that they had more than ten years' experience in the imaging informatics environment. At the time of data collection with questionnaire 3, no imaging informatics teaching and learning programmes were available in South Africa.

4.4.5 Tasks performed by imaging informatics professionals

Tables 4.25 – 4.34 (questions 6 – 18) represent the results from questionnaire 3 and display the frequency distribution of the intervals of tasks performed by imaging informatics professionals in the imaging informatics environment. The six-point Likert scale used in most of the tables comprised intervals of daily, weekly, monthly, quarterly, yearly or less, and not responsible (cf. 3.4.2.1). For this section, in Tables 4:25, 4:26, and Tables 4:29 to 4:34, the researcher will *discuss the ranges from 'not responsible' to 'daily' feedback for tasks performed.* Table 4.25 displays the frequency distribution of the intervals of procurement tasks done.

Table 4.25: Frequency of tasks related to procurement (n = 17)

Procurement	**Frequency**											
Description of action	**Daily**		**Weekly**		**Monthly**		**Quarterly**		**Yearly or less**		**Not Responsible**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Develop a budgetary proposal for strategic capital approval (e.g. total cost of ownership or return on investments)	0	0	0	0	1	6	0	0	7	41	9	53
Develop the request for information, proposals, and quotes for vendor selection	0	0	1	6	2	12	1	6	4	24	9	53

Procurement	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Review vendors responses as technical review	0	0	0	0	1	6	2	12	7	41	7	41
Evaluate the vendor as a business review for industry reputation	0	0	0	0	1	6	3	18	5	29	8	47
Determine or evaluate need for technology enhancement or replacement	0	0	0	0	1	6	7	41	3	18	6	35
Evaluate technical requirements within the technology replacement assessment	0	0	0	0	2	12	4	24	4	24	7	41
Participate in developing contracts	0	0	0	0	0	0	3	18	2	12	12	71
Participate in evaluating contracts	0	0	0	0	0	0	3	18	3	18	11	65
Participate in negotiating contracts	0	0	0	0	0	0	1	6	3	18	13	76
Organise on-site demonstrations	0	0	0	0	2	12	0	0	9	53	6	35
Organise end-user evaluation	0	0	2	12	0	0	0	0	6	35	9	53

The primary job roles of the 17 respondents did not necessarily include all the procurement tasks listed in Table 4.25, which is evident from the responses in the 'not responsible' interval. The initial CIIP exam content outline comprised ten main performance domains, namely, procurement, project management, operations, communications, training and education, management, information technology, systems management, clinical engineering and medical informatics. Procurement only made up a 5% portion of the exam (ABII 2019b:1; Raymond & Nagy 2010:343). Although procurement made up only 5% of the CIIP exam, it is still important and had to be included in the first-round Delphi questionnaire, to seek the opinions of knowledgeable professionals regarding the topics that should be included in the instructional teaching model for imaging informatics.

Table 4.26 portrays the frequency distribution of the intervals of operational tasks done.

Table 4.26: Frequency of tasks related to operations tasks (n = 17)

Operation	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Designing and implementing problem-solving quality improvement, projects and procedures	0	0	1	6	5	29	2	12	6	35	3	18
Utilising common quality improvement tools (run chart or fishbone)	1	6	0	0	1	6	2	12	1	6	12	71
Implement policies to comply with interoperability of the future integrated NHI system	1	6	0	0	0	0	1	6	2	12	13	76
Implement policies to comply with the new POPI Act	1	6	0	0	2	12	0	0	5	29	9	53
Perform problem-solving strategies regarding data (LEAN, SixSigma)	1	6	0	0	0	0	0	0	2	12	14	82

The majority (>70%) of the respondents indicated that they are not responsible for three of the five tasks under operations. The majority (82%) of the respondents indicated that they were periodically involved with designing and implementing problem-solving quality improvement, projects and procedures. Although only 47% of respondents indicated that they are periodically involved in implementing policies to comply with the new POPI Act, the Act plays a vital role in imaging informatics in South Africa. The proclamation compliance requirements section of the POPI Act (RSA DoH 2020:1–4) was announced in the Government Gazette on 22 June 2020 and implemented on 1 July 2020, which means that medical imaging departments now have to comply with legislation that protects personal information of patients. Imaging informatics professionals should be knowledgeable about the Act and the implication of failure to adhere to it. Similarly, the action, implement policies to comply with interoperability of the future integrated NHI system, for which 76% of the respondents indicated that they are not responsible, is vital in the health department's drive to achieve "better health for all South Africans, enabled by person-centred digital health" (RSA DoH 2019:11). Utilising common quality improvement tools and problem-solving strategies regarding data in the imaging department, play an important role in the interaction between multiple medical (imaging) departments under the authority of one coordinating body, which could distribute medical images and other information for viewing in an expanded user community (Bui, Hsu, Arnold, El-Saden, Aberle & Taira, 2013:1057). In an open-ended question, respondents were asked to indicate which problem-solving strategies they used in their line of work. Table 4.27 presents tools for problem-solving strategies used by the respondents.

Table 4.27: Tools used for problem-solving strategies

Problem-solving strategies	n	%
Google	1	50%
Strata	1	50%
Total	**2**	**100%**

One respondent indicated Google, and another Strata as *problem-solving strategies* used in their line of work. Strata is used as an effective stratification design to divide a whole population into homogeneous strata, which achieves better precision in estimation (Reddy, Khan & Khan 2018:1). Table 4.28 portrays the responses of respondents on an open-ended question regarding the decision-making support tools they use in their line of work.

Table 4.28: Decision-making support tools

Description of action	n	%
HISPACS	1	50%
Strata & DHIS2	1	50%
Total	**2**	**100%**

Two respondents reported that they made use of *decision-making support tools,* such as HISPACS (n=1), and Strata and District Health Information System version 2 (DHIS2) (n=1). According to Etamesor, Ottih, Salihu and Okpani (2018:6), DHIS2 data provides a public health decision-making platform for different types of responses to be implemented. Table 4.29 displays the frequency distribution of the intervals for imaging informatics tasks done.

Table 4.29: Frequency of tasks related to imaging informatics (n = 17)

Imaging informatics	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Manage and implement the room or space design of the physical reading environment (e.g. lighting, chairs)	0	0	0	0	0	0	1	6	1	6	15	88
Determine policies and procedures for the import and export of outside images (e.g., images exchange or file exchange)	0	0	0	0	0	0	1	6	4	24	12	71

The majority (>70%) of the respondents indicated that they are not responsible for the imaging informatics tasks listed in the table. Physical reading room environments are usually designed and implemented by the project management team, which usually consists of the designers, architects, radiology or healthcare facility planners and radiology department personnel (clinical, administrative and IT) who are engaged in the preparation, design and upgrading of digital imaging reading room conditions (Amato 2015:3). Only two respondents indicated that they were involved in reading room upgrades. Five respondents reported that they have to determine policies and procedures for the import and export of outside images (e.g., images exchange or file exchange). The feedback could be influenced by the tendency of public healthcare institutions to have policy and procedure committees that are responsible for creating guidelines for the import and export of outside images (Policy Guideline Committee 2018: 1–3). Table 4.30 portrays the frequency distribution of the intervals of execution of clinical informatics tasks.

Table 4.30: Frequency of tasks related to clinical informatics (n = 17)

Clinical Informatics	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Manage or implement mammography interpretation workflow (e.g., breast centres of excellence)	0	0	0	0%	0	0	0	0	0	0	17	100
Design workflow for new implementation	0	0	0	0	0	0	1	6	3	18	13	76
Review workflow for process improvement	0	0	0	0	0	0	2	12	3	18	12	71
HIS	2	12	0	0	0	0	1	6	3	18	11	65
RIS	4	24	0	0	0	0	1	6	5	29	7	**41**
PACS	4	24	0	0	0	0	1	6	5	29	7	**41**
Dictation systems	2	12	1	6	0	0	1	6	4	24	9	**53**
Post-processing software of systems	0	0	2	12	0	0	2	12	4	24	9	**53**
Implement or manage peer review software	0	0	0	0	0	0	0	0	4	24	13	76
Implement or manage systems that comply with accreditation agencies for critical findings notifications	0	0	0	0	0	0	0	0	2	12	15	88
Implement and/or manage urgent findings delivery solutions	0	0	0	0	2	12	0	0	0	0	15	88
Implement and/or manage tumour management software	0	0	0	0	0	0	0	0	1	6	16	94
Perform clinical analytics	0	0	1	6	1	6	0	0	0	0	15	88
Assist to ensure the accurate use of ICD-10 codes	1	6	1	6	0	0	0	0	2	12	13	76
Assist in the implementation of ICD-10 conversion	0	0	1	6	0	0	0	0	1	6	15	88
Implement and/or manage dose tracking	1	6	1	6	0	0	0	0	0	0	15	88
Participate in radiation safety committee dose-tracking efforts	1	6	1	6	0	0	0	0	0	0	15	88
Implement and/or maintain decision support tools	2	12	0	0	0	0	0	0	1	6	14	82

All the respondents indicated that they were not responsible for managing or implementing mammography interpretation workflow (e.g. breast centres of excellence). However, imaging informatics professional or PACS administrators, in conjunction with the PACS IT team, are responsible for the managing or implementation of mammography interpretation workflow (Pham, Forsberg & Plecha 2017:137). Therefore, the topic, manage or implement mammography interpretation workflow, was included in the Delphi questionnaire. All the actions directly related to imaging informatics in a digital radiology department, namely, RIS, PACS, dictation systems and post-processing software of operations, were indicated by 47 to 65% as actions that they have to take on periodically and were, therefore, included in the first round Delphi questionnaire. All topics that respondents indicated that they have to attend to periodically were included in the Delphi, due to the diversity of respondents' current professional roles in the medical imaging informatics environment.

Table 4.31 depicts the frequency distribution of the intervals at which information technology tasks are executed.

Table 4.31: Information Technology (n = 17)

Information Technology	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Assess storage and archiving needs and determine appropriate architecture	0	0	0	0	3	18	2	12	3	18	9	53
Design and specify network architecture	0	0	0	0	0	0	1	6	8	47	8	47
Review and troubleshoot network performance	3	18	0	0	2	12	1	6	4	24	7	41
Manage and evaluate network configuration	2	12	1	6	1	6	1	6	5	29	7	41
Monitor and evaluate network metrics	3	18	0	0	2	12	0	0	2	12	10	**59**
Manage and maintain server architecture	3	18	1	6	1	6	1	6	2	12	9	53
Monitor and access servers	8	47	2	12	0	0	0	0	1	6	6	35
Access data from multiple databases and sources (e.g., SQL query)	6	35	0	0	1	6	1	6	2	12	7	41
Develop appropriate replacement schedule	0	0	0	0	0	0	2	12	6	35	9	53
Participate in the process for obsolescence planning	0	0	0	0	0	0	1	6	6	35	10	**59**
Operating systems	8	47	1	6	0	0	0	0	1	6	7	41
Mobile services	5	29	0	0	0	0	2	12	2	12	8	47
Browser	8	47	1	6	0	0	1	6	0	0	7	41
Domain name system (or service or server)	3	18	0	0	1	6	0	0	3	18	10	**59**
Group policy	3	18	0	0	0	0	1	6	3	18	10	**59**
Remote management (e.g., VM View, VPN)	6	35	1	6	0	0	0	0	2	12	8	47

The respondents declared a 41–65% involvement in all the IT tasks displayed in Table 4.31. As mentioned before (cf. 4.2.3.4), IT plays a very important role in radiology resolutions and quality measurements (Mendelson & Rubin 2013:1197). According to Ranschaert (2016:1), the mixture of two main improvements, that is, digitising of medical data and the internet, plays a fundamental role in the digital revolutions happening in healthcare, as well as in radiology. Several main alterations in communication and computer technologies have changed the delivery of services in radiology and, therefore, in imaging informatics. The internet has become an essential entry point for electronic transfer and distribution of data linked to health, which is a process known as e-Health (cf. 2.3.3.1 & 2.4.2) (Ranschaert 2016:2).

Ten respondents (59%) indicated that they are not responsible for four of the tasks in Table 4.30. According to Branstetter IV (2010:43–44), the PACS administrator is in charge of daily processes, also called the front end of the PACS appliance. In turn, the IT or PACS system manager is responsible for PACS matters that fall outside the range of normal daily processes, also called the back end. However, the imaging informatics professional title encompasses all the tasks under information technology (Branstetter IV 2010:42). Most of the topics in Table 4.30 were included in the first Delphi questionnaire.

Table 4.32 shows the frequency distribution of the intervals for system management tasks that respondents were involved in.

Table 4.32: System Management (n = 17)

System Management	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Determine requirements for systems capacity and performance	2	12	0	0	2	12	2	12	3	18	8	47
Develop and implement disaster recovery plan and business continuity strategies	0	0	1	6	0	0	0	0	7	41	9	53
Test disaster recovery procedures	0	0	0	0	3	18	0	0	4	24	10	59
Use problem management and system availability tools and strategies to monitor and detect problems	6	35	0	0	0	0	1	6	1	6	9	53
Use problem management and system availability tools and strategies to troubleshoot and diagnose problems	6	35	0	0	2	12	0	0	1	6	8	47
Plan and evaluate data migration procedures	0	0	0	0	2	12	0	0	4	24	11	**65**
Provide decision-makers with information about system status (management reporting)	1	6	2	12	5	29	2	12	2	12	5	29

More than 40% of the respondents disclosed that they are involved periodically with six of the seven management tasks in Table 4.32. However, 65% of the respondents revealed that they are not engaged with the planning and evaluation of data migration processes. PACS system managers or analysts usually work in a close relationship with the vendor of the system to manage and resolve important system complications (Branstetter 2010:44). Radiographers, according to Peck (2018:196), are currently the most common imaging informatics healthcare practitioners in the UK, with added duties in the informatics environment. Radiographers with sound IT literacy and who are known as problem-solvers, can, by stepping through the ranks, become PACS administrators and even system managers. These healthcare practitioners will, then, be seen as imaging informatics professionals responsible, as part of a team, for all the task in Table 4.32 (Peck 2018:197).

Table 4.33 reveals the frequency distribution of the intervals when informatics support is provided in clinical engineering domains.

Table 4.33: Clinical Engineering: Provide informatics support (n = 17)

Clinical Engineering: Provide informatics support	Frequency											
Description of action	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Breast imaging: Tomosynthesis	1	6	0	0	1	6	0	0	0	0	15	**88**
Nuclear medicine: PET/CT	1	6	0	0	1	6	0	0	0	0	15	**88**
Nuclear medicine: Nuclear cardiology (under the domain of nuclear medicine)	1	6	0	0	1	6	0	0	0	0	15	**88**
Cardiology: Nuclear cardiology (under the domain of cardiology)	1	6	0	0	1	6	0	0	0	0	15	**88**
Cardiology: electrophysiology	0	0	0	0	1	6	0	0	0	0	16	**94**
Support image chain management (e.g., DICOM, interface, integration, display, and archive)	5	29	3	18	0	0	1	6	2	12	6	35
Support information management (e.g., scanned documents, dictations, interface integration)	4	24	3	18	0	0	1	6	2	12	7	41
Support technical management (e.g., quality assurance/control, hardware, replacement)	4	24	0	0	2	12	3	18	0	0	8	47
Support regulatory policies (e.g., DoH SA, HPCSA, eHealth strategies)	1	6	1	6	1	6	1	6	3	18	10	59
Support standards of practice (e.g., Radiologic Society of SA, South African Bureau of Standards)	2	12	0	0	0	0	1	6	1	6	13	**76**

The majority (>75%) of the respondents indicated that they are not responsible for informatics support in the following clinical engineering domains: breast imaging: tomosynthesis, nuclear medicine: PET/CT, nuclear medicine: nuclear cardiology (under the domain of nuclear medicine), cardiology: nuclear cardiology (under the domain of cardiology), cardiology: electrophysiology (EP), and support standards of practice (e.g., Radiologic Society of South Africa, South African Bureau of Standards). The mainstream of medical practitioners and researchers in nuclear cardiology originate from the domain of cardiology. However, a smaller group of investigators originate from the clear diagnostic imaging fields of radiology and general nuclear medicine. The cardiologist doing nuclear cardiology may practice in the domain of non-invasive cardiac imaging. These non-invasive imaging techniques could include modalities such as electrophysiology, echocardiography, CT and MRI, in alliance with patient care (Zaret 2019:353). Imaging informatics professionals will be responsible for managing all data originating from these imaging modalities, in large public hospitals. More than 50% of the respondents indicated that they were involved in supporting image chain management, information management, and technical management (e.g., quality assurance and control, hardware, replacement).

