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Three-dimensional thinking in radiography

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THREE-DIMENSIONAL THINKING IN RADIOGRAPHY

by

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DECLARATION

I, Dalene Venter, declare that the contents of this dissertation represent my own unaided work, and that the dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed

2 December 2008

Date

ABSTRACT

Introduction

Research to date has not been able to agree whether spatial abilities can be developed by practice. According to some researchers spatial ability is an inherited cognitive ability, compared to spatial skills that are task specific and can be acquired through formal training. It is commonly assumed that radiographers require general cognitive spatial abilities to interpret complex radiographic images. This research was conducted to investigate second year radiography students' three-dimensional thinking skills pertaining to film-viewing assessments.

Materials and methods

The experimental research strategy was mainly applied together with correlation research. Two trials were run (in 2005 and 2006). The sample group consisted of fifteen second year diagnostic radiography students in 2005 and twenty-three second year diagnostic radiography students, of the same institution, in 2006. Each year group was randomly divided into a control group and an intervention group. Two instruments were used, that is a film-viewing assessment and a three-dimensional test, Academic Aptitude Test (University) (AAT) nr. nine: Spatial Perception (3-D). The whole class completed this basic spatial aptitude test, as well as a base-line film-viewing assessment, which focused on the evaluation of technique/anatomy of second year specialised radiographic projections. The marks that the students achieved in the fore-mentioned tests were compared, to determine if there was any correlation between their performances in the different tests. A curricular intervention, which was intended to improve applied three-dimensional skills, was subsequently applied. The students executed certain modified radiographic projections on parts of a human skeleton. For each radiographic projection, the students had to draw the relation of the X-ray beam to the specific anatomical structures, as well as the relation of these structures to the film. The related images of these projections were also drawn. With each of the following sessions, films including images of the previous session were discussed with each student. After the intervention, the whole class wrote a second film-viewing assessment. The marks achieved in this assessment were compared to the marks of the initial film-viewing assessment to determine the influence of the intervention on the performance of the intervention group. Following this assessment, for ethical reasons, the same

intervention took place with the control group. A third film-viewing assessment was then written by all the diagnostic second year students to evaluate the overall impact of the intervention on the applied three-dimensional skills of the class. The marks of both the 2005 and 2006 classes (intervention classes) were compared to the marks achieved by former classes from 2000 to 2004 (control classes), in film-viewing assessments to evaluate the role of the curricular intervention over the years. The students again completed the three-dimensional test, Spatial Perception (3-D) to evaluate the impact of the intervention on students' general three-dimensional cognitive abilities. These marks were also compared to the marks of the third film-viewing assessment, to determine if there was any correlation between the students' performances in the different tests.

Results

The intervention groups did not perform significantly better in film-viewing assessments after the intervention, compared to the control groups, but reasonable differences, favouring the intervention group, were achieved. Statistical significance was achieved in film-viewing assessments with both year groups after the whole class had the intervention. The intervention year groups also performed significantly better than the previous year groups (without the intervention) in film-viewing assessments. The performance in general three-dimensional cognitive abilities of the group of 2006 improved significantly after the intervention, but on the contrary, the performance of the group of 2005 declined. There was a small intervention effect on the performance of the group of 2006. Only a weak to moderate correlation between the marks of the students achieved in the three-dimensional tests and the marks achieved in the film-viewing assessments, was found.

Conclusion

The contrasting evidence between the data of the two groups (2005 and 2006) in the three-dimensional tests and the small intervention effect on the performance of the group of 2006, makes the intervention not applicable for the increase of general spatial abilities. The results of this research show that the applied three-dimensional skills of radiography students in interpreting specialised and modified projections can be improved by intensive practice, independent of their inherited spatial abilities.

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> "Numerous radiographers have not only taken pride in the quality of their clinical abilities but have extended their clinical skills into artistic expressions of creativity."
>
> Carlton & Adler, 1992.

DEDICATION

For my parents, with love and in gratitude
For my husband, Abrie and our children, Ian and Anene
For my role models in radiography: Mignonette du Plessis and Annetjie du Preez

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GLOSSARY

TERMS:

Antero-posterior:	**An antero-posterior projection means that the X-ray beam is directed from the anterior (frontal) aspect of the patient towards the posterior aspect (back) of the patient, with the posterior aspect of the patient in contact with the X-ray film/Bucky.**
Bucky:	**A device containing the cassette with the X-ray film.**
Cassette:	**A device containing the X-ray film/image detector.**
Central executive:	**The central executive is a flexible supervisory system responsible for the control and regulation of complicated cognitive processes occurring in the working memory. This system is linked to the prefrontal cortex of the brain.**
Da Vinci exercise:	**This exercise is used to practice visual memory by observing a complex object thoroughly and memorising it. The eyes are closed afterwards and the object visualised as clearly and in as much detail as possible.**
Depiction:	**The depiction is a mental image that occurs in a spatial medium and includes all the relative pictorial information.**
Description:	**The description is an abstract mental sentence that describes the object or scene and it does not include spatial information.**
Film-viewing assessment:	**The assessment consists of two to four stations (viewing boxes). Three to four films are placed on each viewing box and the student has to complete a questionnaire, on the radiographic appearances of these images, within a certain time limit.**
Infero-superior:	**An infero-superior projection is an axial projection where the X-ray beam is directed from the patient's feet towards the patient's head.**
Mental rotation:	**To mentally execute a spatial rotation of a perceived object.**
Postero-anterior:	**A postero-anterior projection means that the X-ray beam is directed from the posterior aspect of the patient towards the anterior aspect of the patient, with the anterior aspect of the patient against the X-ray film/Bucky.**

Reversed occipito-mental projection of the facial bones: The reversed occipito-mental projection of the facial bones means that the X-ray beam is directed through the symphysis menti (chin) of the patient towards the occipital aspect (back of the skull) of the patient, with the occipital aspect against the X-ray film/Bucky. The radiographic baseline of the patient usually forms an angle of 45° with the vertical/horizontal.

Right anterior oblique: A right anterior oblique projection means that the horizontal/vertical X-ray beam is directed from the posterior aspect of the patient towards the anterior aspect of the patient, with the right anterior aspect of the patient against the X-ray film/Bucky. The coronal plane of the patient's body usually forms an angle of 45° with the film/Bucky.

SAQA credit: A credit is a value assigned to a number of notional hours of learning. One credit equals ten notional study hours. Notional hours mean the estimated learning time it would take an average learner to achieve the prescribed outcomes.

Supero-inferior: A supero-inferior projection is an axial projection, where the x-ray beam is directed from the patient's head towards the patient's feet.

Spatial ability (aptitude): The mental ability to hold and manipulate visual information in space. It consists of two components, namely spatial relations ability and spatial visualisation ability. It is the ability to mentally visualise and manipulate objects before any formal training has occurred.

Spatial intelligence: The ability to generate and manipulate mental images in order to solve problems.

Spatial relations ability: The ability to mentally rotate two-dimensional and three-dimensional objects as a whole.

Spatial skills: The skills that are acquired through training, to hold and manipulate visual information in space.

Spatial visualisation ability: The ability to mentally rotate two-dimensional and three-dimensional objects as a whole, as well as the mental rotation of parts of the objects.

Station: A viewing box used during a film-viewing assessment. Three to four films are placed on the viewing box and the student has to complete a questionnaire, on the radiographic appearances of these images, within a certain time limit.

Visual image-generation: **The mental creation or recreation of images, in the absence of retinal input.**

ABBREVIATIONS:

AAA	**Abdominal aortic aneurysm**
AAT	**Academic Aptitude Test**
ANOVA	**Analysis of variance**
AP	**Antero-posterior**
CHE	**Council on Higher Education**
CT	**Computerized Tomography**
DAT	**Differential Aptitude Test**
DAT	**Dental Aptitude Test**
3DC	**Three – Dimensional Cube Test**
DLPFC	**Dorsolateral Prefrontal Cortex**
EdwgT	**Interactive Engineering Drawing Trainer**
ETQA	**Education and Training Quality Assurance body**
fMRI	**Functional magnetic resonance imaging**
GeoSAT	**Geological Spatial Aptitude Test**
GIS	**Geographical Information Systems**
HEQC	**Higher Education Quality Committee**
HMPAO	**99m-Tc-hexamethyl-propylene-amine-oxime**
KV	**Key view**
MV	**Multiple view**
NQF	**National Qualifications Framework**
OSCE	**Objective Structured Clinical Evaluation**
PA	**Postero-anterior**
SAQA	**South African Qualifications Authority**

SD	**Standard deviation**
SEQ	**Spatial Experience Questionnaire**
SGB	**Standards Generating Body**
SPECT	**Single photon emission computerized tomography**
V1	**Primary visual cortex**
VPA	**Visual penetration ability**
VRML	**Virtual reality modelling language**
VSP	**Visual spatial perception**
VSSP	**Visuo-spatial sketchpad or scratchpad**
VSWM	**Visuo-spatial working memory**

CHAPTER ONE
INTRODUCTION

Diagnostic radiography involves the production of photographic and digital images. It also implies the critical evaluation of these images in order to recognise abnormal appearances (pattern recognition), which includes recognising abnormal anatomy, as well as errors in technique. Radiographers should be able to adapt their technique according to the radiographic images to rectify these errors.

It is generally assumed by radiographers and other role-players in radiography, that diagnostic radiographers have a particular spatial aptitude or “innate” cognitive spatial abilities. In radiography training, it is assumed that specialised spatial skills are acquired through training and that this combination of aptitude and skill will, in time, enables the student to interpret complex radiographic images. This thesis argues that the spatial skills of radiography students in interpreting specialised and modified projections can be developed and improved by intensive practice, independent of their inherited spatial abilities. It is therefore not expected that the educational intervention will have an impact on the spatial aptitude or “innate” abilities of the students, but it is expected to develop their spatial skills in interpreting radiographic images.

In this chapter the history of radiography training in South Africa is briefly described. The curricula for the National Diploma in Diagnostic Radiography, Outcomes Based Education in South Africa, the structure for the subject Clinical Radiographic Practice II and the difficulties students experienced in film-viewing assessments of specialised radiographic projections, are explained. Next follow the objectives of the research, as well as an outline of the research structure.

1.1 Context

1.1.1 History of radiography training in South Africa

Wilhelm Conrad Roentgen discovered X-rays on 8 November 1895. On 28 December 1895 he announced the discovery of X-rays to the Physico-Medical Society of Wurzburg in Germany. Soon after that memorable day, stories and cartoons were published all over the world in newspapers about these mysterious invisible rays (Bensusan, 1967). Six months after the announcement, the president of the Port Elizabeth Amateur Photographic Society, Mr A. Walsh, imported an X-ray apparatus from England. This was probably the first radiographic equipment that was brought to South Africa. On Thursday, 13 August 1896, a trial run with the equipment was carried out successfully. The first radiographic projection executed in South Africa, was a projection of the hand of Mr Walsh. Soon after the trial run, a demonstration was given in the Society's studio to doctors, to awake their interest in the discovery (Bensusan, 1967). Mr R.H. Gould, an engineer working for the firm Siemens and Haske, constructed the first X-ray apparatus in South Africa, in Johannesburg in 1897. He was a Red Cross official during the South African war and with the X-ray apparatus that had been transported to a military hospital in Krugersdorp, he did numerous examinations on wounded men (Rosenthal, 1995).

A South African Radiography Society, which was actually a branch of the British Society of Radiographers, was instituted in 1930, in Johannesburg by two engineers, Mr Fred Gillham and Mr Victor Gillwald. Mr Gillham did radiography in his part-time and also serviced X-ray equipment, while Mr Gillwald sold X-ray equipment. They approached the British Society, requesting the formation of a branch, as well as formal training for radiographers in South Africa (Hochschild, 1983). The Society agreed and the first British radiography examination was written in Johannesburg, in 1933. Following this examination, radiography schools were gradually established in Cape Town, Durban, Port Elizabeth, East London, Pretoria and Bloemfontein (Hochschild, 1983). Ms May Winifred Tompkins played an important role in the development of both the Society and radiography training, in South Africa. She was educated and trained by the famous Ms Kathleen Clark, author of *Positioning in radiography* at the Royal Northern Hospital in the United Kingdom (Irving, 1995). After qualifying as a diagnostic radiographer, she returned to South Africa and was appointed in January 1933 as the radiographer in charge of the radiography training school at the Johannesburg General Hospital. According to Irving she was " . . . as much a legend in her lifetime as was Ms. K.C. Clark in England" (1995: 17). The Society of Radiographers of South Africa was officially instituted in 1951, with Ms May Tompkins as the chairlady. In 1953 the first South African radiography examination was written in Johannesburg. Students had to write both the South African and British examinations to ensure reciprocity. Full reciprocity with Britain was only obtained in the 1960's (Hochschild, 1983).

1.1.2 Curricula for the National Diploma in Diagnostic Radiography

The curriculum for the National Diploma in Radiography was revised in the years just prior to 1993. In 1993, the subject Radiation Technique II became the subject Radiographic Practice II. An additional subject that would formally facilitate and assess the clinical competence of the second year students, was established, namely Clinical Radiographic Practice II.

The curricula are as follows:

Table 1.1: Radiography curricula before 1993 and after 1993 (van der Watt, 1995)

Program	**<u>Initial program</u>:** National Diploma in Diagnostic Radiography (phased out during 1992 to 1995)	**<u>Revised program</u>:** National Diploma in Diagnostic Radiography (phased in during 1993)
First year level	Radiation Technique I Image Recording I Physics Radiation Physics and – Protection Anatomy, Physiology and Pathology I	Radiographic Practice I Clinical Radiographic Practice 1 Radiation Sciences I Anatomy 1 Physiology I Psychodynamics of Patient Management
Second year level	Radiation Technique II Image Recording II Equipment Anatomy, Physiology and Pathology II	Radiographic Practice II Clinical Radiographic Practice 1I Radiation Sciences II A Radiation Sciences II B Radiographic Pathology II
Third year level	Radiation Technique III Specialised Equipment Anatomy, Physiology and Pathology III	Radiographic Practice III Clinical Radiographic Practice 1II Radiation Sciences III Radiographic Management III

1.1.3 SAQA and Outcomes Based Education

The SAQA Act (No. 58 of 1995) and the Higher Education Act (No. 101 of 1997) promulgated by the Department of Education started the restructuring process of Higher Education in South Africa, with the aim to create an integrated national qualifications framework. The Act instituted the South African Qualifications Authority (SAQA) (du Pré, 2000). SAQA is a statutory body of 29 persons appointed by the ministers of Education and Labour. These persons are representatives of all major stakeholders in education and training. The Authority has two main functions, namely to oversee the development and the implementation, of the National Qualifications Framework (NQF). The first appointments to SAQA were made in May 1996 and their first meeting was held in August 1996 (Ramphele, 2000).

SAQA accredited the Council on Higher Education (CHE) as the Education and Training Quality Assurance body (ETQA) for Higher Education. The Higher Education Quality Committee (HEQC) of the CHE accredits institutions and learning programs and conducts audits at these institutions (du Pré, 2000; SAQA, n.d.; MacGregor, 2008).

The NQF is a framework on which standards and qualifications, approved by stakeholders in education throughout South Africa, are registered. The NQF enables students to achieve qualifications that are nationally recognised, as well as internationally comparable (du Pré, 2000). A new higher education qualifications framework, which consists of ten levels, of which levels five to seven will be linked to undergraduate and levels eight to ten to post-graduate qualifications, will be implemented in South Africa in 2009. A request for commentary on the National Qualifications Framework Bill 2008 was gazetted in February 2008 (MacGregor, 2008).

The objectives of the NQF are the following:

- To create an integrated national framework for education.
- To assure the recognition of prior learning, facilitate access to education, mobility within education and life-long learning.
- To promote the quality of education.
- To contribute to the full development of each learner.
- To accelerate the rectification of discrimination of the past (Ramphele, 2000; NQF, n.d.).

The Higher Education Act forced higher education institutions to change their academic courses into degree programs. These programs consist of learning activities pertaining to the curriculum that will lead to obtaining a qualification or part of a qualification (du Pré, 2000). All new higher education programs will from January 2009 have to meet the terms of the new framework, be registered according to it and be accredited by the HEQC (MacGregor, 2008). The curriculum design of outcomes-based learning programs focuses on involvement of the learner in the learning process, as well as the achievement of outcomes. Students' performance should be assessed continuously as assessments form part of the learning process. The demonstrated end products of the learning process (knowledge, skills and values obtained) are the outcomes. Critical outcomes are the generic (essential) outcomes prescribed by SAQA, which should be achieved in all learning programs. The process is learner-driven, which implies that the lecturer should mainly facilitate learning by promoting creativity, critical thinking and self-directed learning (du Pré, 2000; NQF, n.d.). Credits are obtained through achieving the outcomes.

A SAQA credit is a value assigned to a number of notional hours of learning. One credit equals ten notional study hours. Notional hours mean the estimated learning time it would take an average learner to achieve the prescribed outcomes. After one year of full study a student should obtain one hundred and twenty SAQA credits (du Pré, 2000; MacGregor, 2008). According to MacGregor (2008), a maximum of 50% of credits attained in one qualification may be conveyed to another qualification, but it should not comprise more than 50% of the content of the second qualification. According to the Minister of Education, Naledi Pandor, the new higher qualifications framework will improve the articulation of programs and credit transfer, because separate qualifications structures for universities and universities of technology, will no longer exist (MacGregor, 2008).

The Standards Generating Body (SGB) refers to a body registered in terms of section 5 (1) (a) (i) of the SAQA Act. This body is responsible for the determination of education and training standards, or qualifications for a specific program such as radiography (Ramphele, 2000; SAQA, n.d.). Since 2004 the SGB for Radiography in South Africa has been working on the submission of new qualifications. The following qualifications in diagnostic radiography have recently been submitted to SAQA for registration: a Bachelor of Diagnostic Radiography (480 credits), a Masters Degree, as well as a Doctoral Degree in Diagnostic Radiography (Friedrich-Nel, 2008).

1.1.3.1 Revised structure for Clinical Radiographic Practice II

The structure of the subject Clinical Radiographic Practice II has been adjusted in the past few years to meet the SAQA prescriptions for outcomes based education.

<u>Credit level outcomes for Clinical Radiographic Practice II</u>:

The student must be able to:

- apply diagnostic techniques, appropriate to the clinical presentation, for the production of optimum image quality;
- evaluate request forms and radiographic images and apply pattern recognition to techniques at this level;
- care for the patient responsibly and effectively, to ensure the welfare of the patient is maintained;
- manage the department to ensure optimal quality radiographic services; and
- access, organise and present information applicable to the radiography context, using appropriate information technology (Peninsula Technikon, 1999).

The evaluation of radiographic images and the application of pattern recognition, thus form part of the credit level outcomes in the second year (240 credit level), of the current program - National Diploma in Radiography. Radiographic images have to be evaluated for quality and positioning. Normal and abnormal appearances of radiographic images, linked to specialised techniques, must be recognised. Students must be able to recommend and apply corrective measures when necessary.

<u>Critical outcomes for Clinical Radiographic Practice II</u>:

The student must be able to:

- apply problem-solving skills in radiography;
- work effectively within the health care team and educational environment;
- effectively communicate with other health care workers, patients, fellow students and lecturers;
- appropriately use science and technology applicable to radiography; and

- demonstrates skills in information literacy (Peninsula Technikon, 1999).

Problem-solving skills are applied when evaluating radiographic images for quality and technique and especially for the recommendation of corrective measures.

1.1.4 Film-viewing assessments

Problem-solving skills, pertaining to pattern recognition, are evaluated during structured, objective, film-viewing assessments. Each assessment may consist of two to four stations (viewing boxes). Three to four films are placed on each viewing box and the student has to complete a questionnaire, on the radiographic appearances of these images, within a certain time limit (e.g., six minutes per station). The students rotate under direct supervision of the clinical lecturer, from one viewing box to the other, completing the questionnaire at each station. Examination rules of the training institution are strictly applied.

1.1.5 Background to the role of spatial three-dimensional thinking in radiography

1.1.5.1 Difficulties experienced by students in film-viewing assessments

Between the years 2000 to 2004, second year radiography students at site A, performed better when executing specialised radiographic projections on patients/models, compared to their evaluation of radiographic images of similar projections. There was a difference of 6% between the average results (74%) that the students achieved over these five years in radiographic technique assessments and the average results (68%) achieved in film-viewing assessments of radiographic technique for the same period. Approximately 30% of the students had particular difficulties in evaluating the images of modified (oblique/axial) radiographic projections. These students were not able to link the shape and position of anatomical structures on images with the direction of rotation of the patient's body, and they had little success in identifying the aspect of the patient against the X-ray Bucky (device containing the cassette with the X-ray film) in oblique projections. It is thus possible that they could not mentally "see" the rotation of structures when evaluating images of oblique projections, for example, the rotation of the vertebrae on an image of an anterior oblique projection of the chest (Refer to Figure 1.1). These students found it difficult to suggest modifications of technique by angling the X-ray tube, such as removing overlying structures from a region of interest. To be able to suggest such modifications, these students had to mentally relate the positions of structures on the image, to the actual positions of the structures in the patient's body, to know which structure was closest to the X-ray tube and could be displaced by angling the X-ray tube. When evaluating the image of the reversed occipital-mental projection of the facial bones of a seriously injured patient, it is often necessary to suggest angulations of the X-ray tube, to separate the maxillary sinuses from the dense petrous bones (Refer to Figure 1.2).

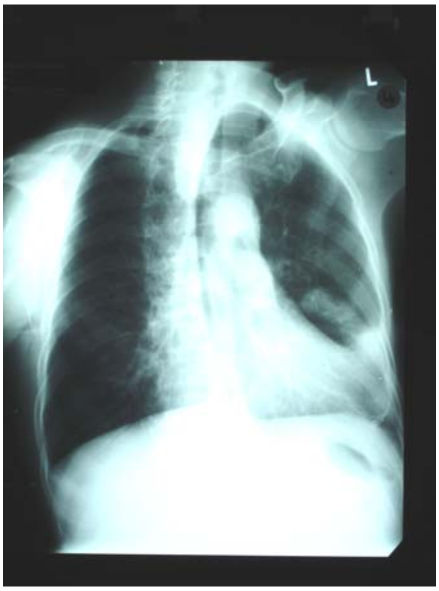

Figure 1.1: Right anterior oblique projection of the chest (photograph of X-ray taken by researcher)

Figure 1.2: Reversed occipito-mental projection of the facial bones (photograph of X-ray taken by researcher)

These students also experienced difficulties in evaluating the images of axial (supero-inferior/infero-superior) projections regarding orientation of structures, for example, to identify which structure was anteriorly and which structure was posteriorly situated. It is especially important for recognising an anterior or posterior dislocation of the humeral head (Refer to Figure 1.3).

Figure 1.3: Supero-inferior projection of the shoulder (photograph of X-ray taken by researcher)

1.1.5.2 Stereoscopic vision versus interpretation of radiographic images

Stereoscopic vision, namely the perception of depth, depends mainly on binocular vision (perception with both eyes). The eyes are situated six to seven centimetres apart therefore two different sides of an object are seen. An object at a certain distance from the eyes produces different retinal images due to the distance. These images of different orientation consist of different encoding information. These images are combined and interpreted by the visual cortex of the brain, with the result that the object is perceived in three dimensions (Hole, 1987).

The image of a radiographic projection on radiographic film (or computer screen) is however a two-dimensional "picture" of three-dimensional structures. Even if radiographers have binocular vision, they will be obliged to use their cognitive skills to think abstractly or "see" three-dimensionally. There are two types of visual images, namely real images, such as photographic or radiographic images, and mental images, which are mental "pictures" within our minds (Ball & Price, 1989). Novelline notes: "The radiograph is a composite shadow-gram and represents the added densities of many layers of tissue. You must think in layers when looking at any radiograph" (2003: 2). During film-viewing assessments of radiographic technique, radiography students should therefore be able to form a three-dimensional mental image of anatomical structures, when observing a two-dimensional radiographic image. Smoker, Berbaum, Luebke and Jacoby state: “Some individuals have an aptitude superior to others to perceive three-dimensional spatial relations from two-dimensional data” (1984: 1). Research in the United States of America has shown that only 30% of people have developed formal-operational cognitive abilities and that this is linked to their cultural background (Van Rensburg, 1985). Not all adults can therefore reason/think abstractly. According to Sorby (1999), spatial ability is a cognitive ability that a person is born with, compared to spatial skills that are acquired through formal training.

1.1.5.3 Interpretation of pictures versus interpretation of radiographic images

According to Reinhardt-Rutland (1996), only a small amount of depth perception can be obtained from the images of a picture, on condition that the objects are well distinguishable and their shapes are known. Barlow and Mollon (1982) maintain that three-dimensional representations of shape and distance depend on different depth cues from visual images of a two-dimensional picture. One of the cues is occlusion, which means the blocking of one image by another (Refer to Figure 1.4).

Another cue is the size of images. The pictorial image, which is occluded or represented as smaller, is usually further away from the viewer. Matteo (2001) adds that shadows and shading in a picture can also provide three-dimensional information. Shadows and shading usually represent depth.

Figure 1.4: Occlusion of part of a bedpan by an urinal, indicating distance from viewer (sketch drawn by researcher)

Due to various technical factors, the radiographer is involved with a much more difficult process regarding the visualisation of depth on a radiographic image. Smaller images on a radiographic film (or a computer screen) mean that these anatomical structures were situated closer to the film (or the image receptor) during exposure and that they are not further away from the person who is examining the film (or the computer screen). Minimal magnification in radiography is achieved when the object-film (or object-image receptor) distance is small, in relation to the focus-film (or focus-image receptor) distance (Ball & Price, 1989). The position of the patient (postero-anterior/antero-posterior) during an exposure should therefore also be taken into account when evaluating radiographic images. For example, the size of the heart would differ from a postero-anterior (PA) projection to an antero-posterior (AP) projection of the chest.

Some anatomical structures would be superimposed on radiographic images. Occlusion of certain structures would occur, due to the density of the overlying structures. As the X-ray beam penetrates the patient's body, the intensity of sections of the beam is reduced. The attenuation depends mainly on the thickness of the tissue through which it has passed (Ball & Price, 1989). Radio-opaque (more dense) structures will absorb more X-rays than radiolucent (less dense) structures, therefore fewer X-rays will reach the film (or image receptor), and the representing area on the film (or screen) will appear white (Ball & Price, 1989). These dense structures will obscure less dense structures. An example of the fore-mentioned would be the heart obscuring part of the lungs (Refer to Figure 1.5).

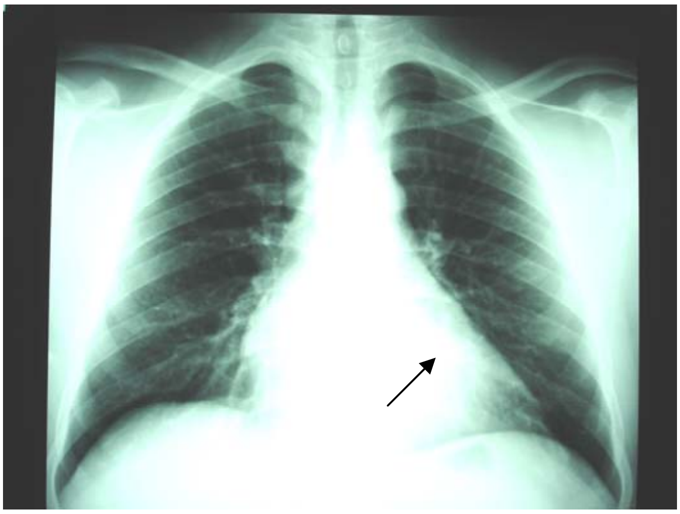

Figure 1.5: Occlusion of part of the lungs by the heart indicating higher density of the heart (photograph of X-ray taken by researcher)

Occlusion in radiography is therefore not indicative of the depth of different structures within the patient's body, or the various distances of these structures from the film-viewer. Shadows on an image would also not indicate depth, but rather radio-lucency (less dense structures).

More problems associated with three-dimensional thoughts during the evaluation of a two-dimensional picture/radiographic image, include the fact that three-dimensional objects represent "stick figures", which are constructed of a number of "axes". If these "axes" are foreshortened on a picture, it is very difficult to recognise the object (Marr & Nishihara, 1978: 277 - 278) (Refer to Figures 1.6 and 1.7).

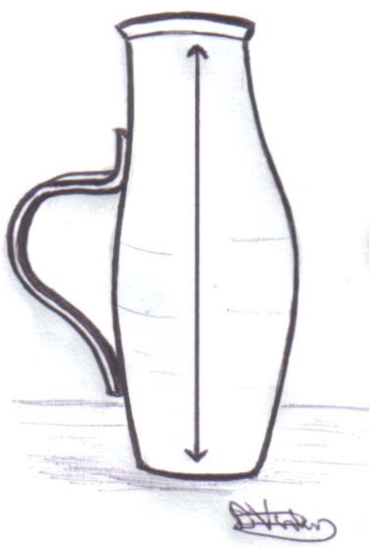

Figure 1.6: Familiar appearance of an urinal
Long axis is visible (sketch drawn by researcher)

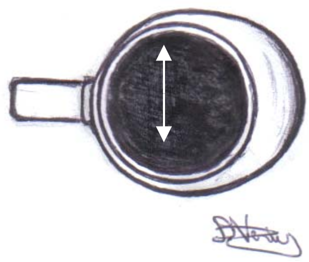

Figure 1.7: Unfamiliar appearance of an urinal
Foreshortening of the structure (sketch drawn by researcher)

Foreshortening also occurs in radiography if the object plane (long axis) of a bone is not at right angles (or more or less at right angles) to the X-ray beam, for example, the calcaneus, when performing an axial projection of the calcaneus (Ball & Price, 1989) (Refer to Figures 1.8 and 1.9).

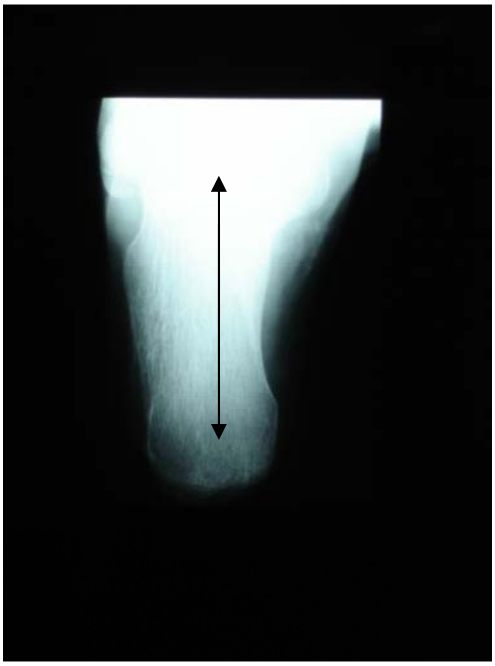

Figure 1.8: Axial projection of the calcaneus
Long axis of calcaneus visible (photograph of X-ray taken by researcher)

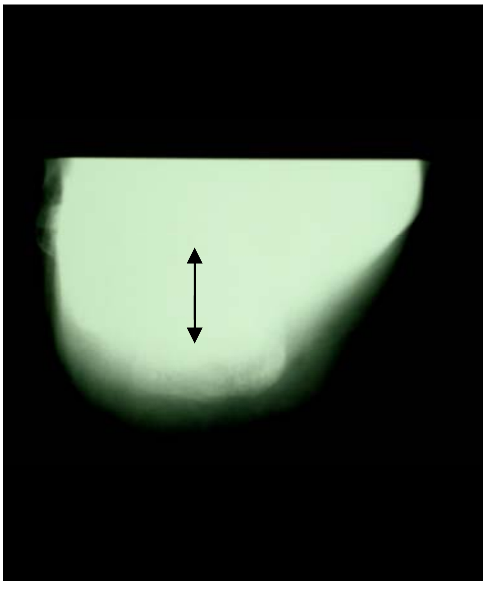

Figure 1.9: Axial projection of the calcaneus
Calcaneus foreshortened (photograph of X-ray taken by researcher)

1.1.5.4 Experience and practice

There might be a solution to the before-mentioned difficulties, regarding the evaluation of radiographic images. According to Scharfetter " . . . every cognition is a re-cognition" (1980: 132). Previous experience of objects/structures would therefore mainly determine if the images of these objects be recognised. Du Toit agrees by stating: " . . . to imagine is to visualise something in your mind. Often it is a matter of remembering things and recalling certain details"(1995: 128).

Du Toit also posits that " . . . imagining is something we can practise, develop and improve, thus expanding our intellectual strength" (1995: 131). Another important fact is that long-term memory is acquired by absorbing meaningful information, by means of repetitive exercising (Winefield & Peay, 1980). Meaningful information means that the students understand the information, leading to insight, analytical thinking and application of knowledge. Köhler's theory emphasises the fact that learning occurs while acquiring insight during the execution of a task (Burns, 1991). The simulation technique could be used to pose a problem situation for students. If they solve the problem, more insight about the problem would be acquired, their critical thoughts would be stimulated and the information would be stored in their long-term memory, for application in future.

1.1.5.5 Previous research done on this specific topic

According to the Nexus and Sabinet database systems (current and completed research), this specific research has not been done in diagnostic radiography in South Africa. Similar research has however been done in America, to see if there is any linkage between the three-dimensional thinking skills of radiologists and their interpretation of radiographic images. The results of the three-dimensional Visual Form Reconstruction Test and the Thurstone Surface Development Test written by these radiologists correlated well with their performance in evaluating radiographic images (Smoker *et al.,* 1984). Similar research has also been done in Great Britain. Two tests for spatial ability were done by qualified radiographers, as well as by student radiographers, namely the Blocks Test and the Dimensions Test. The results of both tests correlated well with their performance (speed and accuracy) at work (Jones, 1977). According to the research done by Jones (1977), there is an indication that spatial aptitude tests could be used for the selection of student radiographers, but she cautions that more research on these tests should be done. According to the researcher, "speed" and "accuracy" are broad terms used in radiographic practice.

Smoker *et al.* (1984), and Jones (1977), do not specifically mention the radiologists'/ radiographers' performance in film-viewing assessments, regarding the rectifying of technique errors. Mackenzie (1992) also emphasises the use of psychometric aptitude testing in the selection of student radiographers, by stating that although this testing is expensive, it should be used together with other selection criteria, if it is affordable. Her research entails personal interviews that were conducted with qualified radiographers and lecturers of different radiography training institutions, mainly in South Africa, to determine the most important aspects of radiography.

Adrian-Harris, on the other hand, stresses the important role of training when claiming that: "A group of radiographers raised their performance on a film-viewing task from 56% - 76% as a consequence of visual search practice . . ." (1979: 237). For 15 working days the radiographers had to time their search for a single vowel amongst a list of 249 consonants. On the other occasions they were asked to find any vowel. They wrote a film-viewing test on pattern recognition before commencing the search tasks, as well as after completing the tasks. By allowing them to acquire these skills, their performance improved significantly (Adrian-Harris, 1979).

As the researcher has previously explained, pattern recognition in radiography comprises the detection of various abnormal appearances, for example, abnormal anatomy, artefacts, technique errors, etc. As with the fore-mentioned research of Smoker *et al.* (1984) and Jones (1977), Adrian-Harris does not specifically mention the performance of the radiographers in film-viewing assessments regarding the rectifying of technique errors.

1.2 Problem statement

The focus of this research is second year radiography students' cognitive skills for relating the positions of visual anatomical structures on modified radiographic images, with the actual positions in the human body. This research could enable a better understanding of students' three-dimensional thinking and thus contribute to an appropriate training program for diagnostic radiographers. An evaluation methodology, which focuses on a particular curricular intervention, was used.

1.3 Sub-problems

The sub-problems are as follows:

- **Sub-problem one**: Correlation between the students' performance in three-dimensional tests and film-viewing assessments must be determined.

- **Sub-problem two**: A curricular intervention, which is intended to improve three-dimensional skills, pertaining to radiographic images, must be developed and applied. The impact of the curricular intervention on students' applied three-dimensional skills must be evaluated and explained.

- **Sub-problem three**: The impact of the curricular intervention on students' general cognitive abilities, pertaining to three-dimensional thinking, must be evaluated and explained.

1.4 Research hypothesis

The research hypothesis involves the following assertions:

- There is a relationship between students' perceived limited three-dimensional thinking abilities and the difficulties they experience in the evaluation of two-dimensional radiographic images.

- There will be a difference in the skills of students who received in-depth training sessions aimed at developing critical thinking skills to interpret radiographic images and those students who did not receive the training.

1.5 Delimitation of the research

The research was limited to the second year diagnostic radiography students of the tertiary institution, site A. Fifteen diagnostic radiography second year students comprised the sample group in 2005 (group A) and twenty-five second year students, the sample group in 2006 (group B).

The data of three of the second year students was excluded from the studies in 2005 and 2006. These students had extra clinical experience. One student had repeated the subject Clinical Radiographic Practice I. The other two students were repeating the subject Clinical Radiographic Practice II. All three students did however participate in the activities.

1.6 Objectives of the research

The research objectives are as follows:

- To determine if the students' general three-dimensional abilities are linked to their performance, pertaining to the evaluation of radiographic images, regarding technique adaptations.
- To design a future curriculum model for developing three-dimensional thinking skills in radiography students, which should enable them to interpret these before-mentioned images and to recommend corrective measures when necessary.

1.7 Research assumptions

Second year students would be willing participants in the research. All student records could be accessed.

1.8 Significance of the research

Since the introduction of community service in South Africa, a huge responsibility has been placed on newly qualified radiographers. The placement of newly qualified radiographers in rural areas in South Africa especially demands a more responsible, competent radiographer to fulfil the needs of those areas. If students have more in-depth training regarding pattern recognition of technique, they should be able to recognise positioning errors and therefore be able to suggest technique modifications in rectifying these errors. These modifications are extremely important when executing examinations on seriously injured patients. The radiologists' ability to make the correct diagnoses should also be enhanced by superior images, and the patients should receive the appropriate treatment or referral. By developing the students' three-dimensional skills, pertaining to film-viewing assessments, they should also be able to apply these skills to more specialised radiographic images, for example, computed tomography and magnetic resonance imaging, where images of axial slices through the patients' bodies have to be interpreted. This research could be of significance to other disciplines in the field of radiography such as ultrasound.

1.9 Contribution of the research

The students should be equipped with critical thinking skills, for example, the ability to recognise and mentally manipulate three-dimensional structures pertaining to radiographic images. They should therefore be able to recognise positioning errors and be able to suggest technique modifications in rectifying these errors, according to the images perceived on the films. High quality images should therefore be obtained.

1.10 Outline of structure of dissertation

- **Chapter two**: The literature review linked to the problem statement, sub-problems and hypothesis is presented. The review focuses on the development of spatial three-dimensional thinking skills and improving the interpretation of radiographic images.
- **Chapter three**: The research design, which includes the methodology, data collection methods and data analysis procedures, is described.
- **Chapter four**: The results of the research are documented. These are the results of the two three-dimensional tests, as well as the three film-viewing tests for each year. Correlations and comparisons between these tests are documented. Patterns in the data pertaining to the problem statement, sub-problems and hypothesis are discussed.
- **Chapter five**: The interpretation of the research results obtained is presented. The relevant link between the results and the literature reviewed is discussed.
- **Chapter six**: The conclusion, which includes a summary of the findings and recommendations regarding future training and research, is presented.

1.11 Conclusion

The context of diagnostic radiography training in South Africa and the difficulties that radiography students experience in assessing complicated radiographic images, have been explained briefly. The literature review in the following chapter focuses on explaining the complexity of interpreting radiographic images, as well as explaining the anatomy and functioning of the human brain and its role in spatial three-dimensional thinking. The review especially focuses on ways of developing three-dimensional visualisation skills. Different psychological tests for measuring spatial aptitude and the importance thereof in selection processes are also discussed.

CHAPTER TWO
LITERATURE REVIEW

2.1 Radiographers are artists

"An important skill that must be developed by the radiographer is the ability to mentally visualize the changing and moving of overlying anatomical structures from any angle in order to provide an image free of superimposition" (Carlton & Adler, 1992: 223). Radiographers use artistic techniques, such as modifying the direction of the X-ray beam to remove dense overlying structures obscuring the region of interest. An example of this is projecting the dense front teeth more cranially than the peg, when executing the open mouth projection of the cervical spine. They especially need to employ innovation, when adapting radiographic techniques in order to protect seriously injured patients. These patients will usually not be able to move into basic radiographic positions, therefore the direction of the X-ray beam will have to be modified instead and often reversed. Radiographers should therefore have an in-depth knowledge of the visual characteristics (shape, size, etc.) of each anatomical structure in the human body, as well as of the spatial characteristics (location in the body and relationship to other structures). Radiographers should be able to generate and manipulate mental presentations, using the permanently stored information. The stored information and mental image-generation skills would also be valuable when assessing radiographic images. As already discussed in Chapter One, radiographic images are two-dimensional images of three-dimensional structures and radiographers should therefore be able to think three-dimensionally (and form mental images) when observing these images, especially when planning modifications to basic/specialised techniques (Novelline, 2003; Carlton & Adler, 1992).

2.1.1 Radiographic projections

Radiographers should never perform only one projection of a specific area, but rather two different projections, 90^{o} to one another to obtain three dimensions, especially for location of abnormalities (Sewerin, 1983). These key/basic projections are the AP projection and the medio-lateral/supero-inferior projection. Each of these key views will only demonstrate two perspectives, for example the antero-posterior projection will demonstrate displacement of fractures in a supero-inferior perspective, as well as in a medio-lateral perspective. This specific projection will, however, not show displacement in an antero-posterior perspective. The term, for example, “antero-posterior” describes the direction of the X-ray beam, as well as the aspect of the patient in contact with the film (latter part of name). The term describing the projection will be the term of the perspective or dimension not visualised. The oblique (intermediate) projections are usually additional projections, but can add extremely valuable information for making a diagnosis, especially when removing superimposed structures from regions of interest (Swallow, Naylor, Roebuck & Whitley, 1986; Carlton & Adler, 1992).

2.1.2 Complexity in interpretation of radiographic images

According to Sewerin (1983), if radiographers have a sound knowledge of the spatial relationship between different anatomical structures of the human body and they know the direction of the X-ray beam for a specific projection, they would be able to perceive the relative image in three dimensions. They would be able to mentally “see” the structures in contact with the film (or image receptor), as well as the structures closest to the X-ray tube. Sewerin (1983) posits that, if these clues indicating the spatial relationships are absent, the radiographic image is classified as “ambiguous”. He researched three-dimensional perception of radiographic images in dental students and experienced dentists. Six radiographic images were used. Three of these images represented human anatomical structures and the other three represented familiar objects in daily use (finger ring, bottle cap and drawing pins). The radiographic images were shown twice to the two groups of participants (76 third year dental students and 76 experienced dentists). In the first round they were questioned on their first perception of each image. An example of the type of question that was asked is: “You are looking at a radiograph showing a finger ring in a box. The ring is seen in an oblique position. Do you have the impression that the pearl and the bow are nearest to you and you are looking at the ring from in front, or do you have the opposite impression?” (Sewerin, 1983: 333). In the second round the participants were asked if they could “see” the image in a reversed position, for example, perceiving the pearl and bow of the ring further away from them (or the opposite, depending on their previous answer). The results of this research revealed no difference in perception of the images between the dentists and the students. Both groups demonstrated a high tendency to perceive the image in only one direction, which was independent of their experience. Their spatial abilities to reverse the images were almost identical. The majority of both the groups were unable to reverse the images. Sewerin (1983) explains that observers are possibly influenced by their perception of real objects in daylight. The cues of depth when observing solid objects, or pictures of solid objects, are totally different from these in radiography. An example according to Sewerin (1983) would be that when a solid object occludes another one in a real life situation, it implies that the occluded object is further away from the observer (see Chapter One). He suggests that when assessing radiographic images, observers also tend to perceive the denser areas, which occlude other structures, as closer to the eye, while in reality it could be either closer to the film or closer to the X-ray tube. The complexity of radiographic images is exceptionally well explained by Squire and Novelline (1988). They state that structures, which appear dense or white on X-rays, can either be thicker or have a higher atomic number than other adjacent structures, or are filled with fluid. Denser appearances can however also be caused by a composition of densities, such as the long-axis of structures not being parallel to the film (e.g., curving of structures) or the overlapping of different structures. A structure, which lies perpendicular to the film (pertaining to its long axis), will appear as if it is much denser. This is explained by the fact that the X-ray beam has to penetrate many more layers of that specific structure and that the X-rays are consequently much more absorbed by these layers; whereas if it is lying parallel to the film, fewer layers will be penetrated. According to Squire and Novelline in the human body " . . . the curved plane is common and the symmetrical plane rare" (1988: 10). They suggest that, when observing radiographic images, it is important to think of structures as "approximately parallel" to the film or "approximately perpendicular" to it (Squire & Novelline, 1988). Interpretation of a radiographic image of the rib cage is extremely difficult due to all the overlying structures (heart, lungs, anterior and posterior parts of ribs) within the thorax resulting in a radiographic image with complex patterns. Squire and Novelline (1988: 37) suggest visualising "coronal slices" when interpreting such an image. This implies mentally "seeing" the thorax in layers from the back to the front: first focusing on the posterior parts of the ribs (excluding the anterior parts from one's mind) then subsequently focusing on the anterior parts of the ribs. They note that radiolucent structures will not be visible on radiographic images, for example, the costal cartilage which forms part of the rib cage. Osterloh, Redmer and Ewert (2004) also emphasise the complexity of interpreting radiographic images. They explain that distant objects in real life will appear smaller than those closer to the observer, while in radiographic images smaller objects will be situated nearer to the radiographic film or image receptor (see Chapter One). Objects situated more distant from the film, will appear magnified and less sharp, because of the divergence of the X-ray beam, as well as the size of the focal spot. Sewerin (1983) mentions that the shape of a structure on a radiographic image could confuse the observer. If the shape, for example, reminds the observer of the clinical appearance of a patient seen from the anterior perspective, the observer will be inclined to perceive the image in a similar way. He concludes that perceiving only one direction when assessing radiographic images, may lead to misdiagnosis and that training is crucial to improve the ability to "see" radiographic images in more than one direction, as well as in three dimensions. As he mentioned earlier, to be able to perform these tasks, knowledge of the locations of the structures, should always be available.