As mentioned in the discussion in Table 4.30, the mammography modality forms part of most private and public diagnostic imaging departments. According to Oosterwijk (2013:Online) and Clunie *et al.* (2016:Online), the two initial informatics-related difficulties with breast imaging tomosynthesis is the workflow, due to a large number of images that need to be moved, and the coding and display of results. The imaging informatics professional or PACS administrator is responsible for monitoring and managing the workflow in this regard, as it is part of the diagnostic radiology department's PACS workflow.

Table 4.34 indicates the frequency distribution of the intervals for managing information or interaction with different medical imaging platforms.

Table 4.34: Clinical Engineering: Manage information and/or interact with (n = 17)

Clinical Engineering Manage information and/or interact with:	Frequency											
Description of actions	Daily		Weekly		Monthly		Quarterly		Yearly or less		Not Responsible	
	n	%	n	%	n	%	n	%	n	%	n	%
Pathology	3	18	1	6	1	6	0	0	2	12	10	59
Ophthalmology	2	12	1	6	2	12	0	0	2	12	10	59
Dentistry	1	6	0	0	2	12	0	0	1	6	13	76
Dermatology	1	6	0	0	2	12	0	0	1	6	13	76
Oncology	3	18	0	0	1	6	1	6	2	12	10	59
Endoscopy	1	6	0	0	1	6	0	0	1	6	14	82
Orthopaedic templates	2	12	0	0	1	6	0	0	1	6	13	76
Surgical planning	1	6	0	0	2	12	0	0	1	6	13	76
Stereotactic imaging	1	6	0	0	1	6	0	0	1	6	14	82

The majority (>60%) of the respondents indicated that they were not responsible for managing or interacting with the medical imaging platforms and software integrated into the platforms displayed in Table 4.34. However, for each of the medical imaging divisions stated under clinical engineering in Table 4.34, at least one of the respondents indicated that they had to manage or interact with the named departments daily.

The subspecialty of imaging informatics has been widely accepted and frequently considered as a crucial function in healthcare. Practically every clinical department in healthcare depends on imaging informatics. Depending on their role in the team, imaging informatics professionals need to interact with other clinical departments in healthcare facilities (ABII 2020:Online).

The majority (n>10) of the respondents indicated that they had had little to no contact with imaging informatics during their IT education programmes. The intervals at which the respondents engaged with topics included under procurement, operations, imaging informatics, clinical informatics, information technology, system management, clinical engineering: provide informatics support and managing information or interacting with different medical imaging platforms, varied. In a study done by Nagy *et al.* (2005:252), the researchers defined the PACS profession by the initial skills, training and capabilities PACS administrators should hold. They developed a list of behavioural, business and technical capabilities that are needed by committed PACS professionals. Few of the listed capabilities and skills required are embedded in a single professional, instead, the skills bridge the domains of radiographers, radiology administrators, IT specialists and information system analysts. Also, imaging informatics professionals who had successfully completed and passed the CIIP certification exam could work as IT specialists, PACS or department administrators, physicists, radiologists, or radiographers (Kho *et al.* 2012:681). Therefore, the finding indicated above 'regarding respondents' responses of not responsible could be the result of diversity in job roles in the imaging informatics team.

Mostly, if there was an indication of involvement on the part of respondents, topics were included in the first Delphi questionnaire under the headings mentioned above. In some of the tasks, no involvement was indicated by any respondents. These tasks were only included in the first-round Delphi questionnaire if they could be supported by the literature. The inclusion of tasks or topics were embedded in the discussion below each of Tables 4.25 to 4.34.

4.5 COLLECTIVE SUMMARY OF DELPHI INCLUSION

The first-round Delphi questionnaire was compiled, with categories (topics) included in imaging informatics principles, and information from imaging informatics or PACS administrators courses in countries globally, such as the USA, Canada and UK, as discussed in the literature review (cf. Chapter 2, Sections 2.4.4 and Section 2.5). Topics embedded in the summated groups derived from structured questionnaires 1 (radiographers' teaching and learning in imaging informatics) (cf. Table 4.10), and 2 (imaging informatics education in South Africa) (cf. Table 4.15) were also included. Furthermore, the relevant topics in questionnaire 3 (imaging informatics professional practice analysis) (cf. Section 4.4.5), where respondents reported their engagement under procurement, operations, imaging informatics, clinical informatics, information technology, systems management, clinical engineering: provide informatics support and managing information or interact with different medical imaging platforms, were also included. Other important candidate topics (cf. Section 4.2.3.4 and Table 4.8) in imaging informatics, as indicated by the respondents in Questionnaire 1, were sorted and then grouped with the categories, making up the six summated themes derived from questionnaire 1 into specific overarching imaging informatics principles (Section cf. 4.4), and formed part of the configuration of the first-round Delphi questionnaire. Other topics included in the first-round Delphi questionnaire are currently included in the radiography curriculum, in management (general management principles) and radiographic imaging technology (cf. 2.5).

4.6 CONCLUDING SUMMARY

In Chapter 4, the results of structured questionnaire 1, 2 and 3 were presented and discussed. The topics and six summated theme scores derived from the feedback of questionnaire 1 were evident in the feedback of questionnaire 2. Respondents to questionnaire 3 indicated their frequency of involvement in tasks associated with the eight categories that they were involved with. Generally, larger sample sizes denote higher accuracy and reliability in quantitative research to determine whether data accurately reflects the population as a whole (Bujang, Omar & Baharum 2018:85). In a study done by Bujang, Omar and Baharum (2018:85) they proposed that the Cronbach's alpha's coefficient be set at a minimum effect size of 0.5 for smaller sample groups (20–30). The reason for the limited sample groups for the three structured questionnaires were discussed under each of the questionnaire, as small sample groups affect the confident interval and the internal consistency and reliability of the research instrument (Frost 2020:128).

In the next chapter, Chapter 5, entitled, ***Results, data analysis and findings of the Delphi survey,*** the consensus, stability and statistically analysed data that was gathered from the three-round Delphi survey will be presented and discussed.

CHAPTER 5

RESULTS, DATA ANALYSIS AND FINDINGS OF THE DELPHI SURVEY

5.1 INTRODUCTION

In Chapter 4, a discussion of the data from the three structured questionnaires was presented. The findings relating to the structured questionnaires, in conjunction with the information discussed in the literature review, primed the final configuration of the first-round Delphi questionnaire. In this chapter, the results and outcomes of the Delphi questionnaires will be presented and discussed. In Chapter 3, the Delphi method was explained (cf. Section 3.4.2.2). The results will be presented and portrayed according to the three rounds in the Delphi survey.

5.2 EXPLANATION AND DELIBERATION OF THE DELPHI SURVEY

In this section, the results and findings of the Delphi survey will be reported for each of the three Delphi rounds, which will be followed by a summative debate of the outcomes of the survey.

5.2.1 Delphi questionnaire Round 1

In this section, an overview of the Delphi process will be delivered, and it comprises descriptive details in connection to the different sections, themes, subthemes, number of topics in each part, as well as the measuring scales that were used. A summary of the results and the analysis of the responses will also be presented.

5.2.1.1 *The data collection instrument*

The questionnaire constructed in QuestionPro included an information letter (cf. Addendum D), in which the respondents were asked to participate and informed about the research, the completion process to be followed and the structure of the questionnaire. After reading the information letter, the respondents needed to select 'I agree' before starting the questionnaire – doing so was considered as informed consent. Data collection for the Delphi questionnaire survey was done over nine months, giving the Delphi panellists 12 weeks to complete each questionnaire (cf. 3.4.4.5). After each subtheme, an option of 'save and return later' was inserted, to enable respondents to complete the Delphi questionnaire rounds as time permitted. The QuestionPro link to the first Delphi questionnaire was sent to 25 experts who are regarded as knowledgeable in the field of imaging informatics; 19 respondents started, but only 15 completed and submitted the first round of the Delphi questionnaire.

The first Delphi questionnaire (cf. 3.4.2) consisted of four themes (sections), which were partitioned into different sub-themes and categories (topics). The separate sections (themes) had between four and six subthemes (A=6, B=6, C=5, and D=4) each. Each of the subthemes had several categories that the Delphi panellists had to assess on an adapted three-point Likert scale. The scale, as outlined in the information letter to the Delphi panellists in the first round (cf. Addendum D), offered the following options:

1) Essential – include (**include in the model**),
2) Useful – include with edits (**can be included in the model**), and
3) Unnecessary – remove from the list (**exclude from the model**).

The first Delphi questionnaire formed the basic structure in the Delphi survey for all three rounds. After each subtheme, space was provided for the respondents who selected the option, 'include with edits' to make comments or suggest edits for the following Delphi questionnaire round. This practice was followed in all three Delphi rounds. The researcher used the comments to make changes to the structure of the topic or statements in the following rounds, to enable a clearer description. The layout of the first Delphi questionnaire will be discussed next, and only comments or edits suggested by the respondents will be highlighted for the second and third round of the Delphi survey. The first-round questionnaire of the Delphi study started with questions on the demographics of the respondents. Thereafter, it was divided into four themes, A, B, C and D, with several subthemes for each theme, and multiple categories or statements under each subtheme, as displayed below.

Each of these subthemes contained several categories or statements (n=60)

(A)	*IT PACS – imaging informatics (for radiographer PACS administrators)*, which was derived from the themes that had emerged from the first structured questionnaire (cf. Addendum D), dealt with IT-related subthemes on imaging informatics. The subthemes included,
A1)	Basic computer science, related to basic computer and network knowledge;
A2)	Networking in imaging informatics, related to networks (familiar mostly to IT

	specialists);
A3)	Quality assurance and quality control for PACS and RIS, related to troubleshooting in these domains;
A4)	HIS and RIS, related to information systems in the hospital and radiology department, as well as the functions on the RIS;
A5)	PACS, related to the elements and actions needed on this platform; and
A6)	Clinical informatics, related to the interaction of other domain software with PACS.

Each of these subthemes contains several topics or statements (n=51).

(B)	*Clinical PACS – clinical training (for IT PACS administrators)*, was constructed from information gathered through the literature review on PACS administration courses internationally, and the comments made by the respondents on the open-ended question (cf. Table 4.8), 'list other possible candidate topics in imaging informatics', of the first structured questionnaire, and the radiographic procedures and clinical modules (RRP and RCP) that radiography students learn about in the four-year professional qualification presented by the higher education institutions where the researcher worked at the time. Clinical PACS dealt with subthemes related to the clinical nature of imaging informatics (mostly familiar to radiographers) and included the following:
B1)	Concepts of medical imaging, related to digital medical imaging;
B2)	Elements of the healthcare structure in South Africa;
B3)	Basic human anatomy concept and body systems;
B4)	Quality assurance and quality control in medical imaging;
B5)	Physics and characteristics of present digital imaging modalities; and
B6)	Digital imaging modalities for inclusion in the teaching programme.

Each of these subthemes contains several categories or statements (n=32).

(C)	*Management and ethical principles in imaging informatics* dealt with the following subthemes related to management and ethical principles:
C1)	Procurement tasks;
C2)	Project management related tasks;
C3)	System management tasks;
C4)	General management tasks; and
C5)	Ethical concepts and principles in imaging informatics.

Each of these subthemes contains several categories or statements (n=27).

(D)	Clinical engineering (for IT and radiographer PACS administrators), which was constructed from the results of the third structured questionnaire, dealt with the following subthemes:
D1)	Manage information and interact with different medical imaging departments;
D2)	Provide informatics support to various medical imaging modalities and healthcare bodies;
D3)	Use different problem-solving strategies; and
D4)	Have a good understanding of the standards for interoperability in imaging informatics and eHealth.

5.2.1.2 *Analysis of Delphi questionnaire Round 1*

The researcher solicited the assistance of a statistician to analyse and verify all three rounds of the Delphi survey responses. The frequency of the responses was calculated for the different statements on the adapted three-point Likert scale (cf. 5.2.1.1). All categories or statements with a consensus score equal to or more than 80%, namely essential – include in the model, were omitted from the next round (cf. 3.4.2.2).

5.2.1.3 *Results of Delphi questionnaire Round 1*

Round 1 was completed by 15 Delphi panellist members who submitted the questionnaire. Consensus was achieved on 58 of the 170 statements (categories) included under the subthemes of the four themes. One of the 170 statements in the first Delphi round was incorporated into two existing statement, which is the reason for the 111 and not 112 statements carried over to the second Delphi round. See the explanation in the next paragraph. In the feedback letter to the respondents (cf. Addendum E) on the results of the Round 1 Delphi questionnaire, the 58 statements were highlighted in green. Participants received feedback on their score status in relation to the total representation, which allowed them the opportunity to review their previous scores in relation to the group response. Delphi questionnaire Round 2 included 111 statements plus 12 new questions (n=123) derived from suggestions made by the respondents, as well as all applicable adjustments to the topics, according to the edits suggested by the respondents during Round 1 (cf. Addendum D). In order to eliminate any uncertainty during Round 2, the researcher also addressed any questions or suggestions by the respondents to add more statements.

Statement B4.4 refers to the quality assurance and control procedures applicable to digital imaging modalities, and accessories such as digital detectors or CR imaging plates, and was omitted from rounds 2 and 3. A comment on the statement by a panellist during Round 1, *needs to be specific to monitor QC [quality control], for QC on modalities and radiation testing this would normally be the responsibility of the chief radiographer,* was incorporated into statements B4.3 and B4.5. In statement A2.1, the research, in error, included IHE together with TCP/IT in the statement. The error was corrected in Round 2’s questionnaire, where IHE was removed from the statement and incorporated into new statements that were added – D4.6 and D4.7 – to the Round 2 questionnaire.

5.2.2 Delphi questionnaire Round 2

Regarding the second round of the Delphi, changes made to the measuring instrument used in Round 1 in response to comments made by the respondents (for possible edits), will be discussed under the data collection instrument. Similar to Round 1, a summary of the findings and the analysis process will be presented.

5.2.2.1 *The data collection instrument*

The feedback on the results sent to the panellists after Round 1 questionnaire, included quantitative data (e.g. frequency distributions of summated selections) and qualitative data (comments made in the questionnaire) (cf. 3.4.4.5). Two weeks after sending Delphi panellists feedback (cf. Addendum E) on the consensus results of the Delphi questionnaire Round 1, the Round 2 questionnaire (cf. Addendum F) was distributed to the 15 panellists via QuestionPro. The layout of the questionnaire in QuestionPro was adjusted to include the comments made by the panellists during Round 1. Similar to the Round 1 questionnaire, an information letter (cf. Addendum F) was included, providing information and completion instructions for Round 2's questionnaire.

5.2.2.2 *Analysis of Delphi questionnaire Round 2*

As in Round 1 (cf. 5.2.1.3), a statistician analysed the data. As for Round 1, the frequency distributions and percentages of the responses to the statements were calculated on the adapted three-point Likert scale (cf. 5.2.1.1) findings. Central tendency and dispersion between rounds 2 and 3 were also calculated for the mean and median (central tendency) standard deviation (level of dispersion) (cf. 3.4.5.2). All categories or statements with a consensus score equal to or exceeding 80%, namely essential – include in the model, were omitted from the Delphi questionnaire Round 3 (cf. 3.4.2).

5.2.2.3 *Results of Delphi questionnaire Round 2*

Only 13 of the 15 Delphi panellists of the second round, completed and submitted the third-round questionnaire. Consensus was reached on 49 of the 123 statements included under the subthemes of the four sections. In Round 2, the 49 statements on which consensus was reached, were highlighted in green in the feedback letter (cf. Addendum G) to the panellists. The Delphi questionnaire Round 3 included the remaining 74 statements on which consensus was not reached, as well as four extra topics that had been recommended (n=78). Adjustments were made to existing questions in relation to comments or edits suggested by the respondents during Round 2 (cf. Addendum G). Any questions that were raised were also addressed, to ensure that there would be no uncertainty during the completion of the Round 3 questionnaire.