2.2 The brain and spatial three-dimensional thinking skills

2.2.1 Basic anatomy and functioning of the cerebrum

The cerebrum, situated in the anterior part of the forebrain, consists of two identical masses namely, the cerebral hemispheres. The outer layer of the cerebrum is called the cerebral cortex and it consists of grey matter. The frontal lobe forms the anterior part of each cerebral hemisphere, while the occipital lobe forms the posterior part of each cerebral hemisphere. The parietal lobe lies posterior to the frontal lobe, while the temporal lobe lies below the frontal lobe (Hole, 1987; Sprenger, 1999). The cerebrum executes complex tasks, for example, the reading and understanding of sensory impulses, the storage of memory information and the retrieval of this information for reasoning purposes (Hole, 360). According to Baddeley, Wilson and Watts (1995: 10) the "central executive" forms a link between the long-term memory and the "slave" systems. The central executive is a flexible supervisory system responsible for the control and regulation of complicated cognitive processes occurring in the working memory. This system is linked to the prefrontal cortex of the brain. High cognitive activity is found by researchers in the DLPFC (Dorsolateral Prefrontal Cortex) of the brain during complicated processes, such as performing technically difficult tasks, decision-making, correcting errors, planning, abstract thinking, focusing attention on an object, shifting from one task to another, etc. (Brain connection, 2008). According to Collette and Van der Linden (2002), the functions of the central executive do not rely on the prefrontal cortex only, but rather on an interaction of a network of regions in the brain, including the frontal and parietal regions. According to Baddeley *et al.* (1995: 11) the slave systems comprise of the "visuo-spatial sketchpad" and the "phonological loop". The visuo-spatial sketchpad or scratchpad (VSSP) is dedicated to the temporary retention of visuo-spatial information, while the phonological loop temporarily maintains verbal information. The parieto-frontal neural networks in the left hemisphere are associated with the phonological component. The parieto-frontal neural networks in the right hemisphere are associated with the visuo-spatial storage system (Baddeley *et al.*, 1995).

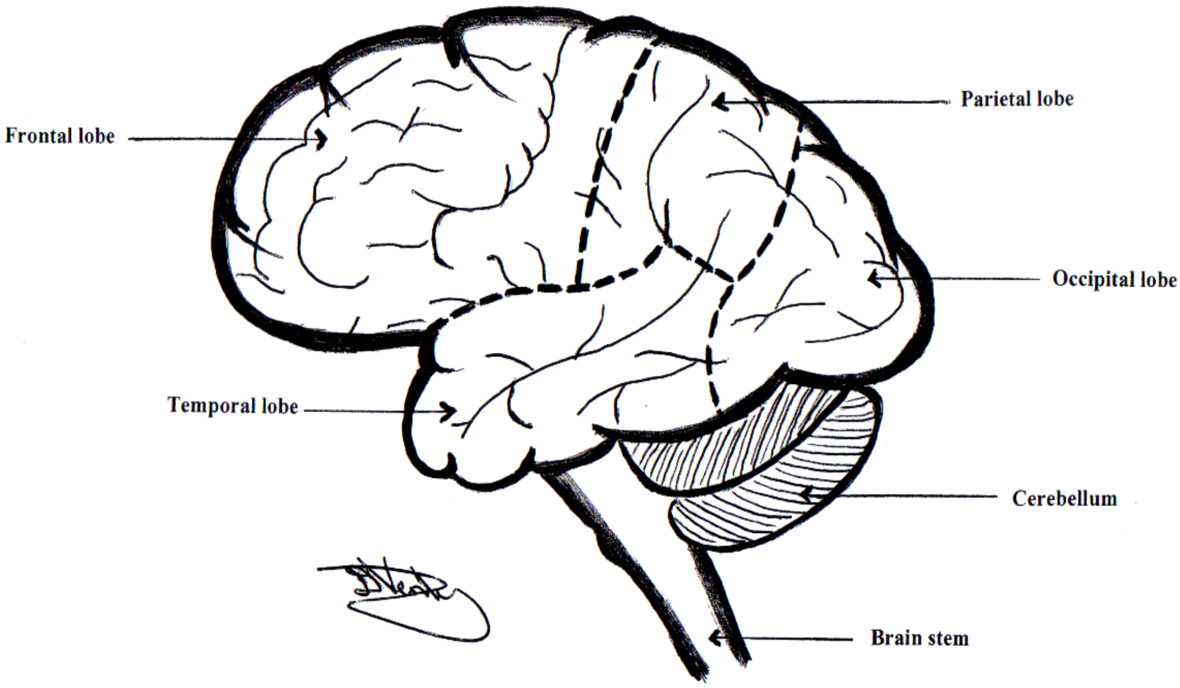

Figure 2.1: The cerebral cortex
(Picture drawn by researcher and adapted from Hole, 1987)

In more than 90% of people the left hemisphere is dominant for speech, reading and writing activities. The non-dominant hemisphere, therefore usually the right one, is involved in non-verbal activities, such as visual experiences, understanding music patterns, emotional processes and motor tasks that necessitate orientation of the body in space (understanding spatial relationships) (Hole, 1987; McKim, 1980; Gardner, 1983). The sensory areas for vision are located in the posterior parts of the occipital lobes. The association areas in the occipital lobes, situated next to the visual centres, are involved in recognising objects (Hole, 1987; Wolfe, 2001). When one recognises an object, the information is stored in the perceptual memory of the right brain. This information can then be described by the verbal and logical left part of the brain

(Cox, 2002). Gardner (1983) states that the parietal lobe in the right hemisphere is especially involved in performing spatial tasks. According to McKim (1980) image-generation processes also occur in the right hemisphere.

2.2.2 Visual perception and radiographic images

Radiography depends on the assessment of complex images, therefore comprehension of the processes of visual perception is extremely important for education. A visual image is formed when the anatomical structures of the human eye, namely the aqueous humor, cornea, iris and lens, aggregate and focus the incoming light. The light-sensitive rod and cone cells of the retina respond by converting this light image to nervous impulses. These neurological impulses are then sent by the optic nerve to the brain for further processing. The cone cells are more sensitive in the detection of contrast differences, such as density differences on radiographic images, than the rod cells. It makes contrast perception, which plays an important role when assessing radiographic images, possible (Carlton & Adler, 1992).

Misperceptions resulting in misdiagnoses sometimes occur in radiography with serious consequences for the patients involved. Carlton and Adler (1992) question the causes for these misperceptions. According to them a deficient conversion process at the retina can result in distortion of the converted visual image; or imperfect neurological processing within the brain, can result in distortion of the mental image. Radiologists and radiographers often tend to stare at an anatomical structure or a certain area on a radiographic image that is obscured and thus difficult to assess. According to Carlton and Adler (1992) staring will increase mental concentration, but it may also cause misperception. An explanation for this phenomenon is that the human visual system can only obtain visual input to form an image for a maximum period of 0.2 second. If it does not receive enough information in that period to be processed, it will automatically “switch off” and thereafter start accumulating information for the next image. Scanning a radiographic image, instead of staring at a certain spot, will also increase contrast perception, because the structures of the visual system can only process a limited amount of information at a time. Eye movement will produce a constant modification of the visual input (different information or images) and therefore also of the neurological signal, which would prevent overloading of the optical nerves (Carlton & Adler, 1992). When assessing areas of perceptual difficulty, radiologists and radiographers should also vary their distances from the viewing box, to obtain clearer images. It is important to bear in mind that at a viewing distance of twenty-three centimetres, the fovea will create a blind spot. When the viewing distance is altered, the intensity of the incoming light and therefore also the visual input, will vary accordingly. Visual processing will also vary with changes in the angle of incidence of the light photons. The eyes of the viewer may also be “blinded” by veil glare. Veil glare means that the intense bright light from uncovered areas of the viewing box reaches the eyes of the viewer, scatters inside the eyes and therefore diminishes contrast perception. It is therefore better when assessing radiographic images, to cover these parts of the viewing box (Carlton & Adler, 1992).

2.2.3 Storage, retrieval and manipulation of visual and spatial information

2.2.3.1 Ways of storing information

Memory entails the storing of information, which is vital for all complex brain functions. This storage occurs in three stages, namely temporary storage of information, which is called the short-term memory (information that lasts only for a few seconds), recent memory (information that lasts for minutes or days) and the long-term memory, which is the most constant form of storage (Refer to Figure 2.2). Short-term memory is processed mainly in the anterior part of the frontal lobe and in the thalamus and it can easily be disrupted. However, if information in the short-term memory is intentionally reviewed, it can be transferred into a more stable phase, namely the recent memory. This stage involves a part of the temporal lobe, the hippocampus. This information however may also be lost if not used often. The long-term memory stage involves large areas of the cerebral cortex. Repeated recall of information or repeated sensory experiences will lead to permanent storage of information. This information is stored in meaningful bits, sorted into groups, in both hemispheres (Hole, 1987). Visual information will only become meaningful and be stored, when it can be associated with previously stored information. It is therefore important for educators to tell students the objective of a task in order for their brains to focus on the relevant information. It is especially vital to explain and emphasise the relationship of new, unfamiliar information with familiar information (Wolfe, 2001).

Glasgow and Papadias (1992: 356) state that when an image is stored in the memory, it is stored in three ways namely as a “deep representation”, a “visual representation” and a “spatial representation”. According to them, permanently stored information of all the characteristics of an object in the long-term memory is called a deep representation, whereas a visual representation means the temporarily stored visual characteristics of an object (e.g., the shape, size, colour and brightness) and a spatial representation means the temporarily stored spatial characteristics of an object (e.g., the location of the object in space, the geometric relationship with other objects and movement of the specific object through space). Both the two last-mentioned representations are created by retrieving information from the deep representation when needed. These two temporary representations are stored in the short-term memory. According to Logie (1995: 69) the “visuo-spatial working memory” (VSWM) implies the functions of the short-term memory which store and process visual and spatial information.

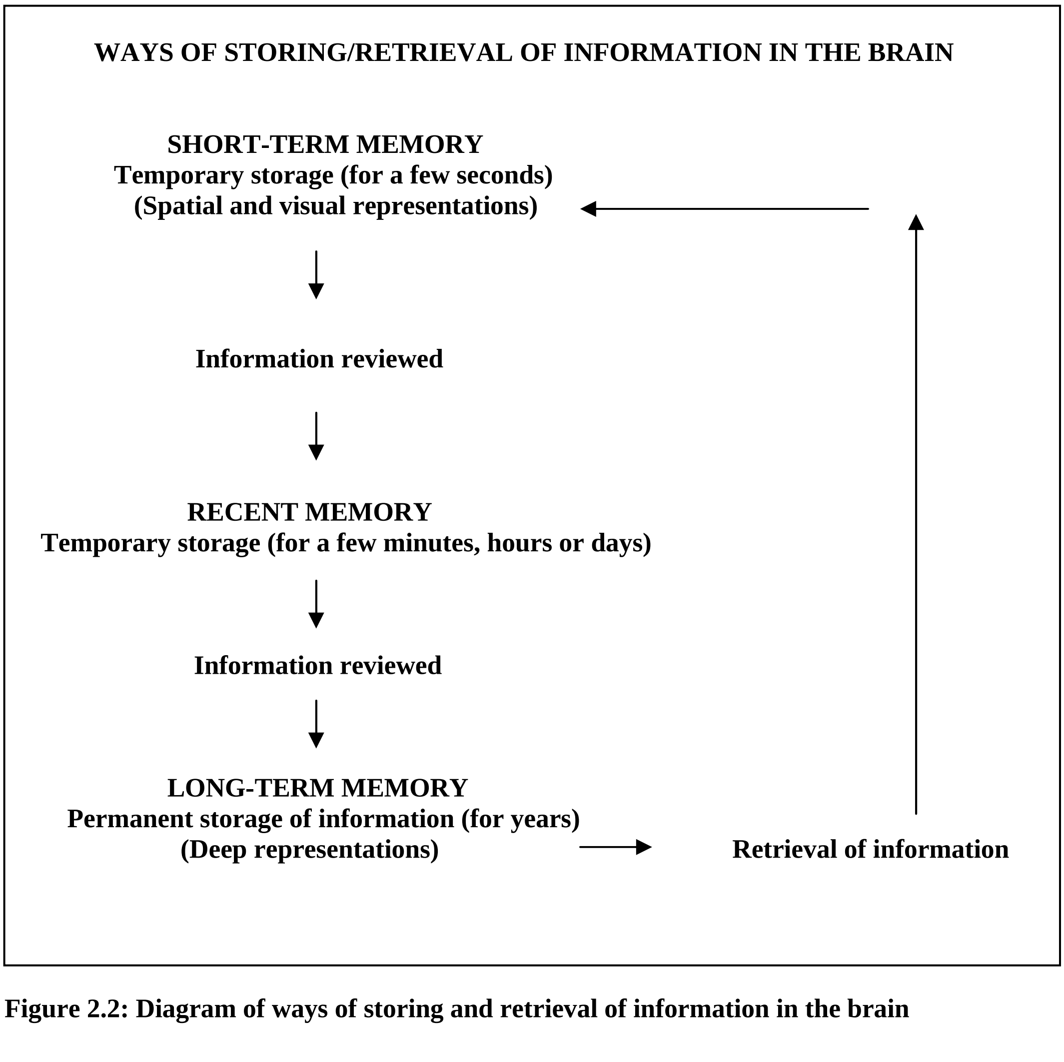

Figure 2.2: Diagram of ways of storing and retrieval of information in the brain

2.2.3.2 Separate cortical pathways for processing visual and spatial information

The ventral system consists of brain sections, which run from the occipital lobe to the inferior temporal lobe and processes only the pattern characteristics of objects (e.g., shape, colour and texture). The dorsal system, which is also a set of brain sections, runs from the occipital lobe up to the parietal lobe and processes only spatial information (e.g., location, size and orientation) (Kosslyn, 1994; Mishkin, Ungerleider & Macko, 1982; Logie, 1995; Glasgow & Papadias, 1992). Former research, on visually handicapped patients, has shown that visual and spatial components are two separate components of mental image generation. Some subjects were able to recognise an object, but not able to locate the object in space, and the other way around (Glasgow & Papadias, 1992). According to Logie (1995), blind people locate objects physically by means of touch, hearing and especially movement in space.

McGee (1979b) states that spatial visualisation tasks are depended on short-term visual memory. However, according to Logie (1995) and previous research done, the manipulation process of mental images can be executed independently of the temporary spatial or visual storage systems. It is therefore not always necessary for an image to be stored in the short-term memory first and then manipulated afterwards. The central executive can directly retrieve the image from the long-term memory and modify it afterwards.

Logie (1995) summarises the visuo-spatial memory as follows:

- It consists of a visual temporary memory store as well as a spatial temporary memory store.
- Visual input (information on spatial features of objects and other visual features, e.g., shape of objects) is first stored in the long-term memory as spatial or visual representations.
- Spatial or visual information will be transferred to the appropriate temporary memory storage system when activating either the spatial or visual representations in the long-term memory.

- The central executive can retrieve information from either the spatial temporary memory store, the visual temporary memory store or directly from the long-term memory, in order to create mental images.

2.2.3.3 Generation of mental images

A visual mental image can occur with the eyes closed. A mental image is a pattern of activation in the "visual buffer" (a short-term specialised memory store) that is not caused by direct sensory input from the eyes (perception) but by information gathered from the memory store (Rock, 1983; Kosslyn, 1994). The visual buffer is a set of spatially organised structures (topographical areas), which form part of the primary visual cortex of the brain (Thomas, 2003; Kosslyn, 1994). Light falls onto the retina, which is in contact with the visual cortex. During vision the cortical neurons communicate with the light pattern at the retina. The neurons map (duplicate) the light pattern. Kosslyn (1994) therefore sees the visual buffer as equal to the visual storage system. Logie (1995), however, argues that the central executive contains the buffer, which is a workspace for the generation of mental images. He states that the central executive retrieves information from the visual storage system and subsequently controls the manipulation processes. However, according to several researchers, area V1, known as the primary visual cortex, is involved in image-generation processes (Kosslyn, 1994).

During perception new information has to be interpreted and matched to stored representations while, with the creation of mental images, the information has already been interpreted and stored. The image-generation task consists of two components: stored information must, firstly be activated to envisage an object in order to, secondly, inspect the characteristics of the image thoroughly (Kosslyn, 1994). Kosslyn states: "The use of stored information is called *top-down processing*" (1994: 73). In contrast with perceptual representations (created while perceiving an object), mental images fade rapidly and cannot therefore be inspected meticulously. It is however inspected and processed following the same paths pertaining to visual images. As previously discussed, according to Kosslyn (1994: 13), the visual buffer is "retinotopically mapped" and is subsequently used in creating mental images, as well as in perception. Mental images within the buffer will therefore alter or lighten with movement of the eyes and persist for about a quarter of a second. A percept, in contrast, exists as long as a person perceives an object. The images in the visual buffer are therefore experienced as short-term memory representations (Kosslyn, 1994).

During perception, the overall shape of an object is initially encoded. The object is further inspected and the features, different parts, as well as the spatial relationships among them, are subsequently programmed, one by one. When recalling the information, all the units (representations) have to be activated to create the entire mental image. The stored representations of spatial relations are used to properly organise the different parts of the object in the correct positions (Kosslyn, 1994). The period of time required to create a mental image will increase with an increased number of units. The nature of verbal description/assignment received before commencement of a mental task, may also influence the mode of image generation. For example, it may increase or decrease the time taken in generating an image. There is a limit on the number of parts that can be held in the mental image. Complicated structures will also require more time for visualising. However, familiar scenes, such as the face of someone that you often see, may be programmed as a single unit and also recalled as one unit (Kosslyn, 1980). According to Kosslyn (1994) the capacity limits for holding mental images depend on three factors, namely how successfully objects can be compressed into fewer units, the fading speed of each unit, how rapidly and how often the image can be revived. As previously explained, short-term memory representations, such as mental images, are difficult to maintain and temporary, compared to information in the long-term memory, which is easy to maintain and lasting. The mental image is only created, using stored information, when needed (Kosslyn, 1994; Kosslyn, 1987; Glasgow & Papadias, 1992).

According to Kosslyn (1994), representations of spatial relations can be encoded and stored as coordinate spatial relations in the right hemisphere or as categorical spatial relations in the left hemisphere. The coordinate spatial relations representations entail the encoding of motor-based coordinates of one part in relation to another, the distances between objects or units, while the categorical spatial relations representations entail categorising spatial properties of objects or encoding categorical relations among parts. When images are generated, either the coordinates or the categorical representations are used to arrange the units of objects into the correct positions. The left or right hemisphere consequently contributes to image production, depending on the method used to generate the image (Kosslyn, 1994).

When the coordinates of spatial relations representations are used, the right hemisphere will mainly be involved in image generation. These tasks involved in creating mental images are usually totally non-verbal task. On the contrary, categorical representations of spatial relations are verbally linked and the left hemisphere is therefore more involved in these types of image-generation task. The right posterior inferior parietal lobe plays an important role in programming representations of spatial relations. Kosslyn (1994) claims that this part of the brain controls the coordinate spatial relations encoding subsystem, while the left posterior inferior parietal lobe controls the encoding of the representations of categorical spatial relations.

According to Kosslyn (1994) several studies of brain activation show that the left hemisphere is involved in image-generation processes. Goldenberg, Podreka, Steiner, Fanzen and Deecke (1991) used a SPECT (single photon emission computerized tomography) examination to investigate the patterns of blood flow in the brain during visual image-generation processes. An isotope 99m-Tc-hexamethyl-propylene-amine-oxime (HMPAO) was injected intravenously, which was subsequently absorbed into the brain tissue. The harder a part of the brain works during a task, the more blood it requires. The blood flow will subsequently increases in the direction of that section of the brain. A dual head rotating gamma camera registered the flow of the isotope in the above-mentioned research. During these visual image-generation tasks, increased blood flow, containing the radio-active and visible isotope, was observed in the left hemisphere, in the occipital lobe, as well as in the left thalamus. This finding is in contrast with McKim (1980) who claims that image-generation processes occur in the right hemisphere. The hippocampus and right inferior temporal regions were only activated when participants created both acoustic and visual images (total amount of information used for creating mental images). Acoustic information entails imagining the sound made by objects, for example, in animals, where visual image-generation requires retrieval of information of the visual characteristics of objects.

Logie (1995) states that a certain disorder of visuo-spatial cognition may be present in some subjects, namely the loss of half of visual space and it is usually caused by lesions in the right hemisphere of the brain. The subjects will only recall half of the images that they have observed and stored in their memory previously. Hughlings Jackson was the first researcher to report this abnormality in 1876 (Logie, 1995). Patients with lesions at the occipital-temporal or occipital-parietal parts of the brain experience difficulties in programming shape or location in images. There is now significant evidence that both hemispheres are involved in generating mental images (Kosslyn, 1994).

2.2.3.4 The image-generation debate: depictions versus descriptions

When we observe an object, an internal representation containing its features is formed. During the creation of mental images, the information is retrieved from the memory store. There is a debate, according to Kosslyn (1994) about the generation of mental images. He states that mental images are depictive representations, in contrast to Pylyshyn (1973), who states that mental images are descriptive representations.

As earlier explained, a visual mental image is a type of short-term memory representation, which occurs when the visual buffer represents information activated from long-term memory. The visual buffer stores the mental image that the person is consciously “seeing” (Kosslyn, 1980; Kosslyn, 1994). This mental image is a quasi-pictorial representation (depiction), which means that the information was originally obtained through visual perception, but is now retrieved as an image from the visual buffer, through the image-generation process. These images are however not like photographs, because they lack certain details. This mental image occurs in a spatial medium and therefore includes all the relative pictorial information, for example, spatial features (size, location and orientation) as well as information about surface features (texture, shape and colour) of the object or scene, which can then be manipulated by certain processes (Kosslyn, 1980). Propositional representations (descriptions) on the contrary, do not include spatial information. A descriptive representation is an abstract “mental sentence” that describes the object (or scene), as well as the relation between two or more objects. Information about an image may be stored in the brain in a descriptive form, but when a person retrieves the information to create a mental image, it will be visual in a depictive form (Kosslyn, 1980; Kosslyn, 1994).

According to Pylyshyn (1981), a keen supporter of the descriptive theory, mental image generation depends on tacit knowledge about events, which have occurred in the past. It involves thought processes to simulate these events. Pylyshyn (1973) states that when a subject claims that s/he is “seeing” a mental image of a tree for example, the features of the tree (or the picture itself) are not inside her/his head. S/he is only thinking about the tree and its features. Pylyshyn (1981) believes that what people think they perceive mentally, is only a description of a picture and not a pictorial form at all.

There is a debate amongst researchers whether images are stored as depictions or descriptions. Finke, Pinker and Farah (1989) argue that if a mental image of an observed ambiguous object contains geometric information, it would be possible for the viewer to recognise the alternative object, when inspecting the first image. If the representation were only a description of the ambiguous object viewed, then recognising the second object would not be possible. According to them the creation of visual mental images from depictions, has to do with the activation of stored perceptual information, whereas the creation of visual mental images from descriptions, excludes all perceptual information. In their research, participants were required to superimpose mental images of familiar shapes in order to discover new shapes. They were asked to describe the new shapes that were combinations of the shapes that they had observed. The description of neither of the two shapes that they initially observed included the new shape. It was therefore impossible to use the initial descriptions in order to formulate a description for the new shape. This implies that the initial images were depictions.

In their second experiment the subjects had to form a mental picture of a familiar pattern. They were then subsequently guided in performing mental transformations of these patterns, to discover a resulting familiar pattern. The results reveal that most subjects could mentally visualise a pattern, could mentally manipulate a pattern and, as a result, identify a new pattern. They conclude that the geometric information necessary for the transformations should have been available in the first image created. The representation of the initial patterns was therefore pictorial (a mental picture) and not descriptive (an interpretation) (Finke *et al.*, 1989).

Kosslyn (1994) posits that, if objects can be reorganised in mental images, there has to be geometric information present in these images, as with perceptual representations. There is adequate evidence that subjects can reinterpret structures in mental images. Logie (1995) agrees that various mental manipulations can be done, such as reconstructing the mental image of an object (e.g., toffee) to appear and be recognised as another object (e.g., fish). He however argues that according to previous studies, people find it extremely difficult to manipulate images of ambiguous figures, for example, the picture of a duck, which also represents the picture of a rabbit. There are, as a result, two perceptual interpretations of the one picture. A possible explanation for people failing to perceive the alternative figure is that they verbally encode the figure (e.g., "a duck") and that they do not form a mental picture at all. They cannot therefore study the image subsequently to discover the alternative figure (Logie, 1995). According to Logie (1995) previous research shows that articulator suppression can be used to suppress the generation of a name for the object. Articulator suppression implies the repetition of an irrelevant word (e.g., "bla") while observing the picture.

Area V1, the primary visual cortex, is situated in the medial segment of the posterior part of the brain (the occipital lobe) and is the first cortical area that receives information from the eyes. According to numerous researchers (see above) this part of the brain is also involved in image-generation processes. Several functional magnetic resonance imaging (fMRI) studies have demonstrated that area V1 is activated during image generation. It is clear that image generation also involves the topographically designed areas of the cortex. These research results consequently support the depictive theory. Area V1 is spatially structured, which is important for generating mental images (Kosslyn, 1994).

2.2.3.5 Recognition of objects and manipulation of the mental image

The occipital-temporal sections are involved in recognising or identifying an object, while the occipital-parietal sections are involved in encoding spatial information. Information from both systems is subsequently combined in the associative memory situated in the posterior, superior temporal lobes and matched to stored information (Kosslyn, 1994).

People are able to identify objects when observing them from different visual angles.

In case of familiar objects, multiple representations of various perspectives of these objects are usually already stored, which are subsequently used for matching with the visual input of the perspective of a similar object in the process of recognition (Kosslyn, 1994; Tarr & Pinker, 1989). The spatiotopic mapping subsystem also aids in the recognition process by matching the three-dimensional properties of objects. Spatial properties will be calculated accurately despite the projected appearance. The spatial relations encoding subsystem, encodes the spatial relations between objects or parts of objects. This information is stored in the associative memory and is subsequently used to identify size, orientation or location of objects. Different representations are created for objects seen at different angles. A mental image will be rotated until it matches the visual input, which implies that the object is recognised. The more rotation needed, the longer it will take to recognise the object. When recognised, a representation of this input will be stored and no manipulation of images will be required in future to distinguish the same orientation of the specific object. The orientation has become familiar to the observer. However, in order to recognise other unfamiliar objects, the same process of image manipulation will be required. Subjects need more time to recognise objects when foreshortened. The spatiotopic mapping subsystem plays a critical role in analysing the spatial properties of foreshortened objects. Additional time may be necessary to execute this process, especially when unique features are obscured with severe foreshortening. Top down processing may be required to recognise the object. To assign a name to an object, visual input has to match a representation in the associative memory. If an object's shape is typical of a category, then the visual input will quickly match a stored representation (Kosslyn, 1994).

Logie (1995) states that there is enough evidence from previous research to show that if two objects are visually similar to one another, visual confusion may occur when a person tries to remember one of these objects. Visual confusion is linked to the characteristics of the codes stored in the temporary visual memory. An everyday example would be, when one meets two persons who look alike, one would probably find it difficult to remember each of their faces.

Tarr and Pinker (1989) investigated the process of recognition of a familiar object when rotated into various positions. The participants were first trained by observing several objects, each in one specific position. Each object was afterwards rotated into alternative positions. They received in-depth training in recognising these alternative versions. The participants were subsequently presented with the same objects, but in different alternative positions than had been used during the training session. The response time of the participants increased in relation to the difference in orientation of the object, compared to the training orientations. The results reveal that participants had stored the representations of each of the orientations used in the training session and that they afterwards recognised the objects in the unfamiliar orientations, by rotating them to the nearest position of one of the stored orientations. It is important for educators to note that the mental representation of each object was rotated and compared to the stored information, whereas according to Kosslyn (1994), the stored mental image was rotated and compared to the visual input. There is, according to Tarr and Pinker, evidence that " . . . people indeed use mental rotation to recognize unfamiliar shapes or examples of shapes" (1989: 239). They also note that with increased training, participants will become more familiar with the objects and will then recognise these objects independently of the mental rotation task. According to Tarr and Pinker (1989), immediate recognition of an object, without rotating it and matching it to previously stored images is only possible with familiar views of the object. If the participants are confronted with unfamiliar perspectives, they will be forced to use the mental rotation task again. Rock (1983) posits an important fact, namely that participants will not be able to recognise, for example, a tilted object if they have not been informed that the object may be in a strange position, or if there are no cues available. Rock (1983) agrees with (Kosslyn, 1994) that participants find it difficult to recognise complicated structures when they are tilted according to their axes in space (foreshortened), even if they are familiar objects. It implies that if participants are suddenly confronted with an "end on" view of a complex object they will experience difficulties in recognising it. Tarr and Pinker (1989) suggest that mental rotation will have to be applied to solve this problem. Tarr and Pinker (1989) argue that a little information, such as the location of four landmarks (image features) in the observed object, will be enough to match it with stored representations. If sections of an object are, however, compared to sections of a representation, difficulties could occur in recognising an object because of small variations between the images.

Visual thinking involves visuo-spatial processes (McKim, 1980). Kosslyn (1994) suggests that image conversion processes, such as image rotation, occur in the visual buffer itself. Two methods are distinguished to visualise moving objects. The first method is where a moving object is perceived, encoded and stored in memory. When this representation is subsequently recalled, movement of the object (e.g., rotation) will be automatically part of the image. Kosslyn names this a “movement-encoded transformation” (1994: 350). Kosslyn (1994) suspects that motor processes are involved (together with visual processes) when activating memory in generating the image of a moving object. It is possible that the left frontal lobe plays a role in movement of images. The second method is when a static object is perceived, encoded and stored in memory. When this representation is recalled from memory, motion needs to be added for any manipulations, such as rotation. It is thus called, according to Kosslyn, a “motion-added transformation” (1994: 350). During the latter transformations, the representation of an object’s spatial properties in the spatiotopic mapping subsystem has to be modified in order for the image to accurately display the changed spatial properties (Kosslyn, 1994). Larger and more complex images also require more time to rotate than smaller less complex images. They will therefore fade more with time than smaller images. Subjects rotate images through intermediate positions with increments of 30º or less (Kosslyn, 1980). More time is also needed to rotate an image farther from the original position (Rock, 1983; Kosslyn, 1980).

The mental rotation of three-dimensional objects requires more time than mental rotation of two-dimensional objects, because alteration of the mapping function becomes more complicated. As previously explained, mental rotation of a stimulus, or input of a perceived object, can be performed to match it with a stored representation of a similar object - but encoded in a different orientation (in order to recognise the object). To be able to do a 100% left-right rotation of an image, the specific object has to be observed in all the different positions when rotated and each of these positions need to be encoded first. Several researchers find that the right hemisphere and more specifically the parietal cortex, is mainly involved in mental image rotation tasks. It was found that lesions in the posterior right hemisphere interfere negatively with processes where exact spatial properties have to be encoded (Kosslyn, 1994). Kosslyn (1994) states that image inspection, as well as image manipulation, are executed by various subsystems. According to Baddeley (1986) the VSSP is particularly well modified for the transitory storage and manipulation of spatial information. There are at least two systems involved in image generation namely the VSSP and the long-term memory store. Baddeley (1986) states it is possible that the mode of storage could be different for the two systems, for example, descriptive in the long-term memory and depictive in the VSSP. His research indicates that the spatial component of image generation is very vulnerable to interference.

2.3 Developmental stages of spatial ability

Olkun states that " . . . timing and content are two crucial elements to be considered in designing instructional tasks to improve spatial ability" (2003: 1). According to Salthouse, Babcock, Skovronek, Mitchel and Palmon (1990), increased age in adults is related to a decline in spatial skills despite widespread spatial visualisation experience. McGee (1979) agrees, by stating that maturation and possible age-linked hormones influence the development of these abilities.

Jean Piaget did extensive research on the development of spatial ability in children. He saw spatial development as part of logical growth and identified the following stages:

- Sensory-motor stage: The infant is able to move around in space.
- Pre-operational stage: The toddler is able to form static mental images, but cannot manipulate these images. These images are recalled from experiences in the past.
- Concrete-operational stage: The primary school child is able to actively manipulate these static mental images, but the child's ability is restricted to concrete situations.
- Formal-operational stage: The adolescent is able to perform complicated spatial tasks, in the absence of concrete stimulation (abstract-thinking) (Gardner, 1983).

Winefield and Peay (1980) claim that Piaget's concrete operational stage begins at seven years and ends more or less when the child is eleven years old. At the end of this stage the child has an understanding of concepts like space. However, only during the formal operational stage (eleven years and above), is the child or adult able to reason scientifically at a high logical level.

According to Bishop (1978) and Sorby and Baartmans (1996), the Piagetian theory involves three stages of spatial ability development:

- Acquiring topological abilities: These abilities have two-dimensional attributes and are usually acquired at the age of three to five years. It entails the ability to recognise an object's position in relation to other objects (its closeness to other objects and its order in a group), as well as its isolation or enclosure by the larger environment. Tasks to assess these abilities include: recognition of simple objects, classification of objects, putting objects in linear and circular order, etc. Building puzzles successfully, will therefore also demonstrate these abilities.

- Acquiring projective abilities: These abilities are usually acquired at the adolescence stage. It entails the ability to create a mental picture of a familiar three-dimensional object and to envisage what the object will look like from different perspectives if the object would be rotated or if the viewing points would change. Problems are however commonly experienced in secondary school learners with unfamiliar objects or when objects are not static. Tasks to assess these abilities would include: identification and drawing of objects in different positions, predicting cross-sections of objects, etc.

- Acquiring Euclidean (geometrical) concepts: This stage entails envision of concepts of measurement, such as area, volume, distance, length and rotation. The person is usually able to use these concepts interactively with projective abilities. Tasks to assess these abilities would include: predicting the water level in a tipped bottle, conservation of volume with solids (direct measurement or estimation), etc.

According to Bishop (1978) high school learners as well as tertiary level students, will, in unfamiliar or complicated situations, experience difficulties in envisaging the alternative perspectives of an object. She also states that spatial skills will develop with experience, if experience includes activities of manipulating objects in space. Research done by Russell-Gebbett (1985), investigating three-dimensional abilities pertaining to biology problems, in secondary school children confirms the above-mentioned statements. Sixty-six learners, from eleven to fourteen years old, completed a three-dimensional biology structure test. The test included visualising the relationships of the internal structure of familiar objects (e.g., a fish) and the drawing of cross-sections of these objects. The results of the test show a highly significant correlation with age groups, as well as with general scientific ability. A small significant difference is however revealed between the results of the girls and the boys. It is found that the following error correlates significantly with age and gender. This is the trend to include features of the external perspective of an object, when drawing a cross-section of the object. External information (visual) and internal (mental) information of the object were therefore "mixed". Boys predominantly made the error. It seems according to Russell-Gebbett (1985) that this tendency decreases with age. The older children made use of verbal and visual cues to assist them in the test and Russell-Gebbett (1985) suggests that teachers should encourage learners to search for cues. Most of the learners did not use the mental rotation technique to assist them in the tasks. It is important to mention that three of the four learners, who also attended technical drawing classes, used this technique successfully. Russell-Gebbett (1985) posits that learners, who performed better with the tasks on the relationships among structures, worked in a more organised way and that this approach gave them a feeling of security, which stimulated their creativity. It is therefore recommended that learners should be taught to work methodically and precisely when performing these tasks, especially when comparing sections of an object.

2.4 Developing spatial three-dimensional thinking

As mentioned in Chapter One, Sorby (1999) defines spatial ability as a cognitive ability that a person is born with, compared to spatial skills that are acquired through formal training. According to her it is impossible to differentiate between skills and abilities in tertiary level students, due to the fact that previous unknown training or experiences could have developed certain skills in them. McGee (1979a) divides three-dimensional spatial abilities into two categories, namely spatial visualisation and spatial orientation. He further explains that spatial visualisation involves moving an object mentally, while spatial orientation involves movement of the observer mentally. In both cases the observer will obtain a different mental perspective of the object. Spatial visualisation also consists of two components, namely mental rotation (mental rotation of the whole object in space) and mental transformation (mental manipulation of a part of the object in space) (McGee, 1979a).

Can spatial ability be developed or not? According to Olkun (2003) and Strong and Smith (2001) there is much conflict in research findings, pertaining to this question.

McGee (1979a) demonstrates this conflict. He lists a number of research studies, which claim that spatial ability can be improved by training, as well as an equal number of research studies, which claim the opposite. Several researchers claim that intensive training and the use of proper learning material, can enhance spatial ability (Ben-Chaim, Lappan & Houang, 1988; Lord, 1985). The majority of professionals in engineering graphics belief spatial visualisation skills can be developed by experience (Strong & Smith, 2001).

Ben-Chaim *et al.* (1988) investigated the role of gender, age, socio-economic status, and formal instruction in the development of spatial ability in fifth to eighth grade school learners. A thousand learners from three different socio-economic sites participated in the research. The MGMP spatial visualisation test was used as a pre-test. The pre-test revealed significant differences in performance pertaining to age, gender and socio-economic status. The development of spatial ability was linked to increased age and socio-economic status. Boys performed much better than girls. After they all had participated in concrete activities, such as building and drawing of objects, they administered a post-test. The performance of all the learners increased considerably. Improvement for boys and girls was similar, regardless of initial differences. Ben-Chaim *et al.* (1988) claim that the period between the sixth and the eighth grade is the best time to develop spatial ability in children.

According to Suppiah (2005), most engineering students experience problems in spatial visualisation. Suppiah (2005) investigated the relationship between students' performance in using a three-dimensional computerised software program and their general spatial aptitude. They had received training before the assessment in constructing and manipulating objects in three dimensions, using the computer interface. The results however reveal that students with low spatial aptitude scores, experienced difficulties in interacting with a computerised program. Following interviews with the participants in the research study, Suppiah (2005: 4) classifies the possible causes for the lack of spatial visualisation ability in three categories, namely "environment", "human factors" and "education and training". According to Suppiah (2005: 4), "environment" comprises several factors, such as not playing with construction toys, not being given the opportunity to practice manual dexterity skills, hobbies not inducing spatial visualisation ability, etc. "Human factors" comprises factors, such as lack of interest, health problems, distraction, lack of motivation, declining of mental state, etc. “Education and training” involves factors such as previous training or experience not including “hands-on” tasks, lack of opportunity for training, neglect of visualisation ability in the class room, etc. (Suppiah, 2005: 4).

According to Hegarty, Keehner, Cohen, Montello and Lippa (2007), previous research reveals that spatial skills could improve with practice and training in a specific field (e.g., radiography). As previously discussed, Sewerin (1983), on the contrary, finds no evidence of improved spatial skills with experience, when investigating three-dimensional perception of radiographic images in dental students and dentists. It must be mentioned that although the objects that were used in his research, were familiar to the participants, not all the images of these objects were familiar in dentistry. No clues on the positions of these objects were available to the participants therefore these images were classified as ambiguous. Sewerin (1983) also recommends more in-depth training to improve perceptual, and more specifically, spatial skills.

Hegarty *et al.* (2007) investigated the relation between spatial abilities and experience in surgery. The subjects were divided into two groups, surgeons with abundant experience and surgeons with minimal experience in invasive procedures. Both groups did a spatial aptitude test to determine their cognitive spatial abilities. Expert observers then rated the operational skills of both groups. Spatial test results correlated significantly with the operational skills of the low-experience group. The spatial test results of the highly experienced group did not correlate significantly with their operational skills. It confirms the results of previous research that the effects of inherited cognitive abilities on performance decrease with practice and the acquisition of skills (Hegarty *et al.*, 2007).

More research by Hegarty *et al.* (2007) followed. Non-medical graduate and undergraduate students participated in this research. A variety of tests, including a spatial aptitude test, a general reasoning ability test and a perceptual-motor ability test, were administered. The students then learned to operate a simulated angled laparoscope over a three weeks period. Despite their initial individual differences, demonstrated by the tests, all the students acquired the skill. In contrast with the previous research done by Hegarty *et al.* (2007), their initial spatial aptitude test results correlated with their initial performance, but follow-up tests done during the learning process, also showed correlation between spatial ability and performance. Differences in their performance, however, decreased over time. Hegarty *et al.* (2007) argue that in their previous research, a variety of operational skills were compared to spatial abilities, while the latter research concentrated on the acquisition of a single skill, which is compared to spatial aptitude. They also argue that initial performance is linked to spatial and general abilities shared, but that later performance is linked to spatial abilities alone. The correlation of general intelligence with performance diminishes with practice.

Hegarty *et al.* (2007) conclude that although spatial visualisation ability tests can predict performance in laparoscopic surgery, their results do not suggest the use of spatial aptitude tests in the selection of candidates for surgical training, because of the following reasons:

- People with different abilities can acquire surgical skills.
- The effects of general cognitive abilities on performance diminish with practice.
- In their initial research, the spatial test results of the highly experienced surgeons did not correlate significantly with their operational skills.
- General intelligence and perceptual-motor skills may be more important than spatial ability at the onset of training.

Hegarty *et al.* (2007) argue that although their follow-up research confirms the results of other research in the past, namely that spatial ability is highly related to the performance of tasks in a variety of medical professions, their results also reveal that extensive practice is more important than spatial aptitude, in predicting future performance. Hegarty *et al.* posit: “Abilities are typically thought of as being relatively general (e.g., spatial, verbal, reasoning) and fairly immutable, whereas skills are thought to be very task specific and determined by experience and practice” (2007: 32). They suggest that future research should investigate whether both specific spatial skills (for executing specific professional tasks) and spatial abilities (which can be applied to other activities outside the profession) can be learned. The research of Keehner, Tendick, Meng, Anwar, Hegarty, Stoller and Duh

(2004) also show the insignificant role of general spatial ability versus experience in learning specific tasks (and acquiring skills). They investigated the relationships between spatial aptitude, surgical performance and videoscopic experience in medical students and experienced surgeons.

2.4.1 Role of the clinical teacher

Whyke (1985: 225) defines "clinical radiographer" as a qualified radiographer employed by a hospital, with a primary duty of executing radiography examinations and a secondary duty of supervising and assisting with the training of radiography students. A "radiography tutor" is defined as a radiographer who has completed postgraduate educational training with the primary duty of formally educating radiography students. A "clinical instructor" on the other hand, is a qualified radiographer with the primary duty of training radiography students in the clinical department. These radiographers are usually appointed in clinical instructor posts (Whyke, 1985: 225). She mentions that not all radiography-training institutions have clinical instructor posts.

Six training institutions in radiography, participated in the investigation of student learning strategies in a study done by Whyke (Whyke, 1985). The results reveal that students prefer small group tutorials to formal classes for assisting them with radiographic techniques. They suggested the ideal number of students per group be between three and four. These students felt that large groups prevented them from asking questions about problem areas. They all rated "discussion" high as a strategy to improve their understanding of topics. They regarded radiography tutors as experts in theory, but as out of touch with clinical work. Clinical radiographers on the other hand, were regarded as experts in clinical work, but as out of touch with theory. Watson (1983), in his report on a Teacher's Seminar of the International Society of Radiographers and Radiological Technicians, summarises the input of various role-players in radiography. The following important facts pertaining to clinical experience in the radiography department and clinical teaching sessions of radiography students, were emphasised:

- Clinical experience in the radiography department must enable the student to think critically about the procedure for a radiographic examination. A variety of increasingly challenging clinical situations must be provided for the students.

Students are usually part of the work force in a very busy department, therefore meaningful experience is difficult to guarantee.

- Clinical teaching sessions should equip students with the necessary skills to cope in the busy clinical department. Adequately trained and enthusiastic clinical teachers must act as role models by demonstrating practical skills to the students. Students should also be given the opportunity to practise these skills themselves, thereby enhancing their understanding and self-confidence. These sessions should therefore play a role in integrating theoretical knowledge with practical application. The problem-solving approach, where complex situations are created for the students to solve, is the best way of integrating theory and practice (Watson, 1983).

Cox (2002) stresses the importance of teacher supervision when students practice their skills. Students should give honest, verbal feedback to their clinical teacher on what they observed. Perceptual gaps can only then be identified and solved. Guidance and feedback by the clinical teacher, while students practice observational skills, will improve perceptual sensitivity and accuracy. Guiding students in problem solving means that teachers should also “reason aloud” (Cox, 2002).

Bishop (1978) states that teachers should inspect the content of their subjects to determine the spatial techniques that can be applied, in order to develop students’ spatial skills. Clark and Lyons (2004) conclude that lecturers usually know the prior knowledge level of their learners and adapt their learning material according to that, but that they usually do not know the level of spatial ability of their learners. Clark and Lyons (2004) suggest the use of practical spatial aptitude tests to identify learners with low spatial ability, in order to assist them with appropriate tasks.

2.4.2 Mental image generation as a component of spatial intelligence

Gardner (1983) posits that spatial intelligence consists of different capacities: the ability to recognise an object or form, the ability to transform an object or to recognise the transformed object, the ability to evoke mental images, the ability to manipulate mental pictures and the ability to draw a picture containing spatial information. These capacities can be utilised when observing a two-dimensional version of real world scenes, which are in fact three-dimensional scenes (Gardner, 1983). Risucci (2002) also points out that when measuring visual spatial perception

(VSP) in surgeons to determine their competency levels, the components of VSP that entail mental image generation and manipulation of three-dimensional structures (spatial visualisation) should be included. According to Thomas (2001) mental image generation, occasionally referred to as “visualization” or “seeing in the mind’s eye” is generally believed to play an important role in visuo-spatial interpretation and ingenious thought processes. Leaf (2005) developed questionnaires to determine the dominant intelligence of a human being out of seven intelligences. These seven intelligences are Gardner’s “multiple intelligences”: linguistic, logical/mathematical, visual/spatial, kinaesthetic, musical, interpersonal, and intra-personal (Gardner, 1983). According to Leaf (2005) if one uses one’s dominant intelligence type when learning, information will enter the brain in such a form that it will be stored permanently. Leaf posits: “If your visual/spatial intelligence dominates, you think in images and pictures. You build memory through imagery and imagination and need to imagine and visualize while learning and concentrating” (2005: 64). According to Leaf (2005) 30% of adults and 40% of children are visual/spatial dominant. Wolfe states: “The ability to transform thoughts into images is often viewed as a test of true understanding” (2001: 153). She also states that some people try to understand information by first creating a mental image of it. Lohman (1993: 20), however, argues that spatial abilities are no longer regarded as linked to “lower-order” thinking, but rather as linked to “higher-order” thinking in science and mathematics. The ability to create spatial images and coordinate these with linguistic input also has a significant impact on cognition.

According to Gardner (1983) mental image generation (and spatial ability) does not only depend on recalling visual input, but may also depend on recalling tactile input. It has been shown that blind people also have spatial abilities, and with exercise, can draw as well as sighted people (Gardner, 1983). There are however wide individual differences pertaining to visual image generation. Some mentally challenged people can easily create and manipulate mental images, whereas people of a high intelligence, may struggle to perform these tasks (Galton, 1919). Spatial intelligence is therefore not necessarily related to other intellectual strengths and can be developed separately to a high degree of performance. Artists and chess-players usually have a strong visual imagination or visual memory (Gardner, 1983). According to Grandin the visual spatial skills of most autistic persons are so well developed that they are able to “think in pictures” (1996: 1) although they are verbally restricted. In some cases the words of other people, or actual experiences, can instantly be transformed into pictures. Grandin, who also suffers from autism, creates new designs, by retrieving small pieces of his memory and combining them. He stores information in his head and replays it in his imagination to solve problems. Kintsch and Greeno (1985) find that children need visual mental images to understand word problems in mathemathics. Gardner (1983) states it is possible that these mental images play a role in problem solving. Some people experience eidetic images. These mental images are clear, accurate and detailed (McKim, 1980; Galton, 1919). Kirby and Kosslyn (1992) argue that, because people differ in their image-generation capacities and abilities, this technique cannot be prescribed for the solving of all problems. Human beings have various techniques available for solving problems, such as creating mental images or using their linguistic skills. They will use the appropriate strategy depending on the requisites of the task (Galton, 1919; Logie, 1995).