5.2.3 Delphi questionnaire Round 3

In Round 3, which was the final round of the Delphi survey, the same procedure was followed as for the first two rounds. A feedback letter (cf. Addendum G) with consensus results from Round 2 was sent two weeks before the Round 3 questionnaire (cf. Addendum H) was dispatched to the panellists via the QuestionPro link. The results included all statement scores with consensus scores equal to or higher than 80%, namely essential – include in the model, which were omitted from the Delphi questionnaire Round 3, and which were highlighted in green. All the comments and suggestions made by the panellists, as well as explanations on the questions posed, were included in the results. Participants were, again, informed of their score status in relation to the total depiction, which enabled them to evaluate their previous scores in relation to the group response.

As in Round 2, a summary of the results and the process of statistical analysis will be discussed.

5.2.3.1 *The data collection instrument*

The same process was followed for the Delphi questionnaire Round 3 as for rounds 1 and 2. An information letter that thanked the panellists for their willingness to take part and provided complete instructions for the last Delphi round, connected to the Round 3 questionnaire (cf. Addendum H), was despatched to the remaining 13 respondents via a QuestionPro link. In Round 3, the goal was to reach maximum consensus. Participants had another opportunity to either change their selections or to retain their previous views.

5.2.3.2 *Analysis of Delphi questionnaire Round 3*

As in rounds 1 and 2 (cf. 5.2.1.2 and 5.2.2.2), a statistician analysed the data. Like in Round 2, descriptive statistics for frequency distributions and percentages of the responses on the statements were calculated in accordance with the adapted three-point Likert scale (cf. 5.2.1.1) findings. Central tendency and dispersion between Round 1, Round 2 and 3 were also calculated regarding the mean and median (central tendency) standard deviation (level of dispersion) (cf. 3.4.5.2). Kendall's CC (weighted) statistics for interrater reliability were processed on the consensus levels of the subthemes between rounds 2 and 3 of the Delphi survey.

5.2.3.3 *The findings of Delphi questionnaire Round 3*

Only 12 of the 13 panellists completed and submitted the Round 3 questionnaire. Consensus was reached on 35 of the 78 statements included under the subthemes of the four sections. After three rounds of the Delphi, consensus was achieved on 142 of the 184 statements. After Round 3, stability was proclaimed on 37 of the 184 statements, presenting a 20% total stability. The following statistical measures were used to enable the researcher to present data about the collective deductions of respondents in the Delphi study: (1) level of dispersion (standard deviation); and (2) degree of central tendency (means, median) (Hsu & Sandford 2007:4). Scheibe, Skutsch and Schoffer (1975 as cited in Hsu & Sandford 2007:4) are of the opinion that percentage measurements for stability are insufficient and suggest that measuring the stability of experts' responses in consecutive iterations is more reliable for proclaiming stability. In this study, stability was only considered in the case of a combined (added) score equal to or larger than 80% for essential – include in the model, and useful – can be included in the model. Consensus or stability was reached on a total of 179 of the 184 statements (97%). On five of the statements, no consensus or stability was reached (cf. A1.11, A1.13, A2.11, A2.13, D3.3).

5.2.4 Demographic information of the Delphi respondents

Demographic information of the respondents was solicited only during Round 1. Thereafter, the respondents only had to confirm their email address for dispatching the next round of the Delphi questionnaire. Table 5.1 portrays the demographic information of the Delphi panellists.

Table 5.1: Demographic information of the Delphi panellists (n=15)

Code	M/F	Country	Highest Qualification	Current work role (job title)	Years of Experience	Delphi rounds
DR1	M	UK	Master's degree	Health informatics director	16-20	3
DR2	M	SA	Electric engineering Diploma	Imaging informatics teaching company director	20 plus	3
DR3	F	SA	Advanced postgrad diploma	Retired radiographer PACS administrator	6-10	3
DR4	M	USA	Master's degree	Radiographer PACS administrator	20 plus	3
DR5	M	USA	Master's degree	Imaging informatics teaching company director	20 plus	3

Code	M/F	Country	Highest Qualification	Current work role (job title)	Years of Experience	Delphi rounds
DR6	M	SA	Master's degree	Vendor application specialist	6-10	2
DR7	M	SA	PhD	Radiologist	6-10	3
DR8	M	UK	PhD	Retired IT PACS administrator and presenter of PACS administration courses	20 plus	3
DR9	M	SA	Master's degree	Radiologist	11-15	1
DR10	M	SA	Master's degree	Radiologist	11-15	3
DR11	M	SA	Master's degree	Radiologist	6-10	3
DR12	F	SA	Diploma in Radiography	Vendor application specialist	6-10	3
DR13	M	SA	Master's degree	IT Manager	6-10	3
DR14	M	SA	Bachelor's degree	Vendor IT specialist	6-10	1
DR15	M	USA	Master's degree	Health information technology consultant	20 plus	3

DR – Delphi respondent

The majority (67%) of the Delphi panellists (N=15) were from South Africa, 13% were from the UK and 20% were from the USA. Only 13% of the respondents were women, and 87% were men. The majority (60%) of the respondents had Master's degrees, mostly in IT and health information technology. Two of the respondents had doctoral degrees. All the respondents had more than six years of experience in the medical imaging informatics field, of which five had more than 21 years.

The Delphi panellists were a heterogeneous group of professionals who were regarded as knowledgeable in the field of imaging informatics. According to Coulter, Adams and Shekelle (1995:577) and Boulkedid *et al.* (2011:5), a heterogeneous sample of Delphi panellists improves the presentation, as it makes a broader diversity of perspectives from the respondents possible. Therefore, in order to enhance the credibility of the results of the Delphi survey, the researcher included a wide range of professionals involved in the imaging informatics environment. The original number of Delphi panellists (N=15) decreased during the second round, to 13, and 12 in the third round.

5.2.5 Summative discussion on the three-round Delphi survey

The results of the three-round Delphi survey indicate a consensus score of 34% (n=58) of the 170 statements after Round 1. After Round 2, the consensus score increased to 39%

(n=49) of the 123 statements, and after Round 3 the consensus score increased to 44% (n=35) of the 79 statements. Total consensus achieved was 77% (n=142) of the 184 statements included in all three rounds. Stability was proclaimed on 20% (n=37) of the 184 statements.

The model for teaching imaging informatics in a future integrated NHI system in South Africa should include all the statements on which consensus was achieved and which were considered to be essential by the panellists. Statements on which consensus was reached and which were deemed useful, but not fundamentally essential, could add value to a model of this kind. Statements on which consensus was reached and which were deemed to be unnecessary by the panellists, were eliminated from the model.

Table 5.2 gives a detailed analysis of consensus statements for all three rounds of the Delphi survey. Consensus statements for the ratings essential – include, useful – include with edits, and unnecessary – remove from the list, were included. For the third – final – round, statements for which stability scores were proclaimed, are displayed in Table 5.2.

Table 5.2: Consensus results for the three rounds of the Delphi survey

SECTION A: IT PACS: IMAGING INFORMATICS (For radiographer PACS administrators)				
A1	**BASIC COMPUTER SCIENCE** ***Radiographer PACS administrators should have a basic knowledge of the following computer components and networks:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A1.1	R1 Hardware components	87	13	0
A1.2	R1Software components	93	7	0
A1.4	R3 Random access memory (RAM) parameters (*the type*)	17	83	0
A1.5	R3 Internal memory parameters and performance (*what it is*)	17	83	0
A1.6	R1 Concepts on computer addressing - Internet protocol (IP)/MAC	87	13	0
A1.7	R1 General computer IT network and information	87	13	0
A1.8	R3 Characteristics of different Operating Systems	17	83	0
A1.9	R1 Basic Windows functions, features and be able to change properties	93	7	0
A1.10	R1 How to use the Browser (Web Browser) like Google (Chrome), Internet Explorer, Firefox, etc.	87	13	0
A1.12	R3 Troubleshooting of hardware components, like printers and CD/DVD robots	100	0	0

A2	**NETWORKING IN IMAGING INFORMATICS** ***Radiographer PACS administrators should be knowledgeable about the following:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A2.1	R2 Transmission Control Protocol/Internet Protocol (TCP/IT) concepts	92	28	0
A2.2	R1 Network infrastructure, basics, terminology, and communication speed	93	7	0
A2.3	R1 How to access network connections	87	13	0
A2.4	R2 How to add components or modalities to the network	100	0	0
A2.5	R2 R1 How to set network downtime procedures	85	8	0
A2.6	R3 The Open System Interconnection (OSI) seven-layer model that 'characterises and standardises the communication functions of a telecommunication or computer system'	0	92	8
A2.7	R3 How to set-up remote management - Virtual Private Network (VPN)	92	8	0
A2.8	R2 The Domain Name System (DNS)/Service or Server (*Basic knowledge*)	15	85	0
A2.10	R3 Set-up and management of mobile services (*PACS related)*	17	83	0
A2.14	R1 How to do network troubleshooting	80	20	0

A3	**QUALITY ASSURANCE AND QUALITY CONTROL** ***Radiographer PACS Administrators should be knowledgeable about and able to do the following:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A3.1	R1 The process of PACS and RIS troubleshooting	100	0	0
A3.2	R3 Appoint responsible person/s for troubleshooting of PACS and RIS	100	0	0
A3.3	R1 Quality Assurance and Quality Control in PACS and RIS	100	0	0
A3.4	R1 Match (merging) images, series or studies in PACS	93	7	0
A3.5	R1 All quality assurance actions needed in RIS and PACS	100	0	0

A4	**HIS AND RIS** ***Radiographer PACS administrators should be knowledgeable about the following concepts:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A4.1	R2 Hospital Information Systems (HIS)	85	8	0
A4.2	R2 Electronic Medical Records (EMR)	85	8	0
A4.3	R1 Radiology Information Systems (RIS) workflow concepts	100	0	0
A4.4	R1 Modality worklist and troubleshooting there-of	100	0	0
A4.5	R1Operation of RIS workstations	87	13	0
A4.6	R1 The reporting workflow information	100	0	0
A4.7	R1 Competency of RIS troubleshooting	87	13	0
A4.8	R2 Different dictation systems	85	15	0
A4.10	R2 Enrolment of new users on RIS workstations and fingerprint scanners	85	8	0

A5	**PICTURE ARCHIVING COMMUNICATION SYSTEMS (PACS)** ***Radiographer PACS administrators should be knowledgeable about the following concepts regarding PACS:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A5.1	R1 PACS components	100	0	0
A5.2	R1 PACS workflow concepts	100	0	0
A5.3	R1 Information technology (IT) concepts in PACS (e.g., image size)	100	0	0
A5.4	R1 Evaluation of image storage, archiving and retrieving needs, operations and architecture	87	7	7
A5.5	R1 All PACS troubleshooting actions	100	0	0
A5.6	R1 PACS specifications	87	7	7
A5.7	R1 Setup of PACS downtime procedures	80	20	0
A5.8	R2 Create policies and procedures for images/file exchanges	85	8	0
A5.9	R2 Operation of PACS in the Rural Hospitals	85	8	0
A5.10	R1 Import and export images from and to CD/DVDs	100	0	0
A5.11	R1 The process of digitization and workflow of hard-copy images (x-ray films)	87	13	0

A6	**CLINICAL INFORMATICS** ***Radiographer PACS Administrators should be knowledgeable regarding the implementation of:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A6.1	R1 Mammography interpretation workflow	80	20	0
A6.2	R2 Post-processing software of digital modalities	85	15	0
A6.3	R3 Tumour management software	8	92	0
A6.4	R3 Accurate use and conversion of ICD-10 codes	8	92	0
A6.5	R1 Dose tracking and efforts	80	20	0
A6.6	R3 Performance of Clinical Analytics in Radiology	8	92	0

SECTION B: CLINICAL PACS – CLINICAL TRAINING (FOR IT SPECIALIST PACS ADMINISTRATORS)				
B1	**CONCEPTS OF MEDICAL IMAGING** ***IT PACS administrators should be introduced to the following concepts of medical imaging:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B1.1	R3 The history of medical imaging	0	92	8
B1.3	R3 The general process of digital medical image formation and processing (*very basic level*)	83	17	0
B1.4	R3 The sequence (cycle) of digital medical imaging (*basic level*)	92	8	0
B1.8	R1 The different aspects of image quality and the factors affecting it	80	20	0

B2	**ELEMENTS OF THE HEALTHCARE STRUCTURE IN SOUTH AFRICA** ***IT PACS administrators should be knowledgeable on the elements of the Healthcare structure in South Africa***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B2.2	R2 Be able to analyse different health systems	0	85	15
B2.3	R2 The administration and organisation of South African hospitals	8	85	8
B2.4	R1 Effective communication between healthcare professionals	80	20	0

B3	**HUMAN ANATOMY CONCEPTS AND BODY SYSTEMS** ***IT PACS administrators should have basic knowledge regarding the following human anatomy concepts and body systems***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B3.1	R1 Medical terminology and general body positions	80	13	7
B3.2	R3 Body landmarks and planes	83	17	0

B4	**QUALITY ASSURANCE (QA) AND QUALITY CONTROL (QC) IN MEDICAL IMAGING** ***Quality assurance (QA) and quality control (QC) in medical imaging for IT PACS administrators***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B4.1	R1 Should have a basic knowledge of radiation protection and radiation safety principles	80	13	7
B4.2	R2 Should be familiar with the term ALARA (radiation exposures 'As low as reasonably achievable') in digital diagnostic imaging and PACS radiation protection	92	8	0
B4.3	R2 Should have a basic knowledge of the South African Department of Health, Directorate: Radiation Control regulations and required QC acceptance and interval testing (the responsible person for QC tests performance is usually a senior radiographer)	100	0	0
B4.5	R2 Should be familiar with testing equipment used in QC testing (*Test patterns for monitors, AAPM TG-18 or SMPTE for contrast and resolution testing)*	100	0	0
B4.6	R2 Should be knowledgeable about labels and measures of QA/QC in digital medical imaging	100	0	0
B4.7 Added in the second round and formulated from the first-round comments				
B4.7	R2 Use of validators (testing on violations of image headers)	85	15	0

B5	**PHYSICS AND OR CHARACTERISTICS OF PRESENT DIGITAL IMAGING MODALITIES** ***IT PACS administrators should have basic knowledge and understanding of the physics and or characteristics of present digital imaging modalities***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B5.1	R3 The performance of x-ray exams on each modality	83	0	17
B5.2	R1 The typical workflow for each modality	100	0	0
B5.3	R3 Image creation and processing on all modalities	83	8	8
B5.4	R2 A basic review for the radiographic quality of digital images	85	8	8
B5.5	R3 Basic physics regarding the output or display of digital image	83	8	8

	systems			
B5.7	R2 Post-processing digital image manipulation	85	8	8

B6	**DIGITAL IMAGING MODALITIES** ***The following digital imaging modalities should be included in the teaching programme***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B6.1	R1 Digital diagnostic modalities (Digital radiography and DDR)	80	20	0
B6.2	R1 Computer radiography (CR)	80	20	0
B6.3	R2 Digital fluorography	92	0	8
B6.4	R2 Digital tomosynthesis	92	0	8
B6.5	R2 Digital mobile radiography units	92	0	8
B6.6	R2 Computed tomography (CT)	92	0	8
B6.7	R2 Magnetic resonance imaging (MRI)	92	0	8
B6.8	R2 Ultrasound	92	0	8
B6.9	R2 Mammography	92	0	8
B6.10	R2 Interventional radiology	92	0	8
B6.11	R2 Bone densitometry	92	0	8
B6.12	R2 Nuclear medicine	92	0	8

SECTION C – MANAGEMENT AND ETHICAL PRINCIPLES IN IMAGING INFORMATICS (FOR RADIOGRAPHER AND IT PACS ADMINISTRATORS)				
C1	**PROCUREMENT MANAGEMENT** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C1.1	R2 Develop, evaluate, and negotiate contracts from vendors	85	15	0
C1.2	R2 Develop budgetary proposals for the IT department	85	8	8
C1.3	R2 Determine and evaluate the need for technology enhancement or replacement	85	15	0
C1.4	R2 Organise demonstrations	85	15	0
C1.5	R3 Do evaluation of end-users (*training and service delivery*)	92	8	0

C2	**PROJECT MANAGEMENT** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C2.3	R3 Interpret manufacturers' descriptions and prepare specifications (*as part of the team*) for the purchase of equipment (*PACS-related equipment*).	100	0	0
C2.4	R3 Interpret manufacturers' descriptions and prepare specifications (*as part of the team*) for the purchase of equipment (*PACS-related equipment*).	100	0	0
C2.5	R2 Organise demonstrations for customers and personnel	85	15	0
C2.6	R3 Evaluate end users' satisfaction	92	8	0