Thomas (2003: 9) defines the term “mnemonic” as a mental technique, which could be used to enhance memorisation of complicated information. Thomas concludes: “Many of the most effective and most widely used mnemonics involve imagery” (2003: 9). Using the image-generation system, spatial relations and shapes can be recalled, inspected, manipulated and re-inspected (Kirby & Kosslyn, 1992).

Radiographic images are, as previously explained, two-dimensional pictures of three-dimensional structures of the human body. Hegarty *et al.* state: “Spatial cognition is central to understanding medical images, including those produced by CT, MRI, X-Ray, and ultrasound” (2007:2). Mental image generation is a capacity, or an ability, which forms part of spatial intelligence.

2.4.2.1 Improving the mental image-generation (visualisation) process

Du Toit (1995) states that a powerful and vivid imagination is an indication of intellectual strength. According to him, image-generation skills can be practised and developed. According to Bishop (1978), in developing spatial skills practice with concrete models and drawing, or studying, photographs of these models from different perspectives could be followed up by guided image-generation exercises. These exercises according to Bishop (1978), and previous research, make use of spatial visualisation. The lecturer, in visualising different perspectives of objects, or different physical processes, guides students.

Lord (1985) compiled a program that significantly improved the spatial abilities (spatial visualisation and spatial orientation) of undergraduate students. Eighty-four undergraduate students participated in the program. They were randomly divided into two groups, an experimental group and a control group. The relationship of males to females was equal in each group. According to previous records the groups did not differ significantly with regard to performance in mathematics. All the participants wrote a spatial aptitude pre-test. The experimental group subsequently participated in a 30-minute training session each week. Those sessions comprised exercises where students had to mentally bisect three-dimensional geometric structures and mentally envisage the internal structure of the bisection. The students also had to draw their mental images of the internal configuration on a sheet of paper. They wrote a post-test fourteen weeks later, which was similar to the spatial aptitude pre-test. The results of the experimental group revealed a significant improvement in spatial orientation and spatial visualisation. Lord (1985) concluded that the ability to envisage the internal structure depends on mental control of the image.

Arvold (1993) posits that practice in mental transformation from the second to the third dimension can develop spatial visualisation skills. She suggests several simple spatial activities to be executed by students. One of these activities entails drawing two circles on a piece of paper (a smaller one inside a bigger one). The student has to stare at the smaller circle and visualise it as the top of a tower. The bigger circle at this stage will represent the lower part of the tower. The student subsequently has to visualise the smaller circle as the bottom of the hole inside a cylinder. During the first task the student is mentally moving the smaller circle closer to her/himself, while during the second task s/he is moving it further away from her/himself. A two-dimensional representation is consequently mentally transformed into a three-dimensional representation.

Due to the memory load on the system, mental image generation will interfere with visual input (and the other way around) if these processes are simultaneously executed (Ishai & Sagi, 1997; Kirby & Kosslyn, 1992).

The imagination of the human being is so powerful that people are capable of making creative discoveries by detecting new patterns when constructing, manipulating (e.g., rotating) and inspecting their mental images (Finke, 1990). According to Finke (1990) certain techniques can be used to stimulate these creative thinking abilities and anyone can learn to use these techniques. Famous scientists (e.g., Einstein and Kekulé) used their imaginations to solve problems and discover new inventions, for example, the concept of special relativity (Einstein) and the molecular structure of benzene (Kekulé). Experiments done with undergraduate students by Finke (1990), involved creating mental combinations of familiar patterns (e.g., capital letters, numbers and geometric forms) with their eyes closed, the mental inspection of these newly created patterns and, most importantly, the recognition and description of the emerged patterns. Fezler (1989) agrees that everyone possesses the power of imagination, but that this should be developed. People should learn to use the right side of their brains.

A person can learn to create a vivid image by concentrating and recalling the image in all five senses (sight, hearing, touch, smell and taste). When creating an image, a person is recalling separate sensory components, as each of these senses consists of sensory components, and combining them as a whole. The vividness of the image will depend on the person’s ability to remember his/her sensory experiences in the past. According to Fezzler (1989) people can develop their image-generation skills by practicing certain scenes (imagining the scenes). A powerful imagination can be used for multiple purposes, such as for treating depression, for helping to cure diseases like cancer, etc. Recent research reveals that positive visualisation can increase the T killer lymphocyte count and thus support the immune system (Fezzler, 1989).

Mast and Kosslyn (2002) also suggest mental visualisation training to improve spatial skills. They researched the reinterpretation of ambiguous pictures using spatial skills. Ambiguous pictures can be interpreted in more than one way. The picture that was shown to the participants was that of the face of a young woman, which, when mentally rotated through 180°, changed to the face of an old woman. The participants had not been informed before the test that they should search for another figure, so they did not anticipate the other interpretation. Performance of this specific mental rotation task, to invert the figure, is complicated and the other version therefore not likely to be perceived without previous experience. An interesting learning program was compiled for Mast and Kosslyn's (2002) research:

- Twenty-two of the forty-four participants studied the old woman's face and the other twenty-two the young woman's face, to form a mental image of the face.
- With the aid of cues (fragments of the picture), they then drew the face from memory as accurately as possible, using translucent paper.
- They afterwards compared their drawing with the original showed to them, by superimposing their drawing on the original and tracing the outline of the original by using a different colour pencil.
- They repeated all the steps for the above procedure, until they could represent the drawing accurately, using their mental image.

The steps of the mental rotation process followed:

- They had to mentally visualise the original face again.
- They then each rated their image in terms of sharpness and detail on a scale from one to five.
- The participants were then asked to mentally represent the image in five orientations (e.g., turning in a clockwise direction to the totally inverted position). Cues were available to aid them.
- All the steps were repeated.

The third part of the process was the image-generation tests:

- With the image still in the inverted position, they were asked what the figure represented.
- If they reported the other face, they were asked to describe it.
- Participants who had not reported the other version were then given hints for where to focus on the picture.

- If they reported the other face, they were asked to describe it.
- Participants who still had not discovered the alternative image were further guided by a reference frame hint on how to perceive the cues.
- If they reported the other face, they were asked to describe it.
- If they still had not discovered the face they were presented with a selection of possible answers (names of figures).
- If they reported the correct alternative version, they were asked to describe it.

A redrawing process followed:

- The participants were instructed to draw their original mental picture again, but now in an inverted position.
- They then compared this with their original drawing to check if all the detail was present.
- Participants, who had not discovered the picture before, were asked if they saw it.
- Immediately afterwards, the inverted version was shown to all the participants.

(Mast & Kosslyn, 2002).

The results of their research reveal that eight of the forty-four participants recognised the inverted figure during the learning phase, sixteen discovered the face after they had mentally rotated the image, in the image-generation phase, while twenty participants were not able to recognise the inverted version at all. Participants who discovered the alternative image in the redrawing phase or when they were shown the picture at the end were classified as “non-recognisers”. When participants were presented with the original picture in the learning phase, they were not informed that they should search for another version. Only after they had created a mental image and inverted it, were they guided to search for the other version. According to Mast and Kosslyn (2002), those facts are therefore evidence that mental images are depictions (appear like pictures), which can be manipulated. They also report that the key factor for recognising the other version is the ability to mentally rotate an image. According to Mast and Kosslyn (2002), it is possible that the non-recognisers needed more time to perform the rotation task and that sections of their images were fading before they could interpret it. They recommend further research, where one group of participants are trained repetitively on mental rotation tasks before performing the above procedure, compared to a control group with no prior mental rotation training. They anticipate that the extra training would improve the spatial skills of the non-recognisers. The quality of the images of the recognisers compared to the non-recognisers, only varied after performing the rotation task. Mast and Kosslyn (2002) conclude that not all people can perform these complicated mental tasks. They also add that some people are able to discover a figure spontaneously, which they had not previously seen.

Repeated exercise is necessary to stimulate inner sensory image generation (McKim, 1980). An image that is difficult to imagine forms a mental block, but this can be overcome by repeated exercise and alternative relaxation. Images should be arranged to increase in difficulty. The easiest image should be first imagined, followed by the more difficult images. The blocked image would therefore be reached step-by-step (McKim, 1980). Bethell-Fox and Shephard (1988) state that students, who exercise mental rotation of objects, create mental representations of the patterns with time and are able to mentally rotate the entire objects very quickly, despite the complexity of the information.

2.4.3 A virtual environment versus real life models

According to Wolfe (2001) the eyes contain almost 70% of the human body's sensory receptors. The human being consequently receives most information visually. Concrete visuals, such as models or drawings are therefore essential for improved understanding, processing and storing of information.

Bishop (1978) suggests three-dimensional models, which resemble the original objects as close as possible, to comprehend perspectives in astronomy. According to her, the ideal situation would be where each student (or group of students) has his/her own model. These models should be large, but easy to manipulate. She concludes that a practical demonstration (with one model per class group) would be more educational than a formal lecture or class notes, containing two-dimensional diagrams. According to Bishop (1978), concrete physical models would also assist biology students in appreciating cross and longitudinal sections, as well as various aspects of the body (e.g., anterior, posterior, dorsal and ventral). If the models are too expensive to buy, students should create similar models. These hands-on activities would also develop spatial comprehension. These models would be of more value to the students when used in combination with diagrams. Modified models, not resembling the actual objects closely (e.g., plastic or cardboard pieces, sticks or wire), could also be used to explain physical structures or processes.

Clark and Lyons state: “Iconic visualizers rely on concrete visual imagery, whereas spatial visualizers can interpret or manipulate spatial information in a more abstract manner” (2004: 210). Clark and Lyons explain “spatial span” as the ability “ . . . to hold multiple visual images in memory” (2004: 197). According to them the spatial span of people varies. They also add that visual models used simultaneously with written information of the same content, will double the chances of building a mental image in low prior knowledge learners, instead of only processing the verbal information. In contrast, experienced learners can create a mental image from either reading a text or observing a model pertaining to certain content. More importantly for the current research, Clark and Lyons (2004) suggest the use of multimedia to assist low spatial ability learners with tasks that demand spatial visualisation. The multimedia should include various representations of the spatial content of the lesson, such as both visual and written information.

McKim (1980) and Petroski (2000) both agree that the students’ interaction with real life hand-held models, which they are able to perceive and simultaneously touch and manoeuvre, will stimulate the visual perception parts of their brains more than perceiving computer images only, thus benefiting the development of spatial skills. Models of cross-sections of objects are especially valuable to teach students structural internal relationships. According to Sorby (1999), in order to stimulate meaningful learning, it is important that students start by observing familiar concrete models, then, secondly, proceed to the semi-concrete by drawing pictorial sketches of these models and, thirdly, proceed to the abstract, by visualising multiple views of the models and creating multi-view sketches. Sorby (1999) suggests that students should sketch a model and subsequently dismantle the model. They should then hand the parts, as well as the drawing, to other students to re-assemble the model. These tasks should assist in developing spatial skills. Kali and Orion (1996) also propose that assistance should be rendered to learners with low spatial abilities in the form of concrete models, which they can dismantle on their own. Petroski concludes that “ . . . hands-on experiences are not intended to replace those learned in a computer laboratory or theory-based course. They are intended to supplement theoretical and computational experiences . . .” (2000: 2). McKim (1980) agrees by stating that absorption of information by all sensory organs is vital for recalling a full sensory experience later. Non-visual sensory information, (e.g., touch of texture and smell) should therefore also be assimilated during a learning process. According to Sorby and Baartmans (1996) the majority of learning occurs by means of visual inspection of the concrete object.

Provo, Lamar and Newby (2002) investigated the role of a cross-section in understanding spatial relationships between anatomical structures in animals, in veterinary students. The goal of the research was to increase their three-dimensional knowledge of anatomy, but also their mental ability in visualising these structures. They decided on the head as research material due to its complexity. Their participants were divided into two control groups and two experimental groups as two trials were run. Both the control and experimental groups dissected carcasses throughout the research period. The control groups received placebo assignments pertaining to the areas they were dissecting, which required the tracing of structures on transparencies using radiographic images. The experimental groups had to study a colour photograph of a cross-section of a dog’s head and subsequently also trace the structures. At that time they were dissecting the head of the animal. Afterwards all groups wrote an examination including questions that involved mental visualisation. All participants subsequently had the opportunity to write a voluntary paper-and-pencil test on the three-dimensional anatomy of the head of the dog. The test consisted of three sections. In Section A they were required to visualise the internal structures of a cross-section at a specific level indicated on a diagram and then choose them from a list. In Section B they had to sketch the position of each of these structures inside a given outline of a cross-section of the head. In Section C they had to sketch the positions of given anatomical structures within drawn outlines of the ventral and lateral views of the head. The participants also subsequently wrote the Purdue Visualisation of Rotations Test (Provo *et al*., 2002). The test measures mental rotation ability. It measures the ability of the participant, when observing a picture of a rotated object, to mentally visualise the direction and amount of rotation of the object. It also measures the ability to subsequently mentally rotate another object in a similar way.

Provo *et al.* (2002) anticipated that they would improve the anatomical three-dimensional thinking of students and that these abilities would be applied to other parts of the animal's body. According to Provo *et al.* (2002) dissection of carcasses, due to the destructive nature of the procedure, is not the ideal method to learn three-dimensional relationships between structures. Provo *et al.* (2002) note veterinary students have to mentally form a three-dimensional image of an animal's body when they learn to interpret two-dimensional radiographic images. The research done by Provo *et al.* (2002) reveals no significant differences in performance between the control groups and the experimental groups in the anatomy tests. The intervention consequently did not improve the ability of the students to mentally visualise anatomical structures in three dimensions. Qualitative data (feedback from students on the exercises), however, reveal that some students felt that the cross-section did improve their knowledge of three-dimensional relationships. Others felt that the dissection process was more valuable. Some of them reported that the cross-section was too complicated to understand. A reason for the nil difference in performances could, according to Provo *et al.* (2002), be that the anatomy tests did, in fact, not measure the spatial ability of the students. It is possible that they could have memorised information on relationships, using verbal clues, instead of mentally visualising the relationships to answer the questions. The test questions required the creation of mental images, but remembering the names of structures was also crucial. All the above-mentioned factors could have influenced the results of this research. The quantitative results show that students, when dissecting carcasses, acquire ample information for creating a three-dimensional mental image of the anatomical relationships (Provo *et al.,* 2002). The results of this research also reveal a statistically significant correlation between the performance of the students in the spatial aptitude test and the anatomy tests. Provo *et al.* (2002) suggest that students with low spatial abilities may fail this subject. They explain that during practical assessments on the carcass, the students had to recognise structures in the carcass. The carcass was however, sometimes in an unfamiliar position, which complicated the task. The students were not allowed to rotate the body into a familiar position and consequently had to execute a mental rotation to be able to answer the questions. The students' achievements in the spatial aptitude tests improved over the year and Provo *et al.* (2002) argue that the anatomy course, as a whole, could have improved these abilities. Provo *et al.* (2002) suggest for future research that more than one cross-section should be used for the practical session. They also suggest that a cross-section of a carcass instead of a photograph be used to create a more realistic experience. The cross-section should demonstrate features (e.g., texture) of structures that would enhance the differences between the structures. Students would also be able to rotate the cross-section to gain more insight on relationships. Provo *et al.* (2002) posit that students should be well informed on how to relate a cross-section to the entire body. Creating their own cross-sectional sketches during the practical session, at an indicated level through the head, would provide more interaction and, as a result, more understanding. Provo *et al.* (2002) suggest that drawing should be excluded from assessments in future, because of differences in drawing abilities. Pictures of the anatomical structures could be provided to the students for them to attach to the correct location in the cross-section. This type of assessment would be easily performed using a computerised program, where structures could be dragged to the correct location in a cross-section. Provo *et al.* (2002) suggest that spatial aptitude tests should be used to identify students with low spatial abilities in order to assist them with extra training to develop these skills.

According to Teichgraber, Meyer, Poulson Nautrup and Rautenfield (1996) medical students claim that they gained understanding of relationships between anatomical structures, when creating cross-section images of the human body, using an ultrasound device. A cross-section provides a two-dimensional image, which should be related by students to their mental three-dimensional configuration of the human body.

Arvold (1993) describes an activity that entailed the placement of different three-dimensional objects, (e.g., a cone on its base, a cylinder on its side, a marble) on an overhead projector. A screen covered the projector so that the students were unable to see these objects. The projector was subsequently turned on and the students were asked to recognise, describe and draw each of the different objects. Following a group discussion, each of the objects was slowly rotated for the students to observe the change from a two-dimensional representation to another two-dimensional representation of it. Observing both two-dimensional representations would aid in understanding of the third dimension. The objects were finally showed to the students and they then had to draw a three-dimensional representation of each one.

Virtual reality modelling language (VRML) has to do with realistic three-dimensional models over the Internet, which can be modified rapidly by users (Gómez, Lemos, de Souza & Speck, 2000). Their research shows that computerised models are just as good as teaching material for technical drawing as conventional wooden models. VRML can be used to teach architectural and engineering students to draw three-dimensional objects in a two-dimensional plane.

Hegarty *et al.* (2007) claim that the importance of spatial abilities in medicine raises a question, namely: How should medical students be trained to be able to cope with modern technology, involving computerised images? Eyal and Tendick (2001) argue that there is insufficient media for training spatial skills. Due to the fact that books, videos and CD-ROMS contain two-dimensional pictures, they are not adequate for the training of spatial skills. Useful media are synthetic models, cadavers and animals, but they are scarce and expensive (Eyal & Tendick, 2001). Hegarty *et al.* (2007) agree by stating that computer models are more flexible and can be re-used.
According to Eyal and Tendick " . . . performance in surgery is strongly dependent on spatial skills" (2001: 146). As with radiologists and radiographers, the surgeon has to create a mental three-dimensional image of anatomical structures, by combining the information of a two-dimensional radiographic image, with his experience and anatomical knowledge. Guiding an angled laparoscope, for example, is a surgical skill that especially requires spatial three-dimensional reasoning, due to the constrained movement and limited viewing perspective within the abdomen. Eyal and Tendick (2001) developed a virtual environment (a simulation) for teaching the use of a laparoscope. The participants' performance in completing the task was compared to their performance in standard spatial ability tests. The participants were undergraduates and therefore initially not familiar with the instrument or procedure. The participants' performances in completing the task correlated significantly with their performance in spatial ability tests. Spatial ability, therefore, plays a role in learning this specific technique. They realised that people with low spatial ability would need more in-depth training to acquire the skills to perform this technique. According to Eyal and Tendick (2001), training methods within this virtual environment have been developed to assist people with low spatial ability. Strategies

that do not depend on mental visualisation should be taught and the emphasis should be on teaching the correct procedural steps.

Garg, Norman, Spero and Maheshwari (1999) investigated the role of virtual computer models in teaching anatomy to medical students. The purpose of their research was to determine if the viewing of computer models from multiple perspectives, instead of a few key perspectives, would benefit or handicap students in learning spatial relationships of anatomical structures. After writing a generic spatial ability test, the students received brief training sessions with either a key view (KV) or a multiple view (MV) computer model of the carpal bones of the right wrist. Key views refer to the basic views that are usually printed in an anatomy book (e.g., anterior, posterior or lateral views). For the skull it would also include an inferior and a superior view. During this experiment, the KV model rotated automatically through 180º, while the MV model rotated automatically through 10º intervals. The students were therefore only passively involved. The students' spatial knowledge of the carpal anatomy was then measured, using a multiple-choice questionnaire. The results show that students with a high spatial ability benefited from both of the before-mentioned models, but, that students with a low spatial ability performed much better using the KV model. Women also performed significantly better when using the KV model. These findings may be applicable to other concrete models, such as skeletons. Garg *et al.* (1999) add that it must be kept in mind that the carpal bones form part of a planar object and that the results may be different when using objects with volume, for example, the skull.

Their results agree with previous studies that the brain can only remember key views (two-dimensional mental views) and only afterwards rotate the information to form a three-dimensional mental view, if requested. Any extra information, such as presenting objects of anatomy in rotated positions will not be remembered and will handicap students with weaker spatial abilities (Garg *et al.*, 1999; Garg, Norman, Spero, Eva & Sharan, 2002). People will remember the first view of an object that they observed, rather than multiple views. The memories of multiple views will blend together and form a vague mental picture. Some people, however, do have complete power over their mental images and are able to manoeuvre them in any way (Galton, 1919). Cockburne and Mckenzie (2004) state that the spatial memory of users does not improve by adding a third dimension (instead of the traditional two-dimensions) to computer displays. In fact, there was no significant difference in the performance of users, pertaining to spatial memory, when using three-dimensional and two-dimensional displays, in their research. Further research done by Garg, Norman and Sperotable shows that “high spatial ability of the student and self-directed examination of an object from multiple different perspectives improves spatial learning” (2001: 363). They suggest that students should use self-controlled multiple-view models, such as skeletons, dissected samples and computer models to improve their spatial skills (Garg *et al.*, 2001). They emphasise active control of models as a prerequisite for gaining spatial skills.

Several researchers agree with Garg *et al.* (2001) that the active manipulation of computer-generated three-dimensional objects by participants will increase the recognition of these objects at a later stage, compared to participants who only passively observe the automatic rotation of these objects. The active inspection of these virtual objects is more or less identical to the active inspection of physical objects (Harman, Humphrey & Goodale, 1999; James, Humphrey, Vilis, Corrie, Baddour & Goodale, 2002). According to these researchers, it is possible that the manual control of the objects provided information that helped the observers to integrate the different views. Active control of an object gave the participant the opportunity to envisage the modified view of the object, before rotating it in a specific direction and then testing his/her prediction after rotating the object. The participant probably also gained information when relating the modified view to the previous view. The participants in these studies spent more time exploring a few KVs when actively involved, namely a fully elongated (side) view and a completely foreshortened (front) view of an object. A possible reason could be that these views displayed the biggest differences in the features of the object. It is also possible that they might have focused their attention only on these key views, while the attention of the passive observers, might have been spread evenly over the entire sequence of views. The active participants also rotated the object slightly from the key positions, into semi-oblique positions, to obtain glimpses of the intermediate views. These continuous small deviations from side to side seemed to provide enough information on the characteristics of all intermediate views, probably because of the similarity in features of these views. It was found in both the two last-mentioned studies that although participants spent more time observing the KVs, intermediate views were better recognised when they were assessed. An explanation could be that although a particular intermediate (oblique) view was not observed for very long, if the time spent on “wobbling” the object into all the oblique positions was added up, it would be significant. The similarity in features also reduced the number of intermediate views to only a few different views (Harman *et al.,* 1999; James *et al.,* 2002).

According to Keehner and Khooshabeh (2002), medical lecturers regard three-dimensional computer exercises as an alternative to traditional learning materials (e.g., cadavers). Computer exercises are more flexible and can be used over and over again. They investigated the interaction of medical students with electronic types of learning materials. The spatial aptitude of the participants was also compared with their performance at drawing a cross-section, using a computer visualisation of “branching vessels” within an egg-shape structure. In the first experiment one of the groups was actively involved in the rotation of the object by using a key press system as an interface. The other group observed the rotation of the object passively. The results showed a significant correlation between spatial ability and the location of the “vessels” (internal structure of the “egg”). The correlation was higher with the passive observers. There was, in contrast with other research, no significant difference between the active and passive results. There was also no consistency in the manipulations of the participants who were actively involved in this experiment.

The experiment was repeated, using a more user-friendly or naturalistic interface (form of control), which was a hand-held tool, to determine if the active group was not disadvantaged because of the interface used in the previous experiment. The overall results were very different from the previous exercise. There were still no significant differences between the performances of the active and the passive groups, but the effect of spatial aptitude on performance was considerably reduced. The results showed only noteworthy significant correlation between spatial ability and the location of the “vessels” (internal structure of the “egg”) in the passive observers. No significant correlation between spatial ability and the location of the “vessels” was obtained with active control of the object. Much more consistency was however found, pertaining to the manipulations of the active group, when using the hand-held tool. Keehner and Khooshabeh (2002) explain the consistent similarity in performance between the active and non-active groups. According to them, in contrast with previous research, the active and passive groups of their research obtained similar information on perspectives of the object. The decrease in the influence of spatial ability on performance in the active group, compared to the previous experiment, was attributed to the use of the intuitive control device. The influence of spatial ability had, however, also decreased in the passive group and the differences in performance between the high and low spatial participants were also less in the second experiment.

Current clinical surgical training entails students practising their skills on patients, under the direct supervision of experienced surgeons (Hegarty *et al.*, 2007). This type of training may hold risks for patients and a supervisor must at all times be present. Virtual reality (computer models) could be used in future to improve medical training. Cohen, Hegarty, Keehner and Montello (2003) performed similar research as Keehner and Khooshabeh (2002) using the same type of virtual object ("egg" containing "vessels"). Participants were asked to imagine a cross-section (two-dimensional "slice") of the three-dimensional virtual object. They had to draw this mental picture. Participants could decide when, how much, and in which direction, to rotate the virtual object, while actively controlling it. Rotating the objects gave them additional depth cues, which helped them to form mental pictures of the internal structures of the object. The virtual object did not show the specific cross-section image. A line drawn previously on a printed image, indicated to them where the cross-section should be made. The results of the drawing task showed large individual differences. According to Cohen *et al.* (2003), the spatial ability of the participants correlated significantly to the accuracy of the drawing task. The results also reveal the following important facts:

- Some participants with low spatial abilities did not understand the term "cross-section".

- Some participants omitted drawing the outline of the object or they drew a cross-section combined with the frontal exterior appearance of the object.

- The participants with low spatial abilities also manipulated the virtual object less often than the participants with high spatial abilities, and they reported that rotating the object, made them feel disorientated.

In an experiment done by Cohen *et al.* (2003), participants were divided into two groups. One group was actively involved in practice with a virtual model, while the other group was unable to manipulate the object. In the latter case, the object rotated automatically around its own axis. The results show that spatial ability correlated equally with performance in both groups. This implies that the superior performance of individuals with high spatial abilities is not due to better manipulation of the virtual object, but rather due to the ability to imagine a cross-section. Spatial ability is therefore strongly related to creating a mental picture of a cross-section. These results also show that active involvement with the virtual object is related to superior performance on the drawing task. Interesting information revealed by this research, is that individuals with low spatial abilities perform better when actively involved in the task, in contrast to individuals with high spatial abilities who actually perform worse at the same interactive task. Hegarty *et al.* (2007) found that manipulating a three-dimensional virtual object could increase performance on the cross-section task. Spatial concepts (e.g., “cross-section”) should be well explained to individuals with low spatial abilities, using concrete practical examples (e.g., cutting a fruit in half).

Rafi, Samsudin and Ismail (2006) investigated the role of a computerised engineering drawing program in developing spatial ability in engineering students. One-hundred-and-thirty-eight twenty-year-old students participated in the research. The roles of gender difference and prior experience in spatial ability activities were also investigated. According to Rafi *et al.* (2006) gender differences in spatial ability may also be caused by gender related experiences (activities) in the past. The subjects completed a Spatial Experience Questionnaire (SEQ), as well as two pre-tests, namely a spatial visualisation test and an on-line mental rotation test. The subjects were randomly assigned into two experimental groups and one control group. Equal numbers of males and females participated in the research. Three interventions were administered. The control group received only conventional instruction, which entailed printed instructional material and engineering drawing exercises, while the experimental groups received enhanced training. The one group used printed materials in combination with digital video clips, while the other group was trained on the computerised program “Interactive Engineering Drawing Trainer” (EdwgT). This program entails problem-solving activities, including exercises in creating orthographic projections from isometric views. Post-tests, comprising the above-mentioned spatial aptitude tests, were administered five weeks after the pre-tests. The reason for the five-week period was to exclude other factors causing an increase in performance (Rafi *et al.*, 2006). Their research reveals interesting information. In contrast with most other literature, there were no significant gender differences pertaining to both spatial aptitude tests prior to the interventions. The post-tests provided the following results:

- <u>Performance in spatial visualisation after the interventions:</u>

  According to Rafi *et al.* (2006) performance in spatial visualisation after using the computerised program, EdwgT, was significantly higher compared to performance after using the other two training methods. The performance of the group trained by using video-clips, in conjunction with a conventional training method, was also better than the performance of the group trained only in the conventional way. The males performed better than the females in spatial visualisation after the intervention. The difference in performance between the high and low spatially experienced groups increased after the intervention. The high spatially experienced group performed significantly better than the low spatially experienced group.

- <u>Performance in mental rotation accuracy after the interventions:</u>

  Performance in the accuracy of mental rotation after using the computerised program was highly significant, compared to the performances of the groups who used the other two training methods (conventional instruction and digital video clips). The experimental group who used the video clips also performed significantly better than the control group who received only the conventional instruction. There was no significant difference in performance between the male and female groups, pertaining to the accuracy of mental rotation. There was however a significant difference between the performances of the high spatially experienced group compared to the low spatially experienced group, favouring the high spatially experienced group. Low spatially experienced subjects performed equally, despite the instructional method used, while the high spatially experienced subjects, when using the computerised program, performed much better than the other groups. It was suggested that the low spatially experienced group might have lacked experience in using computerised programs (Rafi *et al.*, 2006).

- <u>Performance in mental rotation speed after the interventions:</u>

  Speed of performance with regard to the ability to mentally rotate objects, increased somewhat with training despite the method used. No gender difference was revealed. Both gender groups' performances increased slightly with training. Subjects with high levels of experience in spatial representation performed significantly better than the subjects with the low levels of experience in spatial representation.

Rafi *et al.* (2006) conclude that dedicated computerised engineering drawing programs will develop spatial visualisation ability as well as mental rotation accuracy significantly, but will only slightly improve mental rotation speed. They suggest that interaction with the computerised program enhances the comprehension of information. It was found that the level of spatial experience played a significant role in gaining spatial visualisation ability. They also suggest that the role of students' learning strategies in achieving spatial visualisation abilities should be investigated in future. Hegarty *et al.* (2007) agree that external visualisations, for example, computer models or other real life models, can aid individuals with low spatial abilities to understand internal visualisation, such as internal structure of objects. Appropriate task instructions should however be provided before training and assessments.

Tatum (1996) suggests the use of a computer software package, Autodesk's AutoCAD and Three-dimensional Studio, to assist students in developing spatial thinking. He states that three-dimensional thinking is a complicated task for most students. It entails mentally holding several perspectives of an object simultaneously in the mind. Previous research had divided the process of visualisation into four sub-processes, namely depth perception, colour, motion and recognition. The brain subsequently combines these processes. According to Tatum (1996), the computer-based exercise will aid students in comprehending three-dimensional structures. Students start off by constructing a cube and subsequently perform various activities using the cube. The advantages of using the program instead of conventional models, include: no preparation of learning material (which could be difficult and time-consuming), the ability to modify the object in various ways, minimal time needed for manipulations and a broad spectrum of colours and materials that are available to use for alterations (Tatum, 1996).

Hegarty *et al.* (2007) conclude that using three-dimensional computer visualisation in medical training is not always effective. The students' comprehension may depend on the type of interaction with the program and may also depend on their individual spatial abilities. Learners with low spatial abilities should therefore be supported in using these programs. Strong and Smith (2001) question the use of current technologies, such as simulation and virtual reality versus conventional methods for improving spatial skills. Strong and Smith pose the question: "Does one need a certain level of spatial visualisation ability to effectively use these technologies?" (2001: 4). Rafi *et al.* (2006) and Hegarty *et al.* (2007) have both answered that question by stating that individual spatial experience plays a role in gaining spatial abilities/skills electronically.

Gerson, Sorbi, Wysocki and Baartmans (2001) developed a multimedia software program, which according to their research results would enhance spatial skills in engineering students significantly. According to them, this software program should not replace the typical classroom setting. They emphasise the important role of the lecturer and interaction with fellow-students in assisting the student with problem solving. They suggest that the ideal educational tools would be a combination of multimedia software and classroom instruction.

2.4.4 Sketching and drawing

Sketching and drawing are common activities used to develop spatial visualisation abilities in engineering students. Sketching means to create rough pictures by using a pen or pencil and to estimate proportions and lengths by looking at an object. In standardised drawing, a specific scale is used for lengths and proportions (Alias, Gray & Black, 2002). Alias *et al.* (2002) investigated the attitude of engineering students towards sketching and drawing, to study the association between this attitude and their spatial visualisation ability, and also to compare engineering and architectural students with respect to their attitude towards sketching and drawing. Their research findings show that although all attitude aspects correlated positively with the students' spatial visualisation ability, only the tendency to use sketching and drawing, correlated significantly with spatial visualisation ability. Alias *et al.* (2002) state that it is possible that having a high spatial visual ability encourages the use of sketching and drawing, but more important for teaching and learning, it is also possible, that the frequent use of sketching and drawing develops higher spatial visualisation ability.

Baenninger and Newcombe (1989: 329) agree:

> It is an intuitive notion that experience or practice with spatial tasks will increase spatial test performance. The problem with testing this notion is the equal plausibility of self-selection; people with high spatial ability may be the ones who want to engage in spatial activity in the first place.

According to Alias *et al*. (2002) the tendency to use sketching and drawing also correlated significantly with the students' view of the professional role of sketching and drawing. It was found that the architectural students were more positive in their attitude towards using sketching and drawing, than the civil engineering students. More emphasis is placed on sketching and drawing in the architectural curriculum, than in the engineering curriculum, and this could be a reason for the difference in attitude. Alias *et al.* (2002) conclude that the role of sketching and drawing in the engineering students' future profession should be emphasised, to increase the usage of sketching and drawing, and thereby hopefully develop their spatial visualisation ability. An investigation done by Kayan (2005) of high school learners' spatial ability also reveals a significant development in the spatial ability of the learners doing a technical drawing course. This research also shows a significant positive relationship between spatial ability and performance in mathematics.

According to Gardner (1983), the most elementary spatial ability task is, perceiving an object. The ability can be tested, by asking the participant to draw the object. A more complex task would be to ask the person to mentally rotate the object and draw it from another viewing angle. McKim (1980) divides visual thinking into three types of processes, namely observation, image generation and drawing. McKim (1980) claims that if all three of these processes interact in tasks, visual thinking will be at its best. McKim explains that " . . . drawing stimulates and expresses imagining, while imagining provides impetus and material for drawing" (1980: 7). Imagination will also influence what is visually observed, while observation will provide visual information for creating mental images. Drawing according to McKim (1980) involves either the long-term memory (stereotype drawing) or the short-term memory. When you observe a real life object and simultaneously draw it, you make use of your short-term memory to hold the mental image for the short reproduction period.

McKim (1980) posits that awareness of the spatial cues of foreshortening is a prerequisite for accurate perception of a three-dimensional form (especially in a two-dimensional plane). McKim (1980) suggests drawing exercises for comprehending this cue. Pairs of objects can be drawn, for example, two bottles, where the one is in an upright position and the other one lying on its side, in an end-on position to the observer. Other drawing exercises are also suggested to comprehend three-dimensional form, for example, drawing the front, the top and the side views of simple familiar objects. Drawing an apple from different perspectives and subsequently a cross-section thereof is also a simple exercise to understand the term “cross-section”.

Olkun (2003) agrees with Alias *et al.* (2002) that practice in engineering drawings should be able to improve spatial ability. According to Olkun (2003) engineering drawings can be classified into two groups, namely the orthographic view, which demonstrates two dimensions of an object, for example, the front side, the right side or a cross-section and the perspective view, which is a two-dimensional drawing of the object in an oblique position, therefore three dimensions of the object are demonstrated. Drawing skills are obtained through practice with straightforward to more complicated visual structures. Olkun states: “Drawing perspectives or imagining the real object from the orthographic views also involves mental integration” (2003: 5). Ben-Chaim *et al.* (1988) also claim that spatial ability might be improved by concrete activities, for example, using cubes to build structures and then subsequently drawing these structures.

Steps to achieve these spatial abilities are suggested by Olkun (2003):

- Tasks should be arranged from easy to more complicated.
- Learners should begin each task by exploring concrete and familiar objects/models.
- Learners have to observe a perspective (oblique) view of, for example, a rectangular object and then use wooden cubes to build a similar object.
- They then have to compare and discuss the different views of their concrete object with the related drawing. It implies rotating it in various positions to find the exact position, as is demonstrated by the drawing.

- Learners have to focus their attention on the fact that an object will appear different from different angles. To understand the geometrical transformation of images, they have to compare the concrete object with its relative perspective and orthographic view. They first have to choose a specific area of the concrete object and focus on it. They then have to search for that specific area in the perspective and finally find that area in the orthographic view.

- The learners then have to draw the views of their own objects.

Several researchers report that interaction with concrete hand-held models, followed by representing these models in two-dimensional and three-dimensional drawings, such as engineering drawings, will improve spatial ability/skills. It also involves creating mental representations of objects from observing these drawings. Sketching/drawing inspires creativity and develops mental image-generation skills (McKim, 1980; Olkun, 2003; Sorby, 1999). Bishop (1978) explains that students studying earth sciences have to draw topographical maps from landscape models and, conversely, have to interpret the three-dimensional surface of the earth from topographical maps. Bishop (1978) agrees with the previously mentioned authors by suggesting that teachers should make more use of the drawing of perspectives of objects, which would develop spatial abilities. These perspectives also include the intermediate angles of an object and not only the familiar views. Drawing perspectives will assist students in remembering what they have observed.

2.4.5 Verbal strategy training

Schofield and Kirby (1994) suggest that participants use either verbal or visual strategies to solve spatial problems. They investigated the role of verbal and spatial strategies, as well as individual differences, in localising a position on a topographical map. One-hundred-and-eighty-eight Australian army personnel participated in the research. These maps usually represent two dimensions, while the third dimension has to be represented mentally. Positioning location requires composite spatial skills and the spatial visualisation ability is therefore indispensable. Schofield and Kirby (1994), developed two training strategies. One strategy encouraged verbal processing, while the other strategy encouraged visual processing. When training the participants in the verbal strategy, they had to identify and verbally label the most important characteristics of a model, repeating these labels out loud, while searching for them on a map. The visual strategy entailed identifying the most important characteristics on a model and then mentally visualising their appearances on a contour map.

The research shows that verbal strategy is linked to verbal ability. The results also suggest that this strategy could be used to improve performance on spatial tasks. According to Schofield & Kirby (1994) a verbal strategy would provide additional clues (hints) for retrieval of information and would also prevent overloading of the spatial working memory. Bethell-Fox and Shepard's (1988) research reveals that students who only use a verbal analytical approach to rotate objects would not be able to improve their mental rotation rate, even after extended practice; while students who use mental rotation, would be able to improve their time.

According to Lohman (1993) extroverts show a preference for verbal expression, where introverts use visualisation to express themselves.

2.4.6 Practice, experience and recognition

"It requires at least 100 hours of learning and practice to acquire any significant cognitive skill to a reasonable degree of proficiency" (Anderson, 1982: 369). Cox also states: "Personal experience triggers what you notice" (2002: 1191). Practice and experience in a specific field are therefore prerequisites for recognition. According to Wolfe, rote rehearsal is effective in learning a skill and it means " . . . repeating the information or the action over and over" (2001: 101). A skill should be practiced until it can be applied automatically, quickly and perfectly (without focusing on it).

Winefield and Peay (1980) explain that an object perceived by a person will only be stored in the short-term memory for approximately 20 seconds. Information can only be transferred to the long-term memory store if there is a dynamic attempt to learn, for example, by rehearsal, chunking of information into meaningful units or mnemonics. This information should be permanently recallable, but can become impossible to evoke without cues (patterns in a picture) for retrieval.

As previously discussed, according to Wolfe (2001), information will be meaningful, and can easily be stored, when it is linked to previously stored information. Barlow and Mollon (1982) agree with Cox (2002) that memories or experience will influence what you observe. According to them, one will recognise a structure if one has seen it in the past. An example is the following sketch (Refer to Figure 2.3). At first the scene of an island is observed and Napoleon between the trees probably not seen. However, if one has seen a picture of Napoleon before, it is possible that one will recognise him.

Galton states: “The chief art of strengthening visual, as well as every other form of memory, lies in multiplying associations . . . ” (1919: 75). Two or more logical associations will trigger the recalling of information vividly.

Figure 2.3: The silhouette of Napoleon between the two trees in the middle (drawn by researcher and adapted from Barlow & Mollow, 1982)

According to Reinhardt-Rutland (1996) surgical procedures can be difficult to understand when observing the images of the anatomical site of the operation on a television monitor. One reason could be that it is a two-dimensional image and depth perception depends mainly on pictorial information, which can be deceptive. Depth perception will most likely be sufficient if the structures are familiar, are well separated and have sharp borders.

Previous research according to Joliceur (1992), found that practice reduces the problems of recognition of objects in different orientations and that the specific attributes of an object play a role in the recognition process. Joliceur (1992) mentions an important fact: skills obtained by practice cannot be applied in general to other objects/situations.

Risucci (2002) states that surgeons outperformed the general population in visual spatial perception (VSP) tests. According to him VSP is one of the vital components of surgical competence. He suggests the possibility of developing spatial skills (pertaining to surgical anatomy) with training, independent of general VSP aptitude.

Perception can occur without recognition (Rock, 1983). Perceptual categorisation is not dependent on past experience, whereas recognition categorisation is. If observers are not familiar with objects, they will most probably not perceive pictures of these objects as three-dimensional. Spatial relationships among parts of an object are crucial for perceiving form. A picture of a three-dimensional object should display some contours or cues to be recognised as a three-dimensional structure instead of a two-dimensional structure. According to Rock (1983), if the characteristics of the form of an object are stored as a description, the description should be precise to enable subsequent recall of all the information required to recognise the object. If memory is based on pictorial information, it is easier to evoke all the details. Recognition occurs when the perception is successfully matched with previously stored information in memory.

According to Rock (1983), with regard to pictures of unfamiliar objects, form perception will take place, but recognition will often not come to mind. A familiar cue or feature in an unfamiliar picture will only be perceived with time and only after intentional searching for it. As previously mentioned, Winefield and Peay (1980) also emphasise the presence of cues for retrieval of information. Objects that are observed tilted or reversed from their routine orientation will look unfamiliar and therefore also frequently not be recognised. Rock (1983) emphasises that it is not only the unfamiliar position of an object that causes the exceptional change in shape, but rather the modification in the assignment of directions, that is, top, bottom and sides of the object that is critical. Small non-significant differences in pictures of objects will initially not be stored and remembered afterwards, but if those differences form part of the main pattern or outline of the object, they will be remembered. With unfamiliar complex objects only the overall patterns will initially be perceived and remembered. Rock (1983) stresses that only with experience will a subject be able to effortlessly discriminate between similar pictures of such objects, because more details will have been stored for recall. The form of an object plays an important role when an object is categorised and stored. Other characteristics of the object, for example, colour, play minor roles pertaining to categorisation. Failure of recognition is mainly caused by failure of form perception. A fragmented picture of an object may be recognised if a verbal clue (hint) about the category of the object is provided.

Ackerman (1988) posits that practicing consistent tasks will lead to skill acquisition, but he also mentions that complex tasks, as well as tasks containing no consistent components, will rely heavy on general cognitive abilities, even after intensive practice.

2.4.7 Knowledge of anatomy

Hegarty *et al.* stress the importance of knowledge of anatomy by stating: “In interpreting medical images, specialists have to infer the three-dimensional structure of the anatomy of a specific patient on the basis of the two-dimensional view given in the image and their knowledge of anatomy” (2007: 2). Hegarty *et al.* (2007), as well as Garg *et al.* (2001), state that the study of anatomy involves spatial concepts and that students with low spatial abilities find it difficult to understand the spatial relationships of anatomical structures in the human body. According to them a student’s spatial aptitude will therefore predict success in studying anatomy. As previously mentioned, Sewerin (1983) also emphasises the importance of radiographers having a sound knowledge about the spatial relationship between anatomical structures in order to interpret radiographic images.

Rochford (1985) investigated the relationship between underachievement in anatomy and spatial ability in second year medical students from 1980 to 1983. Spatial skills (“applied” or “learned” spatial abilities) were also investigated, because data for spatial abilities were not only obtained from a standard spatial aptitude test (“general” spatial ability) but also from the students’ assessments pertaining to anatomy. Rochford (1985: 14) classifies this as “geometrical spatial ability” and “anatomical spatial proficiency”. The results gained from spatial related tasks in the students’ practical, as well as in theoretical anatomical examinations, were used as “anatomical spatial ability” results. “Non-spatial anatomical” data were also obtained from non-spatial tasks in the theoretical assessments (Rochford, 1985: 14). The performances of the participants with low spatial abilities and the participants with high spatial abilities did not differ in the non-spatial anatomical tasks. However, Rochford (1985) reports that students, who failed the spatial aptitude test and/or struggled with the theoretical anatomical spatial ability tasks, achieved significantly lower results in practical anatomy assessments, than the students who did well in the spatial aptitude test. Rochford posits that “although most of these students acquire anatomical spatial skills over a period of 2-8 months, about 7-10% of students do not” (1985: 24). Rochford (1985) recommends that a program of alternative teaching methods be compiled to assist students with low spatial abilities. Students experiencing these problems can usually be identified by the middle of the year.

Sidhu, Tompa, Jang, Grober, Johnston, Reznick and Hamstra (2004) investigated the relationships between spatial ability, experience and training in vascular surgery. Vascular surgeons study angiographic images to plan and guide their surgical procedures. These images are radiographic images and are taken of human arteries, while a contrast medium is injected to highlight the arteries. In a way that is similar to radiologists and radiographers, they have to create mental three-dimensional images of two-dimensional visual images. Seven vascular surgeons and twenty medical or surgical students participated in the research done by Sidhu *et al.* (2004). The participants completed the spatial aptitude tests, Surface Development and Mental Rotations. They then had to interpret an angiographic image of an abdominal aortic aneurysm (AAA). The results of the film-viewing assessment showed a significant difference between the performances of the surgeons and the students, favouring the surgeons. The student participants were divided into two groups, a control group and an experimental group. The experimental group subsequently received a five minutes training session on AAA anatomy. All participants then interpreted another AAA image. Significant differences were found between the experimental and control groups. The results of the experimental group were comparable with those of the surgeons. No significant correlations were demonstrated between the performances of the students in the spatial aptitude tests and those of the surgeons.

There is thus evidence according to Sidhu *et al.* (2004) that some additional anatomical training could enhance the performance of students pertaining to the interpretation of angiographic two-dimensional images, independent of their spatial abilities.