C3	**SYSTEM MANAGEMENT** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C3.1	R3 Develop and tests disaster recovery plans (*provide input as part of the team*)	100	0	0
C3.2	R1 Develop strategies to monitor, detect, diagnose and troubleshoot problems	87	13	0
C3.3	R2 Plan data migration procedures (input and plan)	85	15	0
C3.4	R1 Manage reporting on system status	87	13	0
C3.5	R1 PACS and RIS management	100	0	0
C3.6	R1 Manage troubleshooting of new diagnostic imaging equipment integration to the network.	100	0	0
C3.7 Added in the second round and formulated from the first-round comments				
C3.7	R3 Understand RTO (recovery time objective) and RPO (recovery point objective) objectives (*provide input as part of the team*)	92	8	0

C4	**GENERAL MANAGEMENT** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C4.2	R1 Explain the different aspects of human resource management	0	8	92
C4.3	R2 Evaluate and apply the communication skills required in the x-ray department	85	15	0
C4.4	R3 Question the purpose and principles relating to the disciplinary procedure	0	8	92
C4.5	R3 Examine labour relations in the workplace	0	0	100

C5	**ETHICAL PRINCIPLES IN IMAGING INFORMATICS** ***Radiography and IT PACS administrators should be knowledgeable on the following ethical related concepts:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C5.2	R1 Orchestrate safe record-keeping of patient information	100	0	0
C5.3	R1 How to ensure patient confidentiality	100	0	0
C5.4	R1 Application of access control for PACS and RIS	100	0	0
C5.5	R1 Ensuring indemnity against liability	87	7	7
C5.6	R1 How to develop and apply policies to comply with the Protection of Personal Information (POPI) Act, No. 4 of 2013, in South Africa	87	7	7
C5.8	R2 Report and explain on professional regulations and competencies	85	15	0
C5.9	R1 Describe the legal rights and responsibilities of the PACS administrator	93	7	0
C5.10	R1 Write practice incident reports regarding PACS related issues	100	0	0
C5.11 Added in the second round and formulated from first-round comments				
C5.11	R2 The Protection of Personal Information Act (POPI) in respect to biomedical data	85	15	0

C6	**MANAGEMENT PROCESS** *Data analytics and report writing/creation Radiography and IT PACS administrators should be able to:*	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
Subtheme C6: Added in the third round and formulated from second round comments				
C6.1	R3 Use PACS data audit tracking for process improvement	92	8	0
C6.2	R3 Create policies and procedures for change management	83	17	0
C6.3	R3 Manage PACS training, as part of the team	92	8	0

SECTION D – CLINICAL ENGINEERING (FOR IT AND RADIOGRAPHER PACS ADMINISTRATORS)				
D1	**CLINICAL ENGINEERING** *IT and Radiographer PACS administrators should be able to manage information or interact with:*	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D1.5	R2 Oncology	85	15	0
D1.7	R2 Orthopaedic templates	100	0	0
D1.8	R2 Surgical planning	85	15	0

D2	**INFORMATICS SUPPORT** *IT and Radiographer PACS administrators should be able to provide informatics support to:*	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D2.1	R1Mammography: Tomosynthesis	80	13	7
D2.2	R2 Nuclear Medicine: PET/CT	92	15	0
D2.4	R1 Image chain management (DICOM, interface, integration, display and archive)	100	0	0
D2.5	R1 Support information management (e.g. scanned documents, dictations, interface integration)	100	0	0
D2.6	R1 Support technical management (e.g. QC/QA, hardware, replacement)	93	7	0
D2.7	R1 Support regulatory policies (e.g. DoH SA, HPCSA, eHealth strategies)	80	20	0
D2.8	R1 Support standards of practice [e.g. Radiologic Society of South Africa, South Africa Bureau of Standards)	80	20	0

D3	**PROBLEM-SOLVING STRATEGIES** *IT and Radiographer PACS administrators should be able to:*	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D3.1	R2 Design problem-solving quality improvement, projects and procedures	85	15	0
D3.2	R1 Use problem-solving tools	100	0	0
D3.4	R3 Use Google	92	8	0

D3.6 Added in the second round and formulated from first-round comments				
D3.6	R3 Troubleshooting using DICOM anDHL7 sniffers	83	17	0

D4	**STANDARDS FOR INTEROPERABILITY IN IMAGING INFORMATICS AND HEALTH** ***IT and Radiographer PACS administrators should be knowledgeable and have a good understanding of:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D4.1	Standards used: Digital Imaging and Communication in Medicine (DICOM) – a standard for handling, storing, printing, and transmitting information in medical imaging.	100	0	0
D4.2	Hospital Level Seven (HL7) - interface or integration engine built specifically for the healthcare industry and connects legacy systems by using a standard messaging protocol.	93	0	7
D4.3	RIS and PACS interoperability/integration with HIS and PACS	100	0	0
D4.4	Integration of all digital imaging modalities ultrasound (e.g. nuclear medicine, CT and MRI) with PACS and manipulation thereof	93	0	7
D4.5	R3 Develop and apply policies to comply with the future integrated NHI system	92	8	0
D4.6 – D4.12 Added in the second round and formulated from first-round comments				
D4.6	R2 A basic understanding of integrating the health enterprise (IHE), profiles, actors, transactions	85	15	0
D4.7	R2 An understanding of how to use IHE profiles in the procurement cycle	85	15	0
D4.8	R3 How IHE fits into the DoH Health Normative Standards Framework (HNSF) document in South Africa	92	8	0
D4.9	R2 A basic knowledge of the different radiology profiles and their usage in imaging informatics.	85	15	0
D4.10	R2 Awareness of system standards are critical to a PACS Administrator, especially when working with other departments who have dissimilar systems	92	15	0
D4.11	R2 DICOM and HL7 test tools and editors	85	15	0
D4.12	R3 Fast healthcare interoperability resources (FHIR) - an extension of HL7	83	17	0

5.2.6 Outcomes on statements with consensus scores

Table 5.2 contains all the statements for the three-round Delphi survey on which consensus was reached during Round 1 (R1); Round 2 (R2); and Round 3 (R3). Some of the statements (names) had to be changed in accordance with recommendations made by the panellists during rounds 1 and 2. The final statements are displayed as the initial statements with changes made in response to respondents' comments and formatted in italics. Before each statement, the Delphi round in which consensus was reached, are indicated as R1, R2 or R3 in the table. The total number of times a certain response was selected on the adapted three-point Likert scale in the three rounds are displayed in percentages in three columns to the right of the final statement in the round when consensus was reached.

Consensus was reached on the following options:

1) Essential, include in model for n=125 (66.8%) statements.
2) Useful, could be included (with edits) in the teaching model for n=13 (6.9%) statements.
3) Unnecessary, should be excluded from the teaching model for n=3 (1.6%) statements.

The three statements where consensus was reached under the category unnecessary – exclude, will be excluded from the teaching model. The three statements are C4.2, C4.4, and C4.5 (cf. Table 5.2, and Section C4). The three statements are displayed in Round 3 Delphi questionnaire as follows:

- Explain the different aspects of human resource management (cf. Table 5.2, C4.2).
- Question the purpose and principles relating to the disciplinary procedure (cf. Table 5.2, C4.4).
- Examine labour relations in the workplace (cf. Table 5.2, C4.4).

Table 5.3 portray the statements where stability was proclaimed after round three of the Delphi questionnaire.

Table 5.3: Stability statements Round 3 Delphi questionnaire

SECTION (Theme) A – IT PACS – IMAGING INFORMATICS (for radiographer PACS administrators)				
A1	**BASIC COMPUTER SCIENCE** ***Radiographer PACS administrators should have a basic knowledge of the following computer components and networks:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A1.3	R3 Central processing unit (CPU) purpose and performance	50	50	0

A2	**NETWORKING IN IMAGING INFORMATICS** ***Radiographer PACS administrators should be knowledgeable about the following:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
A2.9	R3 Basics of Structured Query Language (SQL)	8	75	17
A2.12	R3 Monitoring and access of servers *(monitoring only)*	75	25	0
A2.15	R3 How to develop appropriate replacement schedules - process of obsolescence planning	75	8	17

A4	**HIS AND RIS** *Radiographer PACS administrators should be knowledgeable about the following concepts:*	Essential	Useful	Unnecessary
		%	%	%
A4.9	R3 Operation of fingerprints scanners in digital radiography and CR (*basic usage*)	58	25	17
A4.11	R3 An *understanding* of DICOM structured reporting (SR)	75	25	0

SECTION B – CLINICAL PACS – CLINICAL TRAINING (FOR IT SPECIALIST PACS ADMINISTRATORS)

B1	**CONCEPTS OF MEDICAL IMAGING** *IT PACS Administrators should be introduced to the following concepts of medical imaging:*	Essential	Useful	Unnecessary
		%	%	%
B1.2	R3 Basics of x-rays interaction with matter (*very basic level*)	50	42	8
B1.5	R3 Basics of radioactivity (*very basic level*)	58	33	8
B1.6	R3 Measurement of x-ray radiation (*very basic level*)	75	25	0
B1.7	R3 Basics of x-ray exposure factors (*very basic level*)	58	33	8

B2	**ELEMENTS OF THE HEALTHCARE STRUCTURE IN SOUTH AFRICA** *IT PACS Administrators should be knowledgeable on the elements of the Healthcare structure in South Africa.*	Essential	Useful	Unnecessary
		%	%	%
B2.1	R3 The administration and organisation of healthcare in South Africa (SA)	25	75	0

B3	**HUMAN ANATOMY CONCEPTS AND BODY SYSTEMS** *IT PACS Administrators should have a basic knowledge regarding the following human anatomy concepts and body systems*	Essential	Useful	Unnecessary
		%	%	%
B3.3	R3 Locomotor system	67	25	8
B3.4	R3 Cardiovascular system	75	17	8
B3.5	R3 Respiratory system	75	17	8
B3.6	R3 Digestive system	75	17	8
B3.7	R3 Nervous system	75	17	8
B3.8	R3 Reproductive system	75	17	8
B3.9	R3 Genito-urinary system	75	17	8
B3.10	R3 Endocrine system	75	17	8
B3.11	R3 Biliary tract and liver	75	17	8
B3.12	R3 Identify basic radiographic anatomy demonstrated on digital images	75	17	8

B5	**PHYSICS AND OR CHARACTERISTICS OF PRESENT DIGITAL IMAGING MODALITIES** ***IT PACS Administrators should have basic knowledge and understanding of the physics and or characteristics of present digital imaging modalities.***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
B5.6	R3 The relevance of centring and collimation in digital imaging	58	33	8
B5.8	R3 Multi-modality processing and system limitations (*PET-CT, SPECT-CT, and PET-MRI*)	75	17	8
B5.9	R3 Digital image printing	67	25	8

C2	**PROJECT MANAGEMENT** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C2.1	R3 Manage and design physical space for digital imaging reading environment *(as part of the team)*	25	75	0
C2.2	R3 Appraise equipment (*as part of the team*) with respect to departmental design, staffing requirements and financial implications (*PACS related equipment*).	33	67	0

C4	**GENERAL MANAGEMENT** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C4.1	R3 Explain and apply (*understand)* the basic principles involved in the management	75	25	0

C5	**ETHICAL PRINCIPLES IN IMAGING INFORMATICS** ***Radiography and IT PACS administrators should be knowledgeable on the following ethical related concepts:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
C5.1	R3 Basic understanding about Medical Law	75	25	0
C5.7	R1 Explain the principles of professional ethical practice	75	17	8

SECTION D – CLINICAL ENGINEERING **(FOR IT AND RADIOGRAPHER PACS ADMINISTRATORS)**				
D1	**CLINICAL ENGINEERING** ***IT and Radiographer PACS administrators should be able to manage information or interact with:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D1.1	R3 Pathology	50	50	0
D1.2	R3 Ophthalmology	58	42	0
D1.3	R3 Dentistry	58	42	0

D1.4	R3 Dermatology	42	58	0
D1.6	R3 Endoscopy	75	25	0
D1.9	R3 Stereotactic imaging	75	25	0

D2	**INFORMATICS SUPPORT** ***IT and Radiographer PACS administrators should be able to provide informatics support to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D2.3	R3 Cardiology: Electrophysiology (EP)	50	50	0

D3	**PROBLEM-SOLVING STRATEGIES** ***IT and Radiographer PACS administrators should be able to:***	**Essential**	**Useful**	**Unnecessary**
		%	**%**	**%**
D3.5	R3 Use DHIS2 (District Health Information Software 2 - *national health information systems for data management and analysis purposes)*	8	75	17

5.2.7 Outcomes concerning statements without consensus scores

Statements on which no consensus was achieved can be divided into two groups: 1) statements for which stability was proclaimed (cf. Table 5.3); and 2) statements where no stability could be proclaimed (cf. Table 5.4). According to Linstone and Turoff (2011:1714), group consensus is not the only objective of the Delphi technique. The main principle underpinning this method is that it helps to structure group interaction, to allow a group of knowledgeable individuals to deal with a complicated problem. The wideband Delphi variant developed by Boehm in 1981, promotes interaction among respondents. However, when using the conventional Delphi, deliberations between rounds is not encouraged, under the premise that debate would foster tendencies toward the most dynamic respondents (Valerdi 2011:1249). In order to proclaim stability, the intent is to accomplish convergence. The eventual measure of efficacy of a Delphi survey is whether a central trend is exhibited by the group – to converge or diverge. The mean, median and mode can be used to quantify the central tendency, and the standard deviation indicates the level of dispersion demonstrated (Valerdi 2011:1251). In this study, the mean, standard deviation and median were used to quantify the central tendency demonstrated. According to Frost (2020:338), the mean is not consistently the more suitable measure of central tendency for samples. However, with continuous and symmetrical data distribution, the mean is normally the optimum measure of central tendency.

After Round 3 of the Delphi survey, consensus *had not* officially been reached on 42 of the 184 statements. However, convergence of the selections of the panellists was attained and stability was proclaimed for 37 of the 42 statements, conceding 88% stability on all the statements for which consensus had not been reached. In the third, round, no changes to the respondents' selection were reported for 14 of the 42 statements. The only change that was noted is that one of the 13 panellists dropped out.

Table 5.4 presents the statements where no stability could be proclaimed.

Table 5.4: Statements with no stability or consensus

No.	Statements	Essential %	Useful %	Unnecessary %
A1.11	R3 Data representation *binary (base 2) number system and hexadecimal (base 16) or octal (base 8) number systems, as a compact form for representing binary numbers.*	42	33	25
A1.13	R3 Basic UNIX knowledge to be able to get back into the 'back-end'	8	42	50
A2.11	R3 Appropriate replacement skills (*related to the component in imaging informatics network and PACS)*	0	33	67
A2.13	R3 Design, specify, management and evaluation of the network configuration and performance (*part of design team - input is use requirement and location only)*	0	33	67
D3.3	R3 Use Strata	0	42	58

For the five statements on which no consensus or stability was reached, a score of 50% or more for the category 'unnecessary' on the adapted three-point Likert scale, was considered for exclusion from the teaching model. Four of the five statements had an 'unnecessary' score of 50% and more, and will, therefore, be excluded from the teaching model. The four statements are as follows:

- Basic UNIX knowledge to be able to get back into the 'back-end' (unnecessary=50%) (cf. Table 5.4, Section A1.13).
- Appropriate replacement skills (*related to the component in imaging informatics network and PACS*) (unnecessary=67%) (cf. Table 5.4, Section A2.11).
- Design, specify, management and evaluation of the network configuration and performance (*part of design team - input is use requirement and location only*) (unnecessary=67%) (cf. Table 5.4, Section A2.13).
- Use Strata (*a problem-solving strategies*) (unnecessary=58%) (cf. Table 5.4, Section D3.3)

The results of the fifth statement indicated 15% in the category 'unnecessary' and a convergence score of 75% for the 'essential and useful' categories, and will, therefore, be included in the teaching model. The statement is the following:

- Data representation *binary (base 2) number system and hexadecimal (base 16) or octal (base 8) number systems, as a compact form for representing binary numbers* (cf. Table 5.4, Section A1.11).