2.4.8 Positive feedback, music and exercise

According to Sprenger (1999) giving positive feedback to students stimulates the brain to release neurotransmitters (the body's natural drugs), namely serotonin, dopamine and endorphin. These drugs have a positive reaction on the body's mechanisms, for example, the immune system. It makes the body feel good and will also aid in the transmission of information. Music and exercise has the same effect as positive feedback (Sprenger, 1999). Rauscher, Shaw, Levine and Ky (1994) agree with Sprenger on the important role of music in the functioning of the brain, by stating: "Music lessons, and even simply listening to music, can enhance spatial reasoning performance . . ." (1994: 1). A group of pre-school children, who received eight months of music lessons, performed significantly better on an object assembly task than a group of children who had not received any music training. The object assembly task required the child to create a mental image, independent of concrete models and subsequently position physical objects, to represent that image. The task entailed building a puzzle in order to create a "meaningful whole" (Rauscher *et al*., 1994:1).

During another study, Rauscher *et al*. (1994) investigated the influence of Mozart's Sonata (music) on spatial reasoning ability. The performances in spatial ability activities of the subjects who listened for ten minutes a day to Mozart's music, improved somewhat between day one and day two and significantly between day two and day three. The subjects who did not listen to the music, showed no immediate increase of performance in spatial ability activities between day one and day two, but their performance also improved significantly between day two and day three. The results show the important role of music, but also of practice. The significant increase in performance of the no-music group is ascribed to the effect of learning.

2.4.9 Suggested content and duration for direct training programs

Seymour and Beardslee (1990) and McKim (1980) propose activities, which might improve image-generation skills in students. According to them, students should be encouraged to search for geometric shapes and visual patterns in their surroundings. They suggest students bring pictures from magazines, which exemplify concepts (e.g., rotation and resemblance) to class. Activities, such as searching for missing pieces of a puzzle, the decoding (using mental rotation) of horizontally or vertically reflected sentences, the matching of various (reflected or rotated) figures (e.g., dice), guessing the hidden faces of cubes, the mental "folding" of a two-dimensional sheet into a three-dimensional configuration in order to identify the correct solid, as well as the "unfolding" thereof, are all suggested to develop image-generation skills.

Research done by Gittler and Glück (1998), shows that school courses in descriptive geometry significantly improve the spatial abilities of learners. The changes in performance induced by these courses were similar for male and female participants. A Three-Dimensional Cube Test (3DC) was used to measure the spatial aptitude of learners before and after the intervention. The test entails the mental rotation of each of six cubes when comparing it to a target cube in order to identify similarities. Single or triple rotations of these cubes were required to solve the problems.

As previously discussed, there is evidence, according to Sidhu *et al.* (2004) that anatomical training can enhance students' interpretation of angiographic two-dimensional images, regardless of their spatial abilities. Interpreting these images involves creating mental images of the patient's body in three dimensions. Provo *et al.* (2002) also mentions the possibility of acquiring spatial ability in the subject Anatomy.

Scholnick, Langbort and Day (1982) explain several activities that can develop spatial visualisation skills in children. According to them creating structures in the imagination relies heavily on the spatial visualisation skills of identifying shapes and their relationships towards one another. These activities therefore include recognising shapes and observing the structuring of objects using these shapes. Scholnick *et al.* (1982) suggest casting shadows of objects against a wall while rotating these objects in different positions. These activities develop the spatial visualisation skill of imagining how an object would look when rotated, as well as imagining a cross-section of an object. As discussed earlier, Arvold (1993) describes a similar type of activity that entails the placement of three-dimensional objects on an overhead projector. According to Scholnick *et al.* (1982) mental rotation skills are also exercised when children have to inspect different boxes placed in a row and compare them with drawn patterns, on separate sheets of paper, of the different sides of these boxes in order to match the correct box with the drawn patterns of a specific sheet.

Several authors (listed below) suggest methods to improve spatial visualisation skills. According to them, the identification of students with low spatial abilities, through aptitude tests, should be done first. Building with three-dimensional building blocks or parts of models and dismantling the models afterwards, make the two-dimensional pictures of three-dimensional objects more meaningful. People learn to mentally "see" hidden cubes that are not visible. Three-dimensional computerised programs (virtual reality) should be incorporated in training. Exercises in visual image generation, including manipulations of objects in space, should be done. Exercising visual memory entails observing a complex object thoroughly and memorising it. The eyes should be closed afterwards and the object visualised as clearly and in as much detail as possible. This is called the "Da Vinci" exercise. Free hand sketching/drawing of three-dimensional objects when thinking (from mental images) is important. According to these researchers, emphasis should be placed in the classroom on acquiring spatial visualisation skills. Doing an art course, building puzzles, as well as mathematics exercises, would also improve spatial visualisation skills (Suppiah, 2005; Scholnick *et al.*, 1982; Leaf, 2005; Sorby, 1999; Sorby & Baardmans, 1996; Medina, Gerson & Sorby, 1998; McGee, 1979b; Kali & Orion, 1996; McKim, 1980).

Sorby and Baardmans (1996) compiled an introductory course in engineering to aid entering students with poor mental visualisation abilities. The ten-week course included two hours of formal lectures and two hours of practical work each week. It is important to mention that the pre-test and post-test were performed three months apart. The course focused on learning through visual aids. The three stages of spatial visualisation development were discussed and the importance of visualisation skills in engineering was stressed. Students used cubes to construct buildings from plans and subsequently made isometric and orthographic drawings of these buildings.

They then folded flat sheets into three-dimensional objects. The students afterwards built objects using these cubes. These objects were then each rotated around one axis and the isometric view of the object was sketched. The object was subsequently rotated around two or more axes and the other isometric views were sketched. They also learned to draw cross-sections. The students used a computer exercise to build cones, cylinders and blocks. They subsequently cut planes in different directions through these objects and then studied the resulting cross-sections. The results were statistically significant. In general, the students' feedback on the course was positive. According to Sorby and Baardmans (1996), feedback indicated that 50% of students had no former experience with rotations around one axis and isometric drawing, while 75% had no past experience with rotation of objects around two or more axes and orthographic drawing. Sorby and Baardmans (1996) mention that some of the students did not regard the assessments seriously and consequently did not perform according to their abilities.

Research done by Baenninger and Newcombe (1989) to investigate firstly, the role of spatial experience in real life (indirect training) and secondly, the role of programmed spatial experience (direct training) in classroom, in improving spatial ability, discovered interesting facts. Everyday experience in spatial activities correlated weakly with performance in spatial tests. For males, only previous participation in masculine activities correlated significantly with spatial ability. Experimental research showed that spatial training improved spatial test scores significantly. Short-term training (a single administration or brief administrations over a course of less than three weeks and not part of the curriculum), showed the same results as long-term training (semester-long curriculum-based or not curriculum-based). Short-term training is usually specific training because it focuses on a single spatial measure, while long-term training is usually indirect training, pertaining to spatial ability. Long-term training does not directly train spatial ability, but has an inherent relationship to the acquiring of spatial ability, such as engineering course work. Medium-term training (three or four sessions over a course of more than three weeks, but less than a semester) is often general training because it focuses on a variety of spatial measures. Training in general spatial ability, however, does not improve performance as much as test-specific training. General training is not really training; it is more like a spatial experience. The best results in spatial ability testing were achieved, when medium-term training (three or four sessions) was combined with test-specific training. There were no significant gender-related differences in the improvement of spatial ability after training (Baenninger & Newcombe, 1989).

2.5 The role of the emotional state and environmental factors during assessments

According to Baddeley *et al.* " . . . it is the task-irrelevant, emotionally related thoughts of depressed and anxious subjects which affect their memory performance" (1995: 312). Baddeley *et al.* (1995) state that people who are anxious during assessments may put in extra effort to compensate for their decreased processing resources available and outperform other candidates, while depressed people may fail in their memory tasks. Eye tension will influence perception negatively (McKim, 1980). According to Sprenger (1999) brain function increases when a person is in a relaxed state. Deep breathing will also provide more oxygen to the brain that will, as a result, be able to better process information. McKim (1980) states that relaxed attention and motivation are both prerequisites for creating mental pictures. Deep muscle relaxation will promote vivid image generation. A quiet environment is necessary for complete relaxation. Information stored in the long-term memory will more easily be recalled in a relaxed state of mind. Chairs should provide back support. Each person should determine the location of his or her mental pictures, for example, the focal spot "inside" or "outside the head", where the pictures will be created (McKim, 1980).

McGee (1979b) stresses the influence of attitude on participants' performance. According to him, a significant widespread range of results pertaining to spatial orientation tests might have been caused by motivational factors. Motivation of a subject and practice will play a role in performing mental tasks successfully, for example, creating an image, adding adequate detail to an image and manipulating the image (Kosslyn, 1980).

2.6 The influence of gender

Research done by Garg *et al.* (1999), shows that men perform significantly better on a generic spatial ability test than women. According to McGee (1979b) neurological research provides evidence that spatial processing occurs in the right cerebral hemisphere and that the right hemisphere of the brain is more specialised in males than in females. McGee posits: " . . . a sex difference in spatial task performance favouring males is one of the most persistent and best-documented findings in the mental abilities literature . . .” (1979b: 4). He adds that according to previous research in various populations, genetic factors play a role in spatial aptitude. McGee (1979b) also states that when performing the Differential Aptitude Test (DAT) boys tend to achieve better results in spatial ability tasks compared to girls, who usually perform better in linguistic tasks. The research of Kali and Orion (1996), as discussed previously, which tested spatial visualisation abilities, as well as orientation abilities in high school learners, also notes that the male learners performed significantly better than the females. As previously mentioned, Russell-Gebbett (1985) reveals a small significant difference between the results of the girls and the boys in solving three-dimensional problems in biology, where the learners had to visualise the internal structures of an object in order to draw a cross-section.

Medina *et al.* (1998) used four standard aptitude tests to measure the spatial aptitude of engineering students at two universities. Significant gender differences favouring males were revealed at both of the universities. These differences varied, but occurred independently of the testing instrument used. Background questionnaires, which were completed by these students, indicated factors, which proved to be significant for the development of spatial skills. These factors comprise the following: gender, performance in mathematics, work experience, experience in drafting courses and playing with building toys as a child. Males mainly participate in these activities. McGee (1979b) agrees with Medina *et al.* (1998) that activities performed predominantly by males in the past, for example, mechanical drawing and model building, could play a role in developing spatial skills in males. Females should, consequently, gain more from training in spatial skills than men because of their disadvantage, but this suggestion is not strongly supported by literature.

McGee states: “Accumulative evidence shows that spatial abilities are as heritable as or more heritable than verbal ability”(1979b: 69). According to McGee (1979b: 71), a number of research studies claims the existence of an “X-linked gene” that is transmitted genetically and causes the difference in spatial test performance between males and females. It is suggested by these researchers that this gene, which is attached to the X chromosome, enhances spatial ability. McGee (1979a) states that although spatial abilities are influenced by genetic factors, recent research does not support the X-linked gene theory.

Reliable differences in performing spatial ability tasks between males and females occur only after puberty (McGee, 1979a; Vandenberg & Kuse, 1978). According to previous research, such differences could be due to the role of hormones or “greater sex-role expectations” (Vandenberg & Kuse, 1978: 602). McGee (1979b) states that according to the literature, body androgen level plays a role in spatial abilities. A high level of androgen in males is linked to low spatial performance, while a high level of androgen in females is linked to high spatial performance. Higher body androgen levels are usually associated with a more masculine appearance in males and females. McGee (1979b) suggests the ratio of oestrogen to androgen could be more indicative than the androgen level alone as an indicator of spatial performance. Another interesting fact is that there is a significant difference between the spatial ability of females when they are in the midluteal phase of the menstrual cycle, compared to when they are in the menstrual phase. According to Hausmann, Güntürkün, Slabbekoorn, Van Goozen and Cohen-Kettenis (2000) females perform significantly better at spatial tasks during the menstrual phase. They conclude that spatial ability is influenced by hormonal changes during the menstrual cycle.

Research done by Provo *et al.* (2002) reveals that after using a cross-section of a dog’s head to improve three-dimensional knowledge of anatomy, the difference in performance pertaining to spatial ability disappeared between males and females. Before the exercise, males performed significantly better than females in a spatial aptitude test. The test was, however, repeated and the results revealed similar performances between males and females. They also argue that these results might have been influenced by the fact that the males were in the minority, in comparison with the females. According to Baenninger and Newcombe (1989) the spatial ability of both males and females could improve with test-specific spatial training.

Self, Gopal and Golledge (1992) argue that most researchers have used undergraduates to represent the population when investigating gender differences pertaining to spatial abilities. According to them, these students do not truly represent the population. The inaccuracy of representation consequently led to conflicts in the literature about the ages where gender differences in spatial abilities arise and decrease. They suggest that researchers include subjects of all age groups from all social classes and all races.

They argue that social factors affect the development of the human being and therefore also the development of spatial abilities. Gender roles have changed in society, therefore future research results might be different than those of the past (Self *et al.,* 1992).

2.7 Spatial aptitude tests

2.7.1 General spatial aptitude tests

Lohman (1993) states that there are four different types of psychological test used to measure spatial aptitude, namely performance tests, paper-and-pencil tests, verbal tests and computer-based tests. Lohman defines spatial aptitude as " . . . the ability to generate, retain, retrieve, and transform well-structured visual images" (1993: 20). He argues that these different aspects of spatial aptitude could be measured independently by using a spatial ability test that is specifically designed to measure the relative aspect/s.

Olkun (2003) divides spatial ability into two components, namely spatial relations and spatial visualisation, where spatial visualisation is a more complicated process than spatial relations. As previously explained, McGee (1979a) defines spatial visualisation as the ability to mentally perceive a spatial two-dimensional or three-dimensional image and to manipulate that image. The image can be rotated as a whole, but certain parts of it can be manipulated independently. According to Albert and Golledge (1999), an aspect of spatial aptitude that is hardly ever measured by spatial aptitude tests, is the spatial relations aspect. According to Self *et al.* (1992) this involves mentally analysing patterns, shapes and relationships among the internal structures of an object. Olkun (2003) suggests that tests measuring spatial relations should include the following items: two-dimensional and three-dimensional mental rotation tasks, as well as cube comparison. Tests that could be used for measuring spatial relations abilities are: the Spatial Visualisation Test, the Primary Mental Abilities Test and the French Reference Kit (Olkun, 2003). According to Olkun (2003) spatial visualisation abilities could be measured by tests, which include items like the form board, two-dimensional to three-dimensional transformations, paper folding and surface development. These tests are, according to Olkun (2003), the Differential Aptitude Test, the French Reference Kit, the Minnesota Paper Form

Board, the Purdue Spatial Visualisation Test and the Spatial Visualisation Test. Lohman (1993) suggests the Paper Folding Test for measuring spatial visualisation.

Shepard and Metzler (1971) demonstrate the three-dimensional features of mental images by using mental rotation tasks. They designed a test with which they could determine the time it takes subjects to compare two three-dimensional objects, using the mental rotation task. Each object consists of three "columns" of cubes, of which each column points in a different direction. Each column consists of ten cubes attached to one another. These objects are demonstrated in different positions in a two-dimensional picture. Some of the similarly structured pairs of objects differ by an 80º rotation in the picture plane or an 80º rotation in depth, while the differently structured objects cannot be brought into congruence by any degree of rotation. Subjects have to mentally rotate one of these objects in the same position as the other one in order to identify if it is similar or not.

One-thousand-and-six-hundred pairs of objects were presented to the participants. These unfamiliar and meaningless objects were used to prevent the subjects from recognising certain features when comparing the objects, without performing the mental rotation task. The results show that the average time for rotating these objects is approximately 60º per second, which includes the time for planning the process, as well as the time for executing the process (Shepard & Metzler, 1971).

Sorby (1999) lists several tests that could be used to measure spatial aptitude:

- The Mental Cutting Test by CEEB, reported in Sorby (1999), which is a three-dimensional test that measures performance in recognising the correct cross-section of a structure.

- The Differential Aptitude Test: Space Relations by Bennett, Seashore and Wesman, reported in Sorby (1999), which is a three-dimensional test that measures performance in recognising the correct three-dimensional object from four pictures, which would be the result of folding a two-dimensional structure.

- The Purdue Spatial Visualisation Test: Rotations by Guay, reported in Bodner and Guay (1997), which is a three-dimensional test, which measures mental rotation abilities. The participant first has to observe a diagram of an object and, secondly, another diagram, where the same object was rotated into another position. Thirdly, the participant is shown a second object and then has to anticipate the appearance of the object when rotated similarly as the first one.

- The Mental Rotation Test (Vandenberg & Kuse, 1978), which is a three-dimensional paper-and-pencil test, that also measures mental rotation abilities. Participants have to observe an object and then identify the two rotated views of that specific object from four alternative views. Vandenberg and Kuse (1978) constructed this test, based on the computerised test of Shepard and Metzler (1971), which measures spatial visualisation as effectively as any other spatial aptitude tests.

- The Three-Dimensional Cube Test developed by Gittler, reported in Gittler and Glück (1998), which is a three-dimensional test that also measures mental rotation abilities. The participants have to observe a cube with different patterns on each side, where only three sides are visible to the observers. The participants then have to identify the rotated view of the specific cube from six alternative rotated views.

Medina *et al.* (1998) reveal a test (similar to the Differential Aptitude Test), which was the most significant forecaster of performance in an engineering graphics course, when compared to three other spatial visualisation instruments. The test consists of 45 questions divided into two sections. The first section entails a sheet of paper folded in half and again in half. The folded paper is then cut at a certain place. The students had to envisage how the paper would appear when unfolded. They subsequently had to select the correct answer from five alternative unfolded papers. The second section entails the opposite action. A sheet with fold lines was demonstrated to the students. They had to imagine folding the sheet, using the lines and subsequently select the correct end product from four alternative folded sheets.

Spatial aptitude tests according to Gardner (1983) may include the following tasks:

- Choose a form identical to the two-dimensional target form.

- Choose a form, which is a rotation of the target form, or identify when it is a different form. These two-dimensional alternative forms are rotated through 90° to 360° from the left to the right or the other way around (in the picture plane).

- Compare pairs of three-dimensional forms, where each pair has a target form, to determine if the alternative form is a rotation of the target form or a different form. These alternative forms are rotated through 80° in the picture plane or 80° backwards or forward (in depth).

According to Lohman (1986) the difference in the accuracy of mental rotation between participants with low spatial abilities and participants with high spatial abilities, favouring the latter group, increases significantly with increasing the amount of mental rotation required. High spatial ability includes superior precision in solving difficult rotation problems (Lohman, 1986). Lohman (1993) states that mental rotation tasks are superior to other tasks in measuring spatial ability, due to the fact that they put considerable strain on information storage and conversion processes. Lohman notes that " . . . it is not so much the ability to remember stimuli but the ability to remember systematically structured stimuli that distinguishes between subjects high and low in spatial ability" (1993: 15). Lohman (1993) states that the difference in performance of participants with low spatial abilities, compared to participants with high spatial abilities in spatial aptitude tests, is not because of their different information processing rates, but due to the difference in amounts of information that can be handled by the participants in the working memory.

Spatial tasks may be executed using spatial or non-spatial strategies. Different participants perform rotation tasks differently (Lohman, 1993). According to Just and Carpenter (1985) participants with low spatial abilities rotate an object through one axis and thereafter through the other axis (in two steps), while participants with high spatial abilities perform the task quickly, by rotating it in a single movement (one step) into the other position using a short path. Lohman (1993) also mentions that participants with different spatial abilities apply different strategies in solving spatial problems. These strategies can be anticipated before performing the tests. High spatial subjects tend to solve spatial problems similarly. They consequently use the same kind of strategy.

The research done by Bethell-Fox and Shepard (1988) shows that well-trained participants (and not participants with a high level of spatial ability) rotate an object as a whole, while untrained participants rotate an object section by section. Manipulating complicated patterns increased the students' mental rotation time. As earlier mentioned, the students who exercised mental rotation of these objects, created mental representations of the patterns with time and were subsequently able to mentally rotate the entire objects very quickly, despite the complexity of the information. However, a few students who used a verbal analytical approach to rotate the objects did not improve their rotation rate even after extended practice. Bethell-Fox and Shepard (1988) do not mention the spatial ability level of the well-trained participants.

Strong and Smith (2001) criticise previous investigations of spatial visualisation, because of the small number of participants, as well as the different type of measures used. Strong and Smith (2001) propose the design of a general computerised on-line spatial visualisation test that would be accepted by most of the role-players. They suggest that the test be combined with virtual reality, which would improve measuring the manipulation of three-dimensional objects in space. The computerised on-line test would also make it possible to gather ample data in future research. They suggest that textures and colour be added to these three-dimensional computerised models to improve spatial visualisation skills.

2.7.2 Applied spatial aptitude tests

Kali and Orion (1996) investigated the role of spatial abilities in high school learners studying structural geology. Structural geology involves the study of the layers of the earth in relation to the internal processes of the earth. It is important to be able to create mental pictures of cross-sections of these layers and other structures, as well as of their geometrical relationships, to be able to examine their features. They developed a Geological Spatial Aptitude Test (GeoSAT), which includes a cross-section subtest. The subjects had to draw cross-sections of three-dimensional block diagrams. These block diagrams consist of multiple complex layers, representing the layers of the earth. They had to think in three dimensions to visualise the inside of these blocks and to form mental pictures of the relations of these layers to one another. Interviews were conducted with six of the one-hundred-and-one grade ten learners who participated in the research. These six subjects were chosen because of specific types of problem that they had experienced with the tests. The purpose of the interviews was to obtain more insight into the reasoning of the subjects when performing these tests.

Kali and Orion (1996: 388) classified their results into two types of incorrect answers:

- A group of learners focused on the outside of the block diagrams when drawing the cross-section of the blocks. They were unable to envisage the internal structures of the blocks. Their drawings therefore only represented the external patterns that were visible on the blocks. They could therefore not mentally "penetrate" the exterior surface. They did not possess "visual penetration ability" (VPA).

- Another group of learners did significantly better than the before-mentioned group. They focused on the inside of the blocks when drawing the cross-sections. Their drawings therefore represented the internal patterns of the blocks that were not visible during the test, but unfortunately the relationships between the layers comprising the structure, were not perfectly represented. They therefore possessed VPA, but lacked other spatial abilities.

According to Kali and Orion (1996), only seven of the one-hundred-and-one learners, who completed the cross-section subtest, obtained 100% for their representations and were therefore excluded from the "incorrect" distribution. Forty-four learners produced 100% non-penetrative and incorrect representations and thirty-seven learners produced 100% penetrative, but incorrect representations.

According to Kali and Orion (1996) the learners with low VPA performed much better during the interviews at a multiple-choice questionnaire, where they had to identify the correct cross-section. The interior patterns of the different cross-sections were, at that stage, available to them. Kali and Orion (1996) suggest that multiple-choice questions should be used for future training, due to the possibility that this might improve the performance of learners with low VPA. As previously discussed, they also propose the utilising of solid models that the learners could take apart on their own. Kali and Orion (1996) regard these tasks as possible VPA exercises.

Albert and Golledge (1999) investigated the role of spatial abilities in the use of Geographical Information Systems (GIS) in order to design a GIS that would be user-friendly and appropriate to geography. Spatial abilities are required in the use of a GIS. These abilities enable students to mentally store and manipulate geographical images (e.g., information of maps).

Three paper-and-pencil tests were designed by Albert and Golledge (1999), with the goal to measure performance on spatial ability tasks pertaining to map procedures. The reason for using paper-and-pencil tests was to control the difference in experiences of participants in computer exercises. The tasks in the tests were not meant to be identical to the tasks performed when using a GIS, because in order to operate a GIS, not only spatial abilities are required, but also knowledge of the software and database.

These test results showed no statistically significant differences in performance between GIS-users and non GIS-users, as well as no statistically significant differences in performance between males and females, although males did perform somewhat better than females. Albert and Golledge (1999) suggest that using a larger sample size in future research would provide more reliable results pertaining to gender difference. The research reveals that it is possible to design paper-and-pencil tasks, which could measure the spatial abilities required for using a GIS. According to Albert and Golledge (1999) these paper-and-pencil tests could therefore be applied in future to assess the ability of students to mentally visualise and manipulate geographical images, which is vital in the use of a GIS.