The central tendency of statements on which stability was proclaimed after Round 3 is demonstrated in Table 5.5. The difference on the mean and median between Rounds 2 and 3 is demonstrated. The interpretation of the mean/median is as follows:

- -2 indicates a change from unnecessary to essential
- -1 indicates a change from useful to essential or unnecessary to useful
- 0 indicates no change – stayed the same
- 1 indicates a change from essential to useful or useful to unnecessary
- 2 indicates a change from essential to unnecessary

Table 5.5: Central Tendency and Dispersion: Difference between rounds 2 and 3

No.		Statements (categories)		Round 2 (n = 13)		Round 3 (n = 12)	
		Mean	S.D.	Median	Mean	S.D.	Median
A1.3	Central processing unit (CPU) purpose and performance	-0.15	0.69	0.00	-0.08	0.67	0.00
A1.11	Data representation binary (base 2) number system and hexadecimal (base 16) or octal (base 8) number systems, as a compact form for representing binary numbers.	0.23	0.83	0.00	0.08	0.79	0.00
A2.9	Basics of Structured Query Language (SQL)	0.08	0.76	0.00	0.00	0.43	0.00
A2.12	Monitoring and access of servers (monitoring only)	-0.23	0.73	0.00	-0.17	0.39	0.00
A2.15	How to develop appropriate replacement schedules - process of obsolescence planning	-0.23	1.01	0.00	-0.17	1.27	0.00
A4.9	Operation of fingerprints scanners in digital radiography and CR (basic usage)	-0.08	0.64	0.00	0.00	0.60	0.00
B1.2	Basics of x-rays interaction with matter (very basic level)	-0.15	0.90	0.00	-0.08	0.51	0.00
B1.5	Basics of radioactivity (very basic level)	-0.23	0.83	0.00	-0.25	0.75	0.00
B1.6	Measurement of x-ray radiation (very basic level)	-0.46	0.78	0.00	-0.17	0.72	0.00
B1.7	Basics of x-ray exposure factors (very basic level)	-0.08	0.95	0.00	-0.17	0.83	0.00
B2.1	B2.1 The administration and organization of Healthcare South Africa (SA)	0.00	0.71	0.00	-0.17	0.58	0.00
B3.3	Locomotor System	-0.38	1.04	0.00	-0.33	0.98	0.00
B3.4	Cardiovascular System	-	-	-	-0.25	0.75	0.00
B3.5	Respiratory System	-0.46	0.97	0.00	-0.25	0.75	0.00
B3.6	Digestive System	-0.31	1.18	0.00	-0.42	0.90	0.00
B3.7	Nervous System	-0.46	0.97	0.00	-0.25	0.75	0.00
B3.8	Reproductive System	-0.31	1.18	0.00	-0.42	0.90	0.00
B3.9	Genito-urinary system	-0.46	0.97	0.00	-0.25	0.75	0.00
B3.10	Endocrine system	-0.31	1.18	0.00	-0.42	0.90	0.00
B3.11	Biliary tract and liver	-0.31	1.18	0.00	-0.42	0.90	0.00
B3.12	Identify basic radiographic anatomy demonstrated on digital images	-0.23	0.60	0.00	0.08	0.67	0.00
B5.6	The relevance of centring and collimation in digital imaging	-0.08	0.64	0.00	-0.25	0.62	0.00
B5.8	Multi-modality processing and system limitations (PET-CT, SPECT-CT, and PET-MRI)	-0.15	0.90	0.00	-0.25	0.75	0.00
B5.9	Digital image printing	-0.15	0.55	0.00	0.08	0.67	0.00
C2.1	Manage and design physical space for digital imaging reading environment	0.00	0.82	0.00	0.08	0.51	0.00
C2.2	Appraise equipment with respect to departmental design, staffing requirements and financial implications (PACS related equipment)	0.08	0.86	0.00	-0.08	0.67	0.00
C4.1	Explain and apply the basic principles involved in management	-0.15	0.69	0.00	0.00	0.43	0.00
C5.7	Basic understanding about Medical Law	-0.23	0.60	0.00	-0.08	0.29	0.00

No.		Statements (categories)		Round 2 (n = 13)		Round 3 (n = 12)	
C5.7	Explain the principles of professional ethical practice	-0.08	0.28	0.00	0.00	0.00	0.00
D1.1	D1.1 Pathology	-0.15	0.69	0.00	-0.17	0.83	0.00
D1.2	D1.2 Ophthalmology	-0.08	0.76	0.00	-0.25	0.87	0.00
D1.3	D1.3 Dentistry	-0.15	0.69	0.00	-0.17	0.83	0.00
D1.9	D1.9 Stereotactic imaging	-0.31	0.85	0.00	-0.08	0.67	0.00
D2.3	D2.3 Cardiology: Electrophysiology (EP)	-0.38	0.77	0.00	0.00	0.74	0.00
D3.3	Use Strata	0.38	0.87	0.00	0.33	0.89	0.00
D3.5	D3.5 Use DHIS2 (District Health Software 2 -National Health Information Systems for data management and analysis purposes)	-	-	-	0.08	0.51	0.00

In Table 5.5, most of the mean scores of the different statements or categories for which stability was proclaimed from Round 2 to Round 3, showed minor changes. The difference in the median for the statements from Rounds 2 and 3 is demonstrated as zero because it stayed the same for both rounds.

5.2.8 Nonparametric statistics for interrater reliability

Evidence of the reliability and validity of the Delphi technique can be provided by integrating nonparametric statistics; doing so may enrich its precision as a research method (Ju & Jin 2013:7). In quantitative research, methodological rigour refers to the soundness of a study regarding the preparation, data collection and analysis, and reporting on the findings (Marquart 2017:1). The variation in the number of respondents of the three rounds (R1, n=15; R2, n=13; R3, n=12) affected interrater reliability per category. Therefore, interrater reliability was calculated per subtheme for Round 2 and 3 only. Although three different types of calculations were done during the statistical analysis, the discussion will be on Kendall's CC. When the agreement that exists between the standards of the ranking variable is perfect, $\theta=1$; and with maximum divergence, $\theta=0$. No negative values are reported with Kendall's CC, it is, therefore, bordered on the interval $0\leq\theta\leq1$. Note that, with more than two standards of the ordering variable, total divergence cannot occur (Ju & Jin 2013:7; Verbič & Kuzmin 2009:230).

Figure 5.6 depicts the nonparametric statistics, Kendall's coefficient of concordance (CC), a measure of interrater agreement between the different subthemes.

Table 5.6: Interrater reliability between different subthemes

Sub-themes	Kendall's CC (Weighted)	Sub-themes	Kendall's CC (Weighted)
A1	0.354	C1	0.037
A2	0.268	C2	0.080
A3	0.305	C3	0.236
A4	0.229	C4	0.433
A5	0.160	C5	0.238
A6	0.314	D1	0.155
B1	0.233	D2	0.300
B2	0.367	D3	0.335
B3	0.438	D4	0.200
B4	0.025		
B5	0.141		
B6	0.080		

The interrater reliability between subthemes, according to Kendall's CC, for subthemes B3 (0.438) and C4 (0.433) showed the best results, whereas subthemes B4 (0.025), B6 (0.080), C1 (0.37) and C2 (0.080) presented the lowest interrater reliability.

5.3 CONCLUDING SUMMARY

In Chapter 5, the results and a discussion of the findings from the three-round Delphi study were presented. A response rate of 79% was achieved for Round 1, 87% for Round 2 and 92% for Round 3. Consensus was achieved for 142 of the 184 statements, of which 125 were rated essential, 13 were rated useful, and three were rated unnecessary. Stability, which was considered on a concordance of 80% responses between essential – include and useful – can be included, was reached on an additional 37 statements. Only five statements were regarded as unnecessary, that is, when 50% or more of the responses were in the unnecessary – exclude from the teaching model category.

In the next chapter, Chapter 6, entitled, **A model for the teaching of imaging informatics, a platform in biomedical informatics, in a future integrated National Health Insurance System in South Africa**, the teaching model, which is the final product of the study, will be discussed.

CHAPTER 6

A MODEL FOR THE TEACHING OF IMAGING INFORMATICS, A PLATFORM IN BIOMEDICAL INFORMATICS, IN A FUTURE INTEGRATED NATIONAL HEALTH INSURANCE SYSTEM IN SOUTH AFRICA

The connections made by good teachers are held not in their methods but in their hearts -- meaning heart in its ancient sense, the place where intellect and emotion and spirit and will converge in the human self.

Parker Palmer (2007)

6.1 INTRODUCTION

At the time of the study, accredited and registered postgraduate programmes providing training for PACS administrators coming from a radiographic or general information technology teaching background were not available in South Africa. Health informatics includes a considerable variety of medical imaging informatics fields, of which imaging informatics in the radiology department is just one. In South Africa, radiographers do several modules in their undergraduate four-year professional degree that involves radiographic imaging technology and imaging informatics, and their learning and teaching background also includes a great deal of clinical and practical knowledge and skills. In contrast, the information technologists' background comprises mostly technology and informatics knowledge and skills. When the basic training of a radiographer and an IT specialist is combined, it strengthens the ability of such a candidate to act as an imaging informatics professional or PACS administrator. IT specialists with Master's or Doctorate degrees are more focused on engineering systems in imaging informatics and health informatics. Radiographers with Master's and Doctorate degrees are scarce in South Africa and they are mostly involved in teaching at higher education institution offering the radiography programme, or they are in management positions in the public and private health sector.

With this study, the researcher attempted to address the need for a Department of Education, Science and Information (previously known as DHET) approved, CHE and HPCSA accredited, and SAQA registered postgraduate imaging informatics teaching programme. The model was developed to guide future curriculum development. For the development of the teaching model, the researcher used a literature review (cf. Chapter 2), three structured questionnaires (cf. Chapter 4) and a Delphi survey (cf. Chapter 5) to deliver the data for the subject matter, and professional practices that are necessary for such a programme.

Chapter 1 provided the reader with an introduction and orientation to the research topic and the goal of the study. A literature review was undertaken to investigate the context of the research problem and to support the questionnaire development that was used to survey radiographers and IT professionals and was offered in Chapter 2. The researcher described the research design, methods and the theoretical perspective of the research methodology in Chapter 3. Chapter 4 delivered the findings and discussion of the questionnaire survey, whereas, Chapter 5 provided the results of the Three-Round Delphi study and its analysis, which was concluded with consensus (n=142) and stability (n=37) being proclaimed for the 184 statements.

In this chapter, Chapter 6, the second objective of the research project will be addressed through the development of the teaching model. The teaching model will be presented and discussed comprehensively and independently from the premise. Deliberation of the model's components will be reasoned inclusive of the interaction and interfacing with each other.

6.2 PRINCIPAL FINDINGS FOR INCORPORATION IN THE TEACHING MODEL

The main findings that will be incorporated into the teaching model are the following:

- The information derived from the literature review (1) of national and international publications on the context of imaging informatics principles in medical imaging and radiology; (2) the advances in the field of imaging informatics; and (3) information regarding teaching and learning programmes in imaging informatics or PACS administration, available in South Africa and in other countries, which were used to construct the three structured questionnaires.
- Research-based results from the three structured questionnaires, which were mainly used to inform the Delphi study's questionnaire development, but also confirmed the radiographer respondents' justification for the need for such a teaching and learning programme in South Africa.
- The preference indicated by the radiographer respondents during structured questionnaire 1 regarding the teaching strategies that they would prefer for formal education in imaging informatics.
- The important candidate topics suggested by the radiographer respondents during structured questionnaire 1, which was incorporated in the first Delphi questionnaire.
- The results of structured questionnaire 3, regarding imaging informatics professional practice analysis, were incorporated into the first-round Delphi questionnaire.

- The findings of the three round Delphi survey mainly cover the contents or subject matter that should be used in the development of the teaching model for imaging informatics.

6.3 TEACHING MODEL DEVELOPMENT

A theoretical model is a description or explanation of an abstract phenomenon that cannot be directly observed, that allows someone to use the key concepts contained in it to simulate, imitate or emulate it to develop strategies or solve problems in another field. A model is a way of schematising or visualising a process, system, structure, object, or pattern, and it may highlight or hide details, or certain aspects of it, to focus on the phenomenon at hand. The person wanting to use the model will take the concepts described in it, and adjust them to their situation (B. Taylor 2015:Online; Joyce *et al.* 2015:5). An educational model, referred to as a teaching model in this study and defined in Chapter 1 (cf. Section 1.11), is a description of the teaching and learning context and the conduct of lecturers and learners during the lesson as embedded in the model.

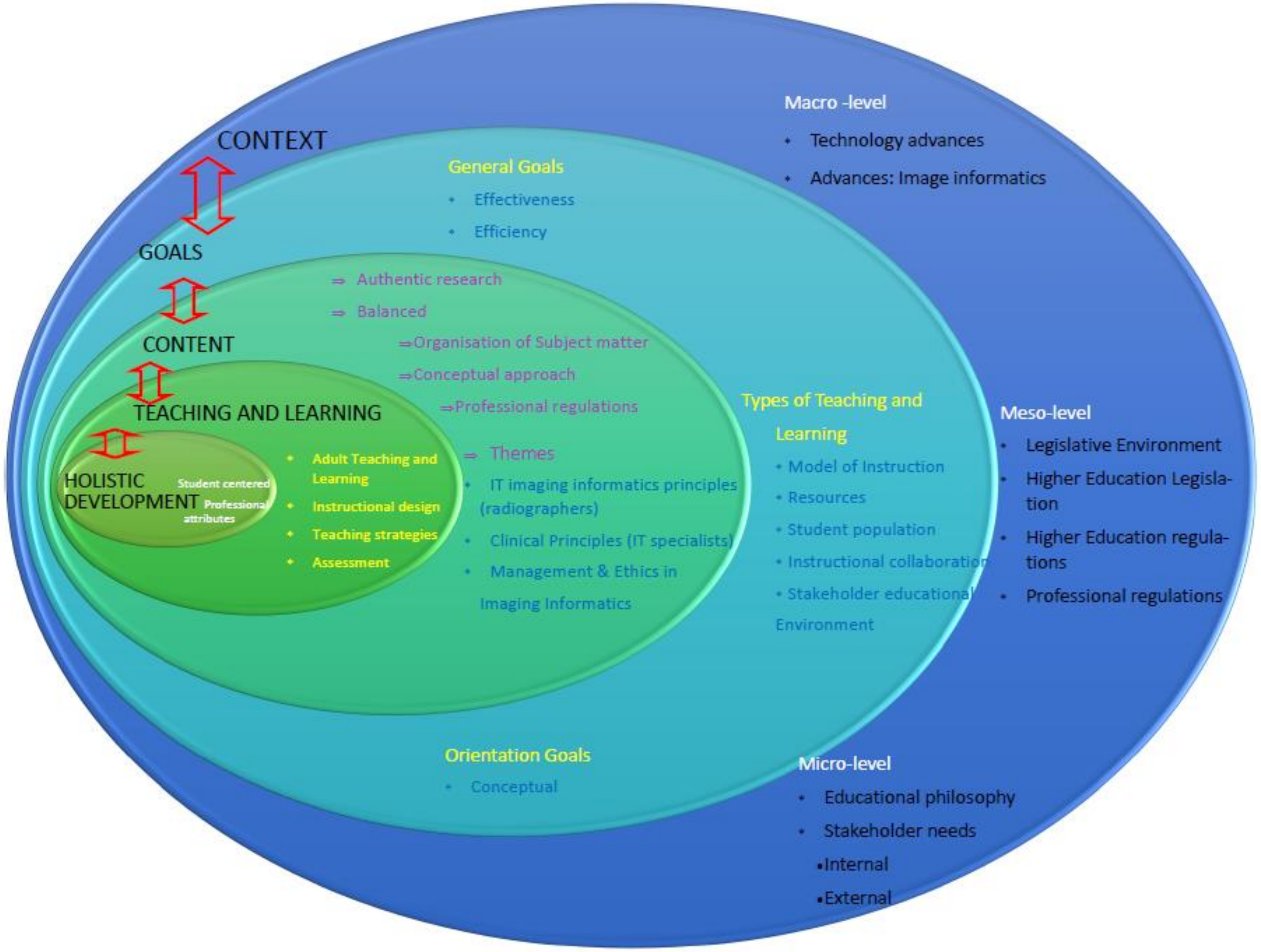
The researcher used Tyler's theory of construct as a conceptual framework to develop the model. The four key concepts provided, namely context, goals, content and learning experience and assessment were then described, using the paradigm as a premise, the findings of the research, and taking the higher education context in which imaging informatics programmes can be developed or offered, into account. The fifth concept in the model, holistic student development, is considered to be the product of such a teaching model.

6.3.1 Description of the layout of the model

Figure 6.1 presents the teaching model for imaging informatics. The model is made up of five circles within each other, with the context in the outer circle (1st), followed by goals (2nd), content (3rd) and learning experience and assessment (4th). The centre circle (5th) represents the overall purpose of the model, *holistic student development*. The holistic student development circle (5th) is positioned in the middle to illustrate the influence of the concepts in the first four circles on student development. The arrows pointing both ways from the outer line of the first to the centre circle indicate the mutual influence between the information within each circle. The same principle is applicable between the circle title and the concepts involved within. The arrow point starting at the outer line of the first circle represent the constant influence the rapidly changing environment in education and medical imaging informatics have on student development.

In this model (cf. Figure 6.1), context means the macro and the micro-environment in which the education can be offered, for example, the legislative environment and the institutional, educational philosophy. Goals in the model refer to general goals (effectiveness, efficiency and appeal) and the makeup of the goals (procedural, conceptual or theoretical). Content in the model portrays the subject matter that should be included for teaching and learning imaging informatics. Learning experiences and assessment in the model refer to, for example, the teaching strategies, like blended learning, and different ways to assess a student's performance, for example, formative and summative assessments. In the model, holistic student development refers to the development of the student (as a whole), engaging the student in the teaching and learning method, and inspiring personal and shared responsibility.

The detailed description of these key concepts, depicted in the model, will be discussed after the figure, as displayed in Figure 6.1.



1	CONTEXT	2	GOALS	3	CONTENT	4	LEARNING EXPERIENCES & ASSESSMENT	5	HOLISTIC STUDENT DEVELOPMENT

Figure 6.1: The teaching model (Compiled by researcher, Grobler, 2020)

6.3.1.1 *Context*

The outer circle (1) of the Figure 6.1 represents the context in which the proposed teaching model was developed. This context is presented in the absence of a postgraduate PACS administration or imaging informatics teaching and learning programme in South Africa that is Department of Educations, Science and Information approved, CHE and HPCSA accredited SAQA registered (cf. Chapter 2; cf. 2.5.2.1). The points of departure identifying, classifying and defining the main concepts for the development of the teaching model under context will be discussed next.

The *literature review* (cf. Chapter 2) gave a *macro* perspective of the trends in the technology, and advances in the discipline of imaging informatics. Other trends highlighted through the literature review are teaching and learning practices in existing education programmes in imaging informatics globally. The NHSs in five different countries globally and South Africa were discussed to provide the background to the proposed NHI system in South Africa, as was the need for knowledgeable, skilled imaging informatics professional to ensure a smooth workflow in an integrated healthcare environment. In Chapter 2 (cf. Section 2.6.3), the researcher also discussed information related to teaching models, and more specifically, instructional design models.

Legislative environment

On the *meso*-level, for the development of the teaching model cognisance is vital regarding the *legislative environment* of the country, for example, the National Health Act, 61 of 2003 as amended and the National Qualifications Framework (NQF) Act, 67 of 2008, as amended, in which a possible curriculum will be developed. Imaging or health informatics, are regulated by the policies and guidelines of the National Regulatory environment that includes the national DoH's role/goal, which is underpinned by the eHealth strategy (2012–2016), the NHSF for Interoperability in eHealth in South Africa (2014) the NHI system policy (2011; 2017) papers, and most recently, the NHSF for interoperability in digital health in South Africa (February 2019 Draft) and the National Digital Health Strategy for South Africa (2019–2024) (cf. Chapter 2; cf. 2.3.3.1). The latter is directed at the South African National Development Plan Vision 2030 of ICT, which underpins the progress of an active, linked information culture and a vibrant knowledge economy (based on intellectual capital) that is comprehensive and successful (RSA CSIR & NDoH 2019:12). The goal is to arrive at an integrated healthcare system that can provide good quality healthcare to all citizens in South Africa. Enabling the integrated healthcare system to operate optimally and provide a smooth flow of information, knowledgeable, skilled health informatics technologists and imaging informatics professionals are needed in South Africa. The first step should be to prioritise digital connectivity in all public healthcare facilities in South Africa, as recommended in the draft paper regarding digital readiness (RSA DOJ & CD 2019:10; RSA. The Presidency: National Planning Commission 2020).

Higher education legislation

Realising that higher education institutions should be registered with the Department of Education, Science and Information, according to the Higher Education Act, 101 of 1997 (RSA DoE 1997) as amended, to offer accredited teaching and learning programmes legally are essential (RSA DHET 2016). According to the NQF Act, mentioned above, higher education is accredited by Quality Councils, which is the CHE, which regulates/accredits higher education programmes that lead to qualifications. (cf. Chapter 2; cf. 2.6.3.3).

Higher education regulation

SAQA developed level descriptors that make comparisons of Higher education qualification possible and serve as the minimum requirements for each NQF level. Level descriptors for higher education begin at NQF Level 5, for a Higher Certificate and progress to Level 10 for a Doctoral degree. In each of these level descriptors, ten categories are employed to portray applied competencies needed for that level. These ten categories are the scope of knowledge, knowledge literacy, methods and procedures, problem-solving, ethics and professional practice, accessing, processing and managing information, producing and communicating information, context and systems, management of learning, and accountability (SAQA 2012:10). According to the HEQSF (RSA DHET 2013:31), a postgraduate diploma qualification is on an NQF Exit Level 8 with a minimum total credit value of 120. The teaching model for imaging informatics will be concentrated on the level of a postgraduate diploma qualification (cf. Chapter 2; cf. 2.6.3.3).

Professional regulations

According to the National Health Act, No. 61 of 2003 as amended, all qualified radiographers should be registered with the PBRCT at the HPCSA in the category independent practitioner.

New higher education qualifications for radiographers should, after going through the higher education institution development processes, be sent to the DHET for approval and financing purposes. The PBRCT at the HPCSA regulate the profession and prescribe training requirements, for example, competencies, minimum hours for experiential learning, and the scope of practice for practitioners. The curriculum developer must take note of these regulations when developing the learning programme. After the DoE, Innovation and Science has approved the programme, and it is put on the university programme qualification mix, the documents go through the internal quality review processes of the higher education institution before it is sent to the PBRCT at the HPCSA, and the CHE (HEQC) (a dual process) for accreditation (cf. Chapter 2; cf. 2.5.2). After accreditation by both institutions, the qualification is sent to SAQA for registration. Only after evidence of the registration of the qualification is received by the higher education institution, can the qualification be offered by the institution.

SAHIA was founded in 1982 to encourage the professional significance of health informatics in South Africa and strives to have health informatics recognised as a specialist discipline, registrable with the HPCSA.

Higher Education Institution

On the micro-level, the institutional, educational philosophy is embedded in the higher education institution's vision and mission statement. In institutions of higher learning, transformation and leadership that focus on servicing the people are prioritized at the moment, to redress past trends. Curriculum developers have to take note of the philosophy of the institution and the educational approaches it utilises and strives to embed these principles and strategic preferences into the curriculum. The institution might be devoted to developing staff and students' individual competence, embrace a humanising educational approach and want to be recognised for its kind, people orientated, value-guided organisational ethos.

For the development of a teaching model, the researcher, therefore, created the awareness of and the alignment with the vision, mission, guidelines, policies, and requirement of the higher education institution where the programme will be developed. A programme development for the imaging informatics teaching model, created in this study, will have to be an interdisciplinary process between the Department of Radiography in the Faculty of Health Sciences and the ICT department (which might fall under IT or engineering) in the institution where such a programme will be developed.

Stakeholder needs

A stakeholder is a person who is influenced by the decision of an organisation, which in this study is a higher education institution. Stakeholders can be groups, individuals or organisations that will be directly involved, or only affected, and either loss or gain from a decision made by the institutions (Australian Government & DFAT 2018:5).

The *internal stakeholders* in the higher education institution whose needs should be considered are the lecturers and administration officials, the timetabling department, the infrastructure department, the systems office, the academic quality assurance office, the finance department, the library staff, other departments that will be, for example, relied on for the interprofessional segment, the student and staff capacity development department and the engagement department, which deals with employers and employees where students will be placed during their programme.

The students are the main stakeholders in the higher education institution, and they come from the workforce in radiography and IT. As adult students, they need the motivation to balance their studies with their personal and work life. Radiographers need to work different shifts on a rotational basis, which may include working during the night and sleeping in the day. The teaching model will enable an effective future instructional programme design for imaging informatics, with engaging activities supporting *skills*, *proficiencies*, and *competence*.

In a transformed world economy, the shift in employer stakeholders is towards employability, that is, making sure they employ knowledgeable, skilled workers with good communication skills and problem-solving competencies. Employed adults continuously need to enhance their skills and adjust quickly to new appointments to ensure that they stay employable. Adult students need *accessibility* to higher education and training to enable them to improve their income and quality of life. Higher education institutions should take a more flexible approach and provide more fast-tracked choices to enhance the needs of adult learners to move through teaching and learning activities faster or at their own pace.

It is recommended that *accountability* mechanisms, such as accreditation of higher education academic programmes' policies and rule frameworks, should change to enable higher education institutions to respond to adult learners' needs.

External stakeholders need to be part of the curriculum development process because they know what the needs are in practice. They usually have the information/technology that is used for patient care and can, therefore, make a significant contribution towards the content of the programme. External stakeholders that should be considered are, for instance, employers in private and public healthcare radiology facilities, who require employability in graduates, or who wish to enhance employee knowledge and skills in imaging informatics. Strategic priorities and planning in the radiology department regarding the implementation of new technology should include best practices based on current guidelines for patient-centred care (DeFino 2018:Online).

Other possible stakeholders will be registered, qualified radiographers or IT specialists who are looking for opportunities to advance their careers in the field of imaging informatics. These professionals, as future students of imaging informatics, together with the radiologist where they are employed, are considered to be the main stakeholders. Consultations need to be scheduled with the employers at private practices (radiology directors) and public radiology departments (radiology managers), to ensure that radiographers and IT technologists will be able to do their practical component in the radiology departments. The future student would typically be part of the workforce, but not necessarily be working in IT or imaging informatics systems administration.

The DoE, Science and Information and the DoH, which need competent, skilled imaging informatics or health informatics professionals, are also external stakeholders. Qualified, experienced professionals, who are required to ensure a smooth exchange of patient information between integrated departments and healthcare facilities, are possible external stakeholders. In the future NHI system in South Africa, a proficient digital integrated healthcare system will provide quality healthcare to all citizens. In other words, all citizens or patients are stakeholders too.

Educational philosophy

There is political pressure on higher education institutions to redress past practices of inequality in South Africa. Higher education institutions strive to deliver programmes that will enable students from all cultures access to education. Knowledge regarding the institutional vision and mission are essential for academics who are interested in developing a curriculum for imaging informatics in South Africa.

In this model, one of the drives in teaching is to create responsible and autonomous students. According to the constructivism theory, students are dynamically engaged in a procedure of building significance and knowledge structure, instead of only passively absorbing information (cf. Chapter 2, cf. 2.6.1.2). The emphasis of constructivist teaching is on critical thinking skills, to create independent students. Constructivist classrooms create a student-centred teaching environment with interactive student involvement and foster a holistic educational approach with a focus on the development of the student's understanding and integration of the information, and also to develop the student as a whole, by allowing debate, questioning and differences of opinion.

Academic discourse comprises of how we modify our interaction during engagement in intellectual conversation. Academic discourse is a critical part of a classroom in this model. There are four key aspects to consider, namely, critical thinking, reflection, norms, and participation, which facilitate discourse rather than a simple conversation. Scholarly communication can take place through, for example, presentations, lectures, debates, and seminar classes.

6.3.1.2 *Goals*

The second circle from the outside (2) in Figure 6.1 portrays the goals for the teaching model. The makeup of the general goals for models of instruction is to enable teachers to know what they should be teaching, and students to know what they need to know to become competent professionals. This is depicted in the exit-level outcomes of the programme. These exit-level outcomes have to be on the required NQF level and are often prescribed by the professional body as a minimum requirement. The students must absorb and integrate the information from lectures (effectiveness), to accomplish a specific level of knowledge and skills within the fewest possible years of study (efficiency), and to experience instruction as enjoyable (appeal). The makeup of the goals could be of a procedural, conceptual, or theoretical orientation. The type of goals needs to be altered for different courses (Reigeluth *et al.* 1980:209). The orientation goal for this model is conceptual.

The goal of the development of the teaching model is to provide a future programme developer in imaging informatics in South Africa with sufficient and relevant information to create an effective, efficient and appealing programme of instruction that meets the exit-level outcomes. An imaging informatics programme of instruction in South Africa will add to the employability (sub-discipline) of radiographers and IT professionals as PACS administrators or imaging informatics professionals in the medical imaging environment. Employing knowledgeable and skilled professionals will enhance the workflow and ensure a shorter turnaround time in the radiology department, which will provide or improve quality healthcare for all patients who need medical imaging.

Resources available

In higher education, *human resources* include all people necessary to ensure that the institution's daily activities run effectively. These people are essential resources, and comprise of, for example, lecturers, with the necessary expertise and experience to teach the different modules; administrators with knowledge of the systems and processes; system administrators and exams officers/systems; infrastructure managers that can develop or unlock infrastructure needs for a programme; an ICT department that can provide computers and also provide end-user backup and equipment maintenance, so that teaching and learning can be done effectively, and security personnel. There should be lecturers allocated by the radiography and ICT departments for the different modules of the imaging informatics course, that is, IT, management and clinical-related disciplines. Where interprofessional education and training is needed, it is also advisable to ensure that the necessary service-level agreements are in place, to ensure effective and good quality teaching and learning.

For the imaging informatics programme, *infrastructure* should include a computer laboratory with workstations and portable devices for online practical sessions or simulation-based learning on a PACS/RIS/HIS or EHR database. The institution can purchase pre-populated DICOM databases from private enterprises. However, the higher education institution could also create a PACS database through collaboration with a local healthcare institution, by transferring a considerable amount of anonymous DICOM data from their server to the institutions' PACS server. Also needed is a fast, secure network with Wi-Fi connectivity and a network hub for linking a compound of Ethernet devices, to engage students so that they can work collaboratively together to solve problems (cf. Chapter 2; cf. 2.6.2).

If new lecturing personnel have to be appointed, they will need offices equipped with furniture, laptops, stationery equipment, telephones, and network connections, the purchase of which should be included in the budgetary process. However, higher education institutions are reluctant to employ new lecturing personnel if the student numbers are too small to make a course feasibly, and it is unlikely that large numbers of students will enrol. It will therefore be regarded in a more satisfactory way if already appointed lecturing personnel can be used from the two departments involved.

Decisions regarding the development and implementation of new academic programmes need to go through an internal institutional process for approval and, after that, financial controls and mechanisms should be in place to monitor expenditure and generate more funding, when and if the enrolment figures increase. The availability of seed funding (e.g. for library resources) and financial sustainability of such programmes are essential aspects to consider when developing a new educational programme. DoE, Science and Information programme subsidies are only available two years after the introduction of the programme, which means the higher education institutions must have enough funding to initiate the programme and sustain it for at least two years.

The availability of lecture halls in higher education institutions could be problematic, due to an increase in student numbers and new programmes that are implemented annually. Therefore, programme leaders have to check for the availability of lecture halls for face-to-face contact sessions (probably, a minimum of four weeks per year) with the institution's central timetabling department or should ask for new lecture halls. The programme leader can alleviate the lecture hall availability problems by offering the programme as a blended learning programme with minimal face-to-face contact time and mostly eLearning.

A consultation process should take place between the programme leader and the employer stakeholders to negotiate the placement of a students at the accredited clinical training sites for completion of their practical or workplace learning sessions. The accreditation for clinical training is done by professional or regulatory bodies.

Accredited healthcare training facilities for students' workplace learning requires a digital radiology department with an EHR and/or RIS/PACS system. Effective interoperability among medical imaging devices, and integration with other programmes in the imaging informatics environment, for example, PACS, EHR, RIS or HIS is vital to enable students to gain practical troubleshooting and problem-solving experience in real-life scenarios. Placement should be considered carefully, to ensure that there are enough resources available for optimal training. Not all radiographers and IT specialists will be actively working as PACS administrators or imaging informatics professionals. Some of the individuals may, even work at healthcare clinics in rural areas, offering x-ray services. They will therefore need to gain access to or be placed in these departments for experiential learning, to complete a portfolio of evidence for specific practical applications. The alternative will be to have practical facilities on relevant databases available at the academic institution, which will enable individuals from all communities to enter as a student in a future imaging informatics course.