2.7.4 Spatial aptitude tests in predicting success in specific occupations

Dakin and Armstrong (1989) suggest that more emphasis should be placed on objective selection methods (e.g., psychological tests), rather than subjective methods (e.g., unstructured interviews), as these tests are more valid predictors of job performance. According to them, interviewing could also be improved by reforming it into a structured interview. Structured interviews imply using identical preset questions with each candidate. The answers are usually linked to certain values.

McGee (1979a) includes a list of 84 occupations, compiled by the United States Employment Service (1957), which require spatial abilities. Spatial ability tests are used widely and effectively in selection procedures of technology related occupations as predictors of success (Ghiselli, 1973; Holliday, 1943; Strong & Smith, 2001). McGee (1979a) posits an important fact, namely that the criteria or standards for success will not be the same for all occupations. Ghiselli (1973) suggests the use of a combination of selected aptitude tests to increase the validity of the measurement.

According to Strong and Smith (2001) there are numerous factors, according to the literature, that play a role in spatial visualisation ability, namely age, gender, individual differences and previously gained experience. They add that according to the literature, adequate training (correct duration and content) might counteract the deficiencies caused by these mentioned factors and consequently enhance performance in spatial visualisation. These activities must be carefully designed so that they do not favour male participants only.

Keehner *et al.* (2004) state that previous research that demonstrated a correlation between spatial aptitude and surgical skills, included participants with minimum experience. According to them, psychological literature argues that the importance of spatial ability and other cognitive factors will fade with increased experience and the acquirement of skills. As previously mentioned, Keehner *et al.* (2004) investigated the relationships between spatial abilities, surgical experience and surgical performance in medical students and experienced surgeons. Spatial abilities were determined by using the Paper Folding Test. The subjects gave input on their own experience pertaining to laparoscopic procedures, by completing a questionnaire that included a list of these procedures. Two clinical lecturers observed and individually assessed the surgical performance of each of the subjects during videoscopic procedures. They rated their performance using a questionnaire especially designed for the research. When comparing the two groups, the results showed significant differences in surgical performance, but not in spatial aptitude performance. The results of the spatial ability test of the students correlated significantly with their performance in the surgical procedures. The spatial ability test results of the surgeons demonstrated a wide range of spatial abilities. They performed at a similar level or worse than the students, with no correlation between spatial ability and operative performance. The results however showed a significant correlation between experience and surgical skills in the group of surgeons only. The fact that the surgeons' mean spatial ability results were lower than public standards might have been caused by age differences. Keehner *et al.* therefore posit that " . . . even experienced surgeons with low spatial ability could achieve acceptable skill rankings" (2004: 74). This shows the reduced role of spatial ability with experience.

Keehner *et al.* (2004) therefore question the use of spatial aptitude tests to determine the spatial abilities of medical students to predict success in surgery. They also question whether the lower spatial ability group of students could be assisted with dedicated training to increase their progress.

According to Ackerman (1988) the role of general cognitive abilities will decrease with experience. The reduced role of cognitive abilities will however only be possible for consistent tasks, where the term “consistent” means that the demands for the processing of information are the same. As previously discussed, practising consistent tasks will lead to skill acquisition. Ackerman (1988) also mentions that complex tasks, as well as tasks containing no consistent components, will rely heavily on general cognitive abilities, even after intensive practice. Each occurrence of inconsistent information will involve cognitive processing and a decrease in the power of learned associations. As a result, a skilled automatic response will not occur.

According to Murdoch, Bainbridge, Fisher and Webster (1994) the American Dental Association instituted the Dental Aptitude Test (DAT) as part of the selection process for dental students. Murdoch *et al.* (1994) state there is no similar aptitude test for the selection of microsurgery students. They investigated the relationships between spatial ability, manual dexterity and microsurgical performance in 37 students of a microsurgery course. The dexterity test involved the manual manoeuvring of a loop from one end of a curved wire to the other end, without touching the wire. Both were connected to an electrical circuit and light bulb, which indicated when a mistake was made. Due to the complicated curves of the wire, it was necessary to use three-dimensional visual cues to perform the test. A spatial relations test was performed, which determined the ability to create a spatial mental three-dimensional image from a two-dimensional diagram. The microsurgical competence experiment included in-depth training of the participants for four days in very complicated micro-surgical techniques, for example, anastomosis (joining) of blood vessels in rats. Their performance in executing these tasks was afterwards assessed by different clinical tutors. According to Murdoch *et al.* (1994) the microsurgical performance of the participants correlated significantly to their manual dexterity, as well as with their spatial abilities. They conclude that the resistance to apply this type of test in the past for the selection of surgery students was due to its failure to predict success, but they suggest that it should be reconsidered.

According to Hegarty *et al.* (2007) the importance of spatial abilities in medicine raises another question, namely: Should spatial aptitude tests be used for the selection of medical students? Dentists are already using these tests as part of their selection procedure for students. Hegarty *et al.* maintain that surgeons " . . . believe in practice, not talent . . ." (2007: 4) and to them the personality of the candidate is more important. They feel strongly that conscientious and hard working candidates should be selected. As previously discussed, according to their research, all candidates (with a high spatial ability, as well as with a low spatial ability) will, after in-depth practice, be able to perform a task with spatial attributes. Hegarty *et al.* (2007) argue that extensive practice is more important than spatial aptitude in predicting future performance.

Graham and Deary (1991) investigated the role of psychometric tests as part of the selection procedure for student surgeons in predicting the competence of future surgeons. According to them, previous research reveals that spatial ability correlates significantly with medical skills (independent of other cognitive knowledge). Graham and Deary (1991) conclude that medical skills, and more specifically surgical skills, are multi-factorial and that the measures for surgical competence in previous research were subjective. Following Ghiselli (1973), they posit that a single aptitude test is therefore not enough to predict the competence of surgeons in future.

How accurately can these spatial tests predict the performance of student radiographers in film-viewing assessments? Jones (1977) finds that the results of spatial aptitude tests correlated well with the overall performance of radiographers. Jones (1977) suggests two types of testing, namely the Blocks Test and the Dimensions Test. When performing the Blocks Test, the participant has to count the piles of blocks in a picture, focusing especially on the hidden blocks. All the blocks are of the same shape and size. During the Dimensions Test, the participant has to identify which of the four pictures in a row, is the inverse of the fifth picture. The research results reveal that a subject, who gains high marks with the Blocks Test, has the potential to become an excellent radiographer, especially with regard to speed and accuracy. According to Mackenzie's (1992) research, many radiographers in

South Africa recommend the inclusion of spatial tests in the selection process of radiography students.

In contrast, Dean and Morris posit that there is a " . . . startling difference in item type between imagery questionnaires and spatial tests" (2003: 16). They further explain the differences between these two assessments. According to them, image-generation (visualisation) questionnaires force the subjects to create and manipulate colourful mental pictures of real life scenes or objects (previously seen), while spatial tests require the manipulation of abstract geometrical shapes (usually not previously seen). These geometrical shapes are usually black and white line drawings. Another major difference is the origin of the stimuli. Representations of real life items are created from information stored in the long-term memory, while these geometrical shapes are unfamiliar to the participants. They are therefore perceived and temporarily stored or manipulated in the short-term memory. Kirby and Kosslyn (1992) agree that low-level visual processes depend on stimulus input, while high-level visual processes (e.g., the recognition of objects), involve the retrieval of stored information.

Radiographic images used in film-viewing assessments are shades of black, not very colourful, but are familiar to most of the students. When radiography students perform these assessments, they have to create and manipulate three-dimensional mental images in order to solve problems of technique. It could therefore be assumed that the information is retrieved from their long-term memory. The researcher would therefore classify radiographic images as real life objects, and the assessment of these images as high-level visual processes. General spatial aptitude tests, on the other hand, would involve low-level visual processes.

Lohman (1993) posits that measuring spatial aptitude involves writing a test and may also include drawings, but applying spatial skills in real life situations, is completely different.

2.8 Conclusion

This chapter has explained the importance of creating mental three-dimensional images in order to interpret complex two-dimensional radiographic images. It has demonstrated the diversity in researchers' views on mental image-generation processes, on the probability of developing spatial abilities, on the role of practice (and experience) in acquiring spatial skills, as well as on the application of spatial aptitude tests in selection processes. Various techniques for developing spatial three-dimensional thinking were suggested.

In the next chapter, the research design, which includes the methodology and data collection methods, will be explained. Data analysis procedures will also be described.

CHAPTER THREE
THE RESEARCH DESIGN

3.1 The research design

Quantitative designs can be divided into experimental, quasi-experimental and non-experimental designs (Welman & Kruger, 2000). In this research, the experimental research strategy was mainly applied. True experimental designs include randomisation of subjects into groups, an independent variable (the intervention), a control group and an intervention group (Berg & Latin, 2004; Brown & Dowling, 2001). A curricular intervention, which was intended to primarily improve three-dimensional skills, pertaining to radiographic images, was developed and applied. The impact of the curricular intervention on students' applied three-dimensional skills was evaluated. The experimental design allows the researcher to observe the effects on the dependent variable (the three-dimensional skills of the students) that were caused by the independent variable (the intervention) (Refer to Figure 3.1).

The pre- and post-test design, also known as "repeated-measures" design, can be used when data is required for group formation (Berg & Latin, 2004; Barker, Pistrang & Elliot, 2001). In this research, due to the small sample group, research groups were formed using the data of the pre-tests. These pre-tests (film-viewing assessment and three-dimensional test before intervention) and post-tests (final film-viewing assessment and three-dimensional test after intervention) were also vital for determining the overall impact of the intervention on the whole class group (Refer to Figure 3.1).

With quasi–experimental designs no randomisation is used. The term "quasi" means that the design approximates the true-experimental design (Berg & Latin, 2004).
According to Berg and Latin (2004), the experimental designs also include the pre-experimental design. This type of design is only called an experimental design because an independent variable is manipulated. The pre-experimental design is different from the quasi–experimental design; it does not include a control group, or the control group and experimental groups are not equivalent. Similar as with the quasi–experimental design, no randomisation is used. Berg and Latin (2004) state that due to the weak degree of control this technique should not be used.

DIAGRAM: RESEARCH DESIGN (2005 AND 2006 CLASSES)

FILM-VIEWING ASSESSMENT 1

Whole class: baseline assessment
(*n* = 15 in 2005 and *n* = 23 in 2006)

↓

THREE-DIMENSIONAL TEST 1

Whole class: baseline assessment, but also to determine correlation with film-viewing assessment 1

NO INTERVENTION

Control group A
(*n* = 8 in 2005 and *n* = 12 in 2006)

INTERVENTION

Intervention group B
(*n* = 7 in 2005 and *n* = 11 in 2006)

FILM-VIEWING ASSESSMENT 2

Whole class: to assess impact of intervention on intervention group

INTERVENTION

Control group A: ethical reasons

NO INTERVENTION

Intervention group B

FILM-VIEWING ASSESSMENT 3

Whole class: to assess impact of intervention on whole group

↓

THREE-DIMENSIONAL TEST 2

Whole class: to assess impact of intervention on whole group, but also to determine correlation with film-viewing assessment 3

Figure 3.1: Diagram of research design

3.1.1 Randomisation

In this research, random assignment (chance assignment) of participants to groups was done for equivalence of groups. According to Barker *et al.* (2001), one of the advantages of randomised designs is that they eliminate threats like selection bias. In order to prevent biased representation due to a small sample size, subjects can also be stratified (reorganised), according to the subjects' performances in the pre-tests and subsequently randomly assigned to the various groups (Brown & Dowling, 2001; Berg & Latin, 2004; Barker *et al.*, 2001). In this research, groups of specific percentage categories were formed before randomisation using the results of the pre-test (first film-viewing assessment). Individuals from these groups were then randomly assigned to the intervention and control groups. Both the control and intervention groups therefore consisted of subjects at various levels of performance. The means of the control and intervention groups were the same using the pre-test results.

Matching subjects may be necessary if there is a considerable correlation between a nuisance variable and the dependant variable, for example, intelligence and the film-viewing assessment marks. More intelligent subjects will almost certainly perform better, than less intelligent subjects irrespective of the influence of the intervention (Welman & Kruger, 2000). In this research, the groups could not be matched precisely according to their performances (forming pairs of similar performances and then randomly assigned each one to a group), because it was difficult to find two individuals, at each percentage level, who were equal.

3.1.2 Control group

In all experimental designs an independent variable is manipulated, while all other variables are kept constant. The measure of the effect of the intervention is known as the dependent or outcome variable (Berg & Latin, 2004; Benwell, 1990; Barker *et al.*, 2001). The control group is not exposed to the intervention but manages the irrelevant variables (nuisance variables) (Welman & Kruger, 2000). Two trials were run over a two-year period (trial one in 2005 and trial two in 2006). Each trial used a control group and an intervention group. In this research a wait-listed control group was used, because the group was, for ethical reasons, only excluded from the initial experiment. After the second assessment they received the same intervention as the original intervention group (Refer to Figure 3.1).

Table 3.1: Research program in 2005

Research activities	Date
First film-viewing assessment	6 September
First three-dimensional test	8 September
Intervention with intervention group	**14 September – 4 October**
Second film-viewing assessment (after intervention)	6 October
Intervention with control group	**19 October – 1 November**
Final film-viewing assessment	3 November
Final three-dimensional test	10 November

Table 3.2 Research program in 2006

Research activities	Date
First three-dimensional test	24 August
First film-viewing assessment	29 August
Intervention with intervention group	**4 September – 4 October**
Second film-viewing assessment (after intervention)	9 October
Intervention with control group	**11 October – 1 November**
Final film-viewing assessment	6 November
Final three-dimensional test	9 November

3.2 Correlation design

In this research the correlation design was used to determine any relationships between radiography students' performance in three-dimensional tests and their performance in film-viewing assessments.

Correlation designs are non-experimental designs, which are used to depict relationships between two or more variables. A positive correlation shows that an increase in one variable corresponds to an increase in the other variable. Two variables that are contrariwise related would produce a negative correlation (Welman & Kruger, 2000; Barker *et al.*, 2001). With correlation designs cause-and-effect relationships, as with experimental designs (variable A, the intervention, causes an effect in variable B), are not examined. Some variables may have a cause-and-effect relationship but a Pearson *r* does not verify it. Other factors or variables could have caused the specific data. If strong relationships occur, experimental research should be done to determine possible causes (by eliminating other variables) (Berg & Latin, 2004). According to Barker *et al.* (2001), a number of reasons for the specific relationships are possible. Pertaining to this research, if variable A presents the general cognitive three-dimensional abilities of the subject and variable B the applied three-dimensional skills of the subject in film-viewing assessments, changes in A could be responsible for the changes in B or visa versa. A third variable C (e.g., clinical experience) could even have caused the changes in both the above-mentioned variables.

The strength of correlation between two variables ranges between perfect positive (+ 1), through zero (0), to perfect negative (– 1). The calculation of a coefficient of correlation is called Spearman's *r*. The Pearson's coefficient of correlation *r* is also commonly used to measure how well two variables are related to each other (Brown & Dowling, 2001; Berg & Latin, 2004). The Spearman (rank order) is a good screening test for the Pearson (product-moment) test. The Pearson *r* calculates raw scores and is therefore a more accurate test, whereas the Spearman *r* calculates converted scores (ranks) (Stein & Cutler, 2000). The Pearson *r* is a parametric test, which should be applied to interval or ratio scale data, whereas the Spearman *r* is a nonparametric test, which can be applied to ordinal scale data (converted scores) (Stein & Cutler, 2000). The two lists of data should however be normally distributed (Brown & Dowling, 2001). During this research all the lists of data were tested for normal distribution and the results were positive. The *r* of 0.969 is almost a perfectly positive relationship, while a negative *r*-value, for example, -0.8 does not mean a weak relationship but rather the direction of the relationship (Berg & Latin, 2004). A significant *r*-value will only confirm the existence of a relationship, but it does indicate the strength of the relationship (Berg & Latin, 2004). A subjective way of evaluating the strength of the correlation is to use the size of *r*, for both positive and negative correlations, for example, 0.25 or less than 0.25 is weak, 0.26 to 0.50 is moderate, 0.51 to 0.75 is fair and above 0.75 is high (Berg & Latin, 2004). In this research the *r*-value was used to determine the strength of the correlation.

3.3 The sample group

The target population in this research were the second year diagnostic radiography students of tertiary institutions in South Africa. The sample is the part of the target population who actively took part in the research, which in this research was the second year diagnostic students, of one specific training institution, at one specific satellite campus. They were not representatives of the target population because the individuals only represented the one institution. The sample group (*n*) consisted of fifteen second year diagnostic radiography students in 2005 and twenty-three second year diagnostic radiography students of the same institution in 2006. The sample size used in this research was for practical reasons and time constraints, small. The research was repeated in 2006. The total duration of the research was between two and two-and-a-half months per year. Groups consisting of four to five students were given a practical session of one hour per week for four weeks.

3.4 Data collection before interventions

- **First three-dimensional test** (addressed sub-problem one).

A three-dimensional test: "Academic Aptitude Test (University) (AAT) nr. nine: Spatial Perception (three-dimensional)" (Owen & de Beer, 1997) was completed by the students. This basic test would indicate the general intelligence of the students pertaining to three-dimensional thinking. The content of test nine Spatial Perception (three-dimensional) of the battery of tests (Refer to figure 3.2) is similar to the Three-dimensional Cube Test developed by Gittler, reported in Gittler and Glück (1998), which is a three-dimensional test that measures mental rotation abilities. The test used in this research involves the following activities: Each question consists of six blocks. The subjects have to inspect a cube with different designs on each side, where only three sides are visible to the observers. The subjects then have to identify the rotated view of the specific cube from five alternative rotated views, by rotating the blocks in their minds. Three sides of each block have designs and the other three are blank (Owen & de Beer, 1997).

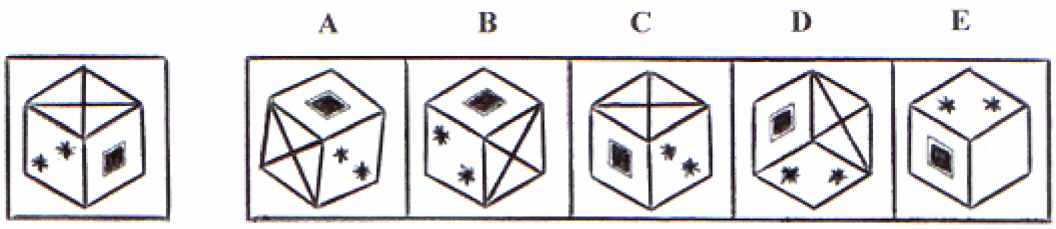

Figure 3.2: Example from the Academic Aptitude Test (University) (AAT) nr. nine: Spatial Perception (three-dimensional) (Adapted from Owen & de Beer, 1997)

As previously discussed, the Dimension Test, which entails similar activities as mentioned above, can predict the performance of future radiographers (Mackenzie, 1992; Jones, 1977). A similar test, the Mental Rotation Test, has been shown to be a reliable measure of spatial visualisation (Vandenberg & Kuse, 1978).

Lohman (1993) states that mental rotation tasks are much better than other tasks in measuring spatial ability. The important role of image-generation skills in spatial manipulations (e.g., the rotation of depicted objects) has been meticulously explained in Chapter Two.

- **First film-viewing assessment** (addressed sub-problems one and two).

  A film-viewing assessment (comprising of four film-viewing "stations") as a baseline test was done after completion of the section of the syllabus, including the specialised projections. Two of the four "stations" focused on the evaluation of technique/anatomy of second year specialised radiographic projections.

  The marks that the students achieved in the fore-mentioned tests (three-dimensional test and the average mark of these two film-viewing stations) were compared, to determine if there was any correlation between their performances in the different tests. The average mark of these two film-viewing stations was used as the baseline marks.

3.5 Intervention with intervention group (addressed sub-problem two).

- The group of students were then randomly divided into two groups, namely the control group and the intervention group. In-depth training sessions with the intervention group of students (group work) were executed, following on completion of the above tests. The students executed certain modified radiographic projections on parts of a human skeleton. The position, shape and rotation of the anatomical structures were compared with the relative radiographic images. Problem situations were created for them to solve in order to stimulate their analytical and critical abilities (difficult projections had to be executed and complex images interpreted).

- For each radiographic projection, the students had to draw the relation of the X-ray beam to the specific anatomical structures, as well as the relation of these structures to the film. The related images of these projections were also drawn.

- The researcher assisted them by verbally providing guidelines on creating mental images of the movement of anatomical structures, as well as clues on recognising these structures on radiographic images.

- In each of the following sessions, films containing images of the previous session were shown by the researcher to each student separately. The student then had to recognise the specific projection (e.g., left anterior oblique of the chest) and discuss the relation of the X-ray beam to the anatomical structures, as well as to the cassette. The student had to point out directions (e.g., anterior and posterior on the image of a pelvic inlet projection), suggest ways to separate overlying structures (e.g., on the image of an occipito-frontal projection of the skull), recognise foreshortening (e.g., the raised iliac bone on the image of an oblique pelvis projection) and suggest ways to rectify it. The student subsequently had to demonstrate each of the projections, using the skeleton, while comparing it to the specific image. If the projection was done incorrectly, the researcher would inform the student and gave him/her time to correct it.

3.5.1 Motivation for specific program

As previously discussed, according to Gardner (1983) spatial intelligence consists of different capacities: the ability to recognise an object or form, the ability to mentally modify an object or to recognise the modified object, the ability to recall and control mental images and the ability to sketch a picture containing spatial information. Spatial visualisation consists of two main components, namely mental rotation (mental rotation of the whole object in space) and mental modification (mental manoeuvring of a part of the object in space) (McGee, 1979a).

Spatial skills can be developed by practising with real life models, drawing these models from different perspectives, and by guided mental image-generation exercises. Sketching/drawing inspires creativity and develops image-generation skills (McKim, 1980; Petroski, 2000; Du Toit, 1995; Olkun, 2003; Sorby, 1999). Models of cross-sections of objects are especially valuable in teaching students structural internal relationships. Spatial skills are also related to creating a mental image of a cross-section (Cohen *et al.*, 2003; Sorby, 1999). Arvold (1993) posits that practice in mental transformation from the second to the third dimension can develop spatial visualisation skills.

Clinical lecturers do not generally make use of sketching during the students' practical sessions when exercising radiographic projections and comparing the projections to the related images. Students themselves mimic patients or they use a pixie model, which resembles a human body, for mimicking patients; related radiographic images (films) are usually used during these demonstrations.

A complete human skeleton is often used during the practical sessions for demonstrating anatomical structures, but it is not flexible enough and too fragile, to be used for demonstrating projections.

The radiographer has to be able to mentally visualise the separation of anatomical structures, which are superimposed on one another, by angling the X-ray beam or by rotating the patient (Carlton & Adler, 1992). According to Squire and Novelline (1988) interpretation of a radiographic image of the rib cage is extremely difficult due to all the overlying structures. According to the researcher, the students also find the postero-anterior projections of the skull and facial bones, as well as axial projections, very difficult to interpret.

Students need more time to recognise objects when foreshortened (Kosslyn, 1994; Tarr & Pinker, 1989; Rock, 1983). According to Tarr and Pinker (1989), participants use mental rotation to recognise unfamiliar shapes. They also note that with increased training, participants will recognise these objects independently of the mental rotation task.

Cox (2002) stresses the importance of teacher supervision when students practice their skills. Perceptual gaps can only be identified and solved if students give verbal