Students should have access to the internet or Wi-Fi connectivity with a download speed that will allow the student access to information. A laptop with at least 4 GB RAM is required to enable the students to work from home at a comfortable speed on the EHR and/or RIS/PACS simulation program of the higher education institution from home. Students will also need access to the teaching and learning material, the institutions' library services and digital copies of supplementary instruction from lecturers. In the healthcare training facility, students will need enough, adequately trained and experienced preceptors and facilitators to provide support during their workplace learning.

Student population

The student population for the teaching model in imaging informatics in South Africa will originate mainly from registered qualified radiographers and IT specialists but other groups like prospective medical physicists, radiation science and medical science student could also wish to continue in medical imaging informatics instead of qualifying as independent medical physicist or scientist. Radiographers and IT specialists are already part of the workforce of radiology departments or other medical imaging departments, and wish to advance their careers by specialising in becoming imaging informatics professionals or PACS administrators. As adult students and part of the workforce, face-to-face contact sessions should be scheduled in such a way as to enable as many as possible students to engage.

Clinical training platform

Workplace learning, a sub-division of work-integrated learning in healthcare professionals' training is a medium to apply theoretical knowledge gained in higher education to real-life scenarios in professional practice. The integration of theoretical and workplace-relevant knowledge fosters integrative learning and the development of skills through critical thinking and reflection on real-life scenarios. Students should be able to increase their competence and professional knowledge and skill throughout the process.

As external stakeholders in the teaching and learning process of imaging informatics professionals and PACS administrators, employers in radiology departments need to have their departments accredited as training sites for workplace learning. They also need to have the necessary equipment, technology and student support for workplace learning in the imaging informatics programme, and a signed agreement with the higher education institution for the placement of these students in the programme.

6.3.1.3 *Content*

> *The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly (Ausubel, 1968, p. vi).*

The third circle (3) from the outside in Figure 6.1, represents the content for the teaching model. The content of the teaching model in imaging informatics is grounded on systematic, flawless and authenticated *research results*. The three processes described for data collection in Chapter 3, the triangulation of the result in structured questionnaire 1 and 2 (cf. Chapter 4), the statistical analysis to ensure reliability, the execution of pilot studies, and input by a statistician during the construction of the questionnaires should all ensure the authenticity of the research results (cf. Chapter 3).

Graduate radiographers' knowledge of IT and networks need to be expanded, from a basic level to a more advanced level of imaging informatics. Equally, the IT specialists' experience regarding clinical principle in the imaging informatics field should at least be elaborated to, at least, a more than a basic level.

The themes used in the Delphi study include, (A) IT PACS (imaging informatics) for radiographer PACS administrators; (B) Clinical PACS (clinical training) for IT PACS administrators; (C) Management and ethical principles in imaging informatics (radiographers and IT professionals; (D) Clinical engineering for IT and radiographer PACS administrators, the subthemes and categories under each theme were all arranged or layered in sequence.

The information in the model should be relevant because adult learners will not study details that they believe is unnecessary. The ***relevance*** of an imaging informatics teaching model should be aimed at the learning experiences and needs of the graduate radiographers and IT specialists as adult students.

The researcher created the contents of the teaching model from a systematical research process with conclusions derived from valid and reliable results. In Reigeluth's elaboration instructional design, the instructions start with an epitome (Reigeluth *et al.* 1980:210). The epitome begins with acquainting the students with subject matter that is already known to them, before moving to the unknown, as in Ausubel's (1978) advanced organiser model, which also had similarities with the spiral learning model created by Bruner's in 1960 (Efland, 1995:134). Reigeluth recommends organisation of the subject matter from simple to complex, general to specific, and concrete to abstract.

There should be adherence to educational principles, which is how the content should be organised, for example, whole to part (zoom lens effect), theory to practice (learning the theory and then developing the skill), understanding the principles to integrate them, and empirical to rational (thinking process).

When selecting educational programme content, the principle of progression must be used to report all learning for sustaining advancement. The principle of sequencing relates to the effective ordering of subject matter to advance students' understanding. The volume of the subject matter should be adequate and include up-to-date content because adult students need information that is useful and suitable learning material, that is challenging and applicable. Adult students should be allowed adequate time to practise and learn through experience. The programme must be flexible, and the focus must be more on skills development. Education is complete when theoretical knowledge is united with ability.

6.3.1.4 *Organisation of the subject matter*

Type of teaching model

Reigeluth's elaboration model of instructional design guided the development of the teaching model. The elaboration model describes means of achieving specified goals and is, therefore, a prescriptive model (Hamidi, Hkoshbakht & Abdolmaleki 2011:798).

Reigeluth's instructional design model assisted the selection process and sequencing of subject matter, in a manner that will optimise achievements of learning goals (cf. Chapter 2; cf. 2.6.3). Incorporated in Reigeluth's model are Bruner's spiral curriculum, Norman's web teaching, Gagné's cumulative learning theory and Ausubel's advanced organiser model (scaffolding), which all played a role in the teaching model's development.

The researcher organised the subject matter through a conceptual approach. The subject matter is organised according to layers (zoom lens effect) as described by Reigeluth's elaboration instructional design (cf. Chapter 2; cf. 2.6.3). In academic programmes at higher education institutions, elaboration on information starts on a tertiary level (undergraduate). As the student of the imaging informatics programme will be graduates, elaboration on previous concepts will be picked up at a tertiary exit level and elaborated on at a quaternary level (postgraduate level) (Reigeluth *et al.* 1980:211). Elaborating on previous principles reiterates prior knowledge and improves retention.

The zoom lens sequencing method is described as the well-organised arranging of the content to advance the students' understanding, to assist them in achieving the objectives (Morrison, Ross & Kemp, 2007). Although particular contents may be sequenced in many ways, other contents must be sequenced in a particular order to enhance their presentation. The content derived from the three-round Delphi survey was arranged in a systematic, logical and sequential way. The information was presented in a progressively (from simple to complex), but also with a measure of continuity (from known to unknown).

Balance in the imaging informatics teaching model is the result of the design of the structure being sufficiently detailed for comparable future development and implementation of a curriculum, yet comprehensive enough to give lecturers the autonomy to use the model to accommodate their learners.

The educational system and therefore, the lecturers at higher education institutions should adjust according to societal, professional, employers and learners' changing needs. Educational technology should evolve with the altered educational system to denote functions aligned to the changes (Aslan & Reigeluth 2013:19).

Blended teaching and learning strategies, for example, e-learning, simulation training and online 'flipped classroom' approaches will be most suitable for adult learners. According to the andragogy learning theory (Knowles, 1978), adult learners are internally motivated and self-driven as autonomous individuals, and they prefer to learn through experiences and at their speed.

6.3.1.5 *Learning experiences and assessment*

The second circle from the inside (4) in Figure 6.1 shows the learning experiences and methods of assessment for the teaching model.

Theory underpinning teaching and learning in imaging informatics

The teaching model for imaging informatics is intended for postgraduate programme development, and the students involved are, therefore regarded as graduate adult students. The andragogy learning theory of Knowles (1978) underpinned the development of the teaching model for imaging informatics (cf. Chapter 2; cf. 2.6.1.4). Adult students' self-conception moves from limited dependence to *autonomy*; they learn through experiences, are more focused, and have an internal drive to learn. Independence in the learning process is one of the key elements that was considered for the teaching and learning of students in imaging informatics. Autonomous learners are self-directed in their learning process and need the information to be coherent. They resist the coaching approach, where lectures are content-loaded, and assessments based on examinations (cf. Chapter 2; cf. 2.6.2.1).

Adult students, according to Knowles (1978), should learn by experience, which is acquired through workplace learning. The four principles applied to adult learning, as suggested by Knowles (Pappas 2013:Online) were considered for the development of the teaching model, that is, 1) the radiographers and IT professionals, as adult students, should be included in the preparation for an appraisal of their instruction; 2) their experience (positive and negative) contributes to the foundation of the learning endeavours; 3) the learning subjects presented should have direct relevance to and impact on their work or private life; and 4) that their learning is problem-based, instead of content-orientated (cf. Chapter 2; cf. 2.6.1.4).

Instructional design

Gagné's cumulative learning theory suggests the existence of nine steps of instruction (Khadjooi *et al.* 2011:117). Conditions of learning include an internal learning process that is related to students' prior knowledge, and an external process – the stimuli presented by the lecturer. For instructions to be effective and systematic,

i. Stimuli should be used to gain the adult students' attention;
ii. The objectives of the learning must be clearly stated;
iii. Recall of students' prior knowledge should take place, before elaborating on new information;
iv. The stimulus material (contents) should be presented;
v. Students should be provided with learning guidelines;
vi. Student responses should be elicited for the demonstration of understanding;
vii. Performance levels should be communicated to students through regular feedback;
viii. Formative or summative assessments of performance should be conducted; and
ix. Retention and transferring of knowledge must be enhanced (cf. Chapter 2; cf. 2.6.3). (Khadjooi *et al.* 2011:117)

<u>Instructional collaboration</u>

An interprofessional team representing the radiography and ICT departments needs to develop the future instructional programmes from the model collaboratively. Team teaching could be considered, though the collaboration must be in the classroom and in practice, to optimise the integration of theory and practice, and for the student to learn role differentiation.

<u>Teaching strategies</u>

From the results of the first structured questionnaire, it is evident that adult learners, in this study identified as qualified radiographers (and IT specialists) and prefer part-time and blended teaching strategies (cf. Chapter 2; cf. 4.2.3.5). Different teaching strategies should be used to meet all students' needs. Face-to-face or online lectures should still be offered, but with a 'flipped classroom' approach, which requires the student to engage with the theoretical concepts before the contact session, and applies the information in the lecture to accomplish interactive learning and reflective thinking skills. Shorter periods of contact times should be scheduled for about four weeks in the year.

As part of blended learning, internet-based e-learning and computer-assisted teaching strategies can also be used (cf. Chapter 2; cf. 2.6.2). Imaging informatics instruction should also include conceptual and project-based learning for collaborative problem-solving to foster critical thinking and competence. Real-life scenarios that develop problem-solving techniques could also be done on integrated simulation platforms in imaging informatics of PACS/RIS/HIS/EHR, which will prevent patients from being exposed to harm, and will prevent confidentiality and privacy breaches of personal information (cf. Chapter 2; cf. 2.6.1.3).

The goal is to apply different teaching strategies that best suit the content and the student, to foster deep learning, critical thinking and competence, and ensure a skilled, knowledgeable PACS administrator or imaging informatics professional, as the product of such a teaching and learning programme in the future.

6.3.1.6 *Methods of assessment*

Evaluation of the course should be done with stakeholders like the employers (radiologists), the DoH, and radiographers and IT specialists, as future students.

Teaching and assessment in advanced competencies are challenging. The affective domain of learning can aid, as an organising structure, to develop objectives and select teaching and assessment methods selection (Yanofsky & Nyquist 2014:1–2). The aim of educators in the health sciences should not only be to impact attitudes, knowledge and skills, but also to influence the daily behaviour of graduates. Their communication, teamwork, adherence to values and ethical rules, and respect for others are all examples of soft skills that make graduates in health sciences competent employees. Students need time to practise these soft skills and, if outcomes are not reached, remediation should take place.

Assessments are not only done to evaluate students' progress and attainment of learning outcomes; it also assists lecturers in determining whether their teaching material, presentations and assessments are on standard. Assessments are needed to test students' knowledge, understanding, applications and critical thinking skills for the attainment of learning outcomes. Assessments for adult students should be learning-oriented, to prepare adults students for their upcoming responsibilities and decisions. The following four principles of assessment should be considered:

i. *Validity* of the assessments: the assessment technique should measure what it claims to evaluate, that is, the elements of competency;
ii. *Reliability* of the assessments: relates to the consistency of the evaluation of evidence and assessment outcomes, which should be on the appropriate exit level outcomes;

iii. *Flexibility*: different types of assessment should be used to accommodate different students learning styles. The assessment tool should be contextualised to applications in the adult students' work environment;
iv. *Fairness*: assessment is believed to be fair when the assessment technique is clearly understood by adult students, and the needs of the different learning styles are addressed through agreement by both assessors and students (Rawlusyk 2018:4, 7).

Assessment should be done as frequently as possible to evaluate student learning and enable the identification of problems. Different people should be used to do assessments in the context of the higher education institution and the work environments of the adult student applicable to this study, to ensure flexibility.

Formative assessments, sometimes in the form of peer or self-assessment, should be done frequently to measure students' progress regarding the achievement of the learning outcomes (e.g., tests, case studies, OSCEs, quizzes and in-class discussions) (cf. Chapter 2; cf. 2.6.2.1). Reflection and feedback should be shared immediately after each formative assessment (Bin Mubayrik 2020:1), whether graded or ungraded, to identify students with learning problems as soon as possible, to enable interventions timeously and to facilitate self-confidence in adult students.

A final summative assessment should be done after completion of the modules, which could integrate the contents from all the units in the teaching and learning modules (e.g., IT, imaging informatics principles, clinical, management and ethical principles). Summative assessments can be done in written or online formats, and questions can take on forms such as the multiple-choice single answer, multiple-choice multiple answers, one-word answers, true and false, drag-and-drop or essay type questions. For a higher cognitive order, the problem could set a scenario with four multiple-choice questions connected to it, called a 'testlet'.

Although authentic assessment is the best in the workplace when students are doing what they are supposed to do at the end of the programme, integrated assessment is better when all aspects of learning (e.g., anatomy, imaging, management, ethical and professional practices and IT) is evaluated at the same time. Authentic and successful formative and summative assessments during workplace learning could include project-based collaboration in small groups to solve problems and foster critical thinking skills (e.g. case studies and practical problem scenarios). A portfolio of evidence for tasks that need to be observed or performed could also be incorporated.

6.3.1.7 ***Holistic student development***

The inner circle (5) of Figure 6.1 represents the student, as the model aims to ensure holistic development of the student using a student-centred approach to teaching and learning. The holistic development of students is mainly focused on the *interconnectedness* of reality and experience.

Holistic education encompasses a wide range of philosophical orientations and pedagogical practices. Its focus is on wholeness, and it attempts to avoid excluding any significant aspects of the human experience. It is an eclectic and inclusive movement, of which the main characteristic is the idea that educational experiences foster a less materialistic and a more spiritual worldview, along with more dynamic and holistic views of reality. It also proposes that educational experience promote a more balanced development of – and cultivates the relationships among – the different aspects of the individual (intellectual, physical, spiritual, emotional, social and aesthetic), as well as the relationships between the individual and other people, the individual and the natural environment, the inner self of students and external world, emotion and reason, the different disciplines of knowledge, and different forms of knowing. Holistic education is concerned with life experience, not with narrowly defined 'basic skills'.

Although lecturers in the current higher education environment are supposed to design and deliver instruction as a one-size-fits-all solution, there should be a shift to learner-centred instructions and assessments, that treat each student as an independent adult learner. Students should be allowed to plan their progress and study independently, which should be self-driven and enable achievement-based assessment of the progress of the students. The volume of information that needs to be completed in a specific time may not be achievable by all students, and may then be managed by the individuals to meet their specific learning needs (Aslan & Reigeluth 2013:20). The competence and development levels of the students coming into the programmes cannot be assumed to be exactly the same, therefore, the learning programme should be flexible enough to create more learning opportunities for students who need more time or exposure to reach the exit level outcomes or desired competence levels.

Student-centred approach

A student-centred approach to teaching views adult learners as 'active agents'. In the constructivist teaching environment or 'flipped classroom', the adult learners need to engage with the learning material prior to the lecture to promote interactive student involvement and foster a holistic educational approach. Fundamentally, holistic development refers to the growth of social, emotional, physical, intellectual and mental abilities in students, so that they are proficient to handle everyday life challenges. Holistic development can be traced to prior notions of instruction, where the development is centred on the whole growth of the student experience.

Holistic teaching in higher education is entrenched in experiential learning (skills) and centres education on learning through interaction in the community (community-based learning) of the professional discipline (cf. Chapter 2; cf. 2.6.1.2 & 2.6.2). This type of interaction, in combination with problem-based and collaborative learning, support academic learning and learning in ethical and public engagement. Holistic development of the adult learner should be framed according to NQF level descriptors for South Africa, which is level 8 for a postgraduate diploma.

Student success

Student success in higher education institutions is dependent on the knowledge and skills of the lecturer. The lecturer(s) for imaging informatics courses should be skilled and knowledgeable in IT and networks, clinical domains in radiography, management in IT and imaging informatics. If one individual is not available, the radiography and ICT department should both be involved.

Prior experience and involvement of students play a vital role in their success at higher education institutions. Formative and summative assessments should be done regularly and should include timeously feedback, to enable students to reflect on their performance and facilitate self-confidence amongst themselves.

Students' ability to handle everyday life challenges are of vital importance to ensure success in the professional disciplines of employment. Holistic teaching in higher education is entrenched in experiential learning (skills) and centres education on learning through interaction in the community (community-based learning) of the professional discipline (cf.

Chapter 2; cf. 2.6.1.2 & 2.6.2). This type of interaction in combination with problem-based and collaborative learning supports academic learning and learning in ethical and community engagement.

Type of graduate produced

Attributes of the professional, adult graduate in imaging informatics should be individuals with:

- The ability to work effectively with members of all cultures;
- Excellent communication skills in the working environment;
- Effective engagement in the discipline-specific practice;
- Efficient interprofessional critical thinking skills;
- A balanced life, and respect for others and the environment;
- Good leadership abilities, to lead an interdisciplinary team during collaborative problem-solving;
- The ability to bear full responsibility for work done, use of resources and decision-making;
- Thorough knowledge of the context, systems and applications in imaging informatics; and
- The ability to apply ethics in professional practice (Hayes 2006:19).

Roles of professionals within the NHI system

As the world, including South Africa, is moving to more intensive use of digital technologies for health, including health and imaging informatics systems, the role of the imaging informatics professionals is expanding. The imaging informatics professional (or PACS administrator) as part of a team, is responsible for ensuring a smooth flow of medical and imaging information in an integrated healthcare system. Knowledgeable, skilled individuals in imaging informatics are needed to meet the expanding medical imaging informatics needs in a future national integrated healthcare environment.

6.4 CONCLUSION

In Chapter 6, the model for the teaching of imaging informatics, a platform in BMI, in a future integrated NHI system in South Africa was explained, which included the context, goals, content, and learning experiences. Recommendations were also made regarding teaching strategies and methods of assessment. In Chapter 7, conclusions will be derived, which will comprise a discussion of the implications of the research study and recommendations.

CHAPTER 7

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

In this research project, the researcher conducted an in-depth investigation into imaging informatics, a study level in BMI, to develop a teaching model for imaging informatics that could benefit the integration of radiographers and IT specialist who want to advance their careers in the imaging informatics field in South Africa.

The proposed model was discussed in Chapter 6, including the different aspects involved in holistic education to develop students as a whole to manage all aspects of life. The information in the teaching model is used as a guide for future curriculum development in imaging informatics in South Africa.

In Chapter 7, an overview of the study is given first, followed by the conclusions drawn from the study's results, a brief discussion of the limitations of the study, the contribution to the body of knowledge and the study's significance. Lastly, the recommendations for future study and concluding remarks will be presented.

7.2 OVERVIEW OF THE STUDY

The study was inspired by the researcher's experiences as a PACS administrator for a private radiology practice in South Africa. During her preparations before installation, and experiences afterwards, she realised that formal teaching programmes for imaging informatics (PACS administration) are not available in South Africa. Although professional training was provided by the vendor application specialist, the researcher was also required to engage in self-training. When the researcher was appointed as a lecturer at a higher education institution that offers a radiography programme, her emphasis shifted to the teaching component of imaging informatics.

The overall goal of the study was to improve the training/education of radiographers and IT specialists in a future integrated NHI system, by developing a model for the teaching and learning of imaging informatics in South Africa. The study aimed to develop a model for the teaching and learning of imaging informatics in a future integrated NHI system in

South Africa, in order to address the current shortcoming in the training of imaging informatics.

The researcher investigated aspects of the different study levels that exist in BMI, in order to contextualise imaging informatics. This study used information in the literature, and data gathered from respondents, who comprised of qualified radiographers, IT specialists, PACS administrators, vendors' applications specialists and PACS administrators, e-Health information specialists, lecturers in imaging informatics and digital imaging physics at higher education institutions that offer radiography programmes in South Africa, and an expert panel in imaging informatics, to achieve the goal of this study.

The research project included information originating from the literature review, three structured questionnaires for three distinct sample groups and a three-round adapted Delphi survey. A mainly quantitative research approach with qualitative elements embedded in the Delphi survey was used to answer the research questions. Open-ended qualitative questions were used to prompt the participants to make suggestions, which enabled the researcher to add possible themes or topics after the results from each round in the Delphi survey.

In Chapter 1 (cf. 1.2), the background to the study, and the outline of the reasons that led to the formulation of the research questions, and the outline of the research questions were presented. Two main objectives were pursued in order to obtain answers to the research questions and achieve the aims of the study. In Sections 7.2.1 to 7.2.3, the research questions will be reviewed together with the two objectives and the findings of the research study.

7.2.1 Research question 1

i. What should the necessary component for imaging informatics, in a new NHI system in the South African context, be?

Research question 1 was addressed through objective 1

7.2.1.1 ***Research objective 1***

i. To gather data regarding imaging informatics nationally and internationally.

The first research objective explored the components of imaging informatics principles in a future NHI system in the South African context. The information provided in Phase 1, the literature review (cf. Chapter 2), on the current state of imaging informatics in South Africa and other countries was used to construct structured questionnaires, which were used in Phase 2 to collect quantitative data and analyse the data statistically (cf. Chapter 4). The researcher achieved positive confirmation of the first objective, which was achieved by the development of the three structured questionnaires from the background information in the context of imaging informatics obtained through the literature review and the syllabus of radiography and IT at the local university. The data from the literature review and the findings of the three structured questionnaires, provided the imaging informatics information necessary to develop the first adapted Delphi questionnaire. The first objective, thereby, answered the first research question.

7.2.2 Research question 2

ii. What should be included in a model for the teaching and learning of imaging informatics in a new, integrated NHI system in South Africa?

7.2.2.1 ***Research objective 2***

ii. To develop a teaching model for imaging informatics, a platform in BMI, in a future integrated NHI system in South Africa.
Research question 2 was addressed through objective 2

The second research objective explored the content of imaging informatics that should be included in a teaching model for imaging informatics in a future integrated NHI system. This objective was pursued by the development of an adapted Delphi questionnaire from the findings of the three structured questionnaires, information in the literature review regarding imaging informatics or PACS administration teaching courses abroad, and the syllabi of radiography and IT programmes at the local university. The adapted three-round Delphi survey was structured mainly to incorporate the contents (subject matter) of the imaging informatics teaching model, and the practices of imaging informatics professionals.

The researcher achieved positive confirmation of the second objective. This resulted from the development of the teaching model in imaging informatics. The model development was made possible by the combination of the findings from the adapted Delphi survey (cf. Chapter 5), the structured questionnaires (cf. Chapter 4), and the literature review (cf. Chapter 2). The teaching model development, therefore, also indicate that the second objective answered the second research question, affirmatively.

The researcher was successful in answering the research questions by achieving the research objectives.

7.3 CONCLUSIONS

The teaching model developed through this research study will be useful for developing and implementing a curriculum for imaging informatics teaching and learning in South Africa.

7.3.1 Value of the study

An imaging informatics teaching and learning programme will benefit radiographer and IT specialists by giving them another career path to specialise in imaging informatics. Also, to provide skilled, knowledgeable professionals with a more integrated approach to share medical imaging information in and across healthcare institutions. These individuals will also ensure a smoother workflow within radiology departments', which include PACS administration, promote interprofessional teamwork (role contributions), and reduce variance between health professionals and healthcare institutions.

7.3.2 Significance of the study

The study will contribute significantly to postgraduate academic education programmes for diagnostic radiographers, PACS administrators and IT specialists. It will also contribute to the significant role the radiographer will be able to fulfil in the imaging informatics team and the clinical environment.

7.4 RESEARCH DESIGN

The study is based on the premise that there is no imaging informatics (PACS administration) teaching programme available in South Africa. Guided by the pragmatist paradigm (cf. Chapter 3, Section 3.3), which emphasises solving practical problems, and the researcher staying on course with the rapidly changing digital environment in medical imaging informatics, the researcher used a Lockean inquiry system through an adapted Delphi technique (cf. Chapter 3, Section 3.3.3) to gather data. The design was representative in that it included participants from different spheres within medical imaging, including clinical and technical (ICT) respondents. The design, therefore, assisted in developing a model that allows for different professions, similarly to interprofessional outcomes, to also learn with and about each other. It is grounded in literature and included national and international perspectives on medical imaging informatics training and how it relates to the NHS.

7.5 VALIDITY, CREDIBILITY AND RELIABILITY

Validity in quantitative research represents the credibility of the findings, which is measured by regulating the risk to internal validity and through the research instruments validity (cf. Chapter 3, Section 3.6.1). Face validity refers to the linking of all the questions in the questionnaire to an objective, and contents validity points to the extent the research instruments measure what they were supposed to measure and not something else (Kumar 2019:273). Content and face validity was ensured by formulating the topics for the first and second questionnaire from the information derived from the literature review on imaging informatics principles, and the aspects of imaging informatics included in the modules concerning radiographic imaging technology for the four-year professional degree programme in radiography at the higher education institution where the researcher worked. Pilot studies were conducted for all three structured questionnaires to test for validity before the primary data collection processes. From the six summated scores derived from the first and second structured questionnaires (cf. Chapters 4, Section 4.3 and Section 4.7), and the pretested third structured questionnaire (cf. Chapters 4, Section 4.11), it can be stated that the structured questionnaires measured what they were intended to measure.

Through external validity, the criteria for *credibility* or *generalisability* were demonstrated. The large sample size for questionnaire 1 and the national representation of the population of radiographers enabled the researcher to make realistic and truthful statements and to generalise from the sample to a larger population. The thorough description of the context also allows for possible generalisation. The model developed in the South African context can be applied in different contexts as it was created using a flexible, pragmatic approach, and involving available national and international researchers and experts. The use of a pretested research instrument (ABII) for structured questionnaire 3, the triangulation between structured questionnaire 1 and 2, and the input and statistical analysis by a statistician, also contributed to the credibility of the study. The sample size for questionnaires 2 was fairly small because only eight higher education institutions in South Africa offer radiography programmes, and just lecturers in radiographic imaging technology were targeted. The sample size for questionnaire 3 was also fairly small and diverse in the imaging informatics environment.

Reliability in quantitative research is an indication of the internal consistency of a measurement process to obtaining the same results each time when measuring the same variables under the same conditions (Heale & Twycross 2015:66-67). Cronbach's alpha coefficients for the theme scores in structured questionnaires 1 and 2, was used to measure the reliability of the results statistically. The Cronbach's alpha coefficient for all six themes scores indicated a good to excellent (0.70–0.95) reliability score. The pretested third structured questionnaire's results were considered reliable due to it being used successfully before and a pilot study done before collecting the primary data. It can therefore be said that the results of the structured questionnaires are reliable. In the three-round Delphi survey, a pilot study was done for the first-round questionnaire to test the validity and reliability of the research instrument. Kendall's CC was used to measure interrater reliability of the second and third rounds, which was measured on the level of the subthemes and not the categories, due to the decrease in respondent numbers during the three rounds.

7.6 FACTUAL CONCLUSIONS

From the finding of this research study, the following conclusions were made possible.

7.6.1 To gather data regarding imaging informatics nationally and internationally

In the problem statement, the researcher identified the need for a programme to develop imaging informatics professionals at higher education institutions in South Africa, to improve efficiencies in radiography departments, and improve the quality of patient care. The information obtained from the literature reviews, structured questionnaires and the Three-round Delphi study made it possible to make inferences and deductions regarding the context, goals, content, learning experience and assessment that were used for the model development (cf. Chapter 2, 4 and 5).

The holistic approach to identifying the necessary components within imaging informatics allowed for contextual analysis and identification of relevant concepts. Interpretation of the relationships and approaches to integration scaffolded to create the final teaching model. Therefore, the model guides as to the basic and advanced and can be applied in a variety of environments.

From the literature, the researcher was able to use the combination of different teaching strategies approaches and model development to create a hybrid model that includes best practice elements associated with the various strategies, approaches and models. Radiographers and IT specialists indicated that they prefer blended teaching and learning strategies. We can therefore conclude that the model should include adult learning approaches using a blended learning approach. They also prefer part-time learning, the model and implementation thereof should, therefore, be structured to allow learning on a personalised level and at a rate taking the learner and learner level and learner environment into consideration.

7.6.2 To develop a teaching model for imaging informatics, a platform in BMI, in a future integrated NHI system in South Africa

Using the Delphi, the necessary content was further sifted using the rating of essential, useful and unnecessary. The findings in chapter 5 where only 4 components (statements) were disqualified through saturation and stability indicate that the content of the final model was well correlated (cf. Chapter 5, Table 5.4). It can additionally be concluded that the model does have not only a broad scope but also depth as the comments received strengthened the final inclusions.

The researcher developed the teaching model for imaging informatics as the final product of this research study. If the model is used to prepare a curriculum for imaging informatics, it should be recognised as an evidence-based curriculum. If it is implemented, the graduates should be able to drive the integration of imaging informatics systems into the NHI, and as such improve patient care in the future NHI system.

7.7 RETROSPECTION OF THE RESEARCH JOURNEY

In hindsight, the researcher's knowledge regarding imaging informatics has increased extensively during this research study. The researcher believes that the methods used were relevant to the study, and good quality, useful data were obtained during the process. She built a network with international imaging informatics professionals that allowed for frank, productive discussions during communication, which lead to suggestions and critique of the data.

7.7.1 Limitations of the study

During the research study, the researcher was faced with the following limitations:

i. The respondents in the third structured questionnaire, *professional practice of imaging informatics professionals*, came from diverse backgrounds in the medical imaging informatics and health informatics environment, which made it difficult to evaluate the imaging informatics professionals' periodical practices.
ii The small sample sizes in the three structured questionnaires influenced the reliability and accuracy of the research instruments, and therefore, the confidence level, which is set at 95% with a margin of error of 5% for the health sciences.
iii. The researcher had to limit the information included in the Delphi survey to the content (subject matter) needed for a teaching and learning programme in imaging informatics, due to the volume of the information and the time constraints of the expert panellists.
iv. The unexpected drop-out of Delphi panellists during the second and third round of the survey, and the anonymity of the panellists made it challenging to measure interrater reliability on a category level, therefore the statistician suggested that it be done on a subtheme level only.

The suggestions for future research are supported by the limitations faced by the research study, information from the literature review and the current advances in the domain of imaging informatics.

7.7.2 Recommendations of the study

The researcher, therefore, recommends that other professionals or academics could undertake the following research in the future:

i. An imaging informatics curriculum can be developed in South Africa, and the programme implemented and evaluated.

ii. The researcher recommends that another investigation into the technological developments in the imaging informatics field be done before a curriculum is developed from the model and updated on a continuous basis, to ensure that the imaging informatics graduates are on par with the latest digitalisation, and management practices.

7.8 CONTRIBUTION TO KNOWLEDGE, RESEARCH AND CLINICAL PRACTICE

The research contributed to the contextual creation of new knowledge by developing a model for the teaching of imaging informatics in a future integrated NHI system in South Africa, in order to address the current shortcomings in higher education institutions' training of imaging informatics professionals in medical imaging informatics.

The development of the teaching model described (cf. Chapter 6, Section 6.3) to enable interested educators to develop and implement an imaging informatics curriculum in South Africa in the near future. However, the use of a flexible, pragmatic approach and available research national and international allows for the model to be applied in different contexts.

7.9 CONCLUSIVE REMARK

This study described the development of a model for the teaching of imaging informatics – a platform in BMI – in a future integrated NHI system. The research involved the intensive generation of information on the subject matter needed in an imaging informatics teaching and learning programme, and the required practices necessary to develop such professionals.

> *The number one benefit of information technology is that it empowers people to do what they want to do. It lets people be creative. It lets people be productive. It lets people learn things they didn't think they could learn before, and so in a sense it is all about potential.*
> Steve Balmer

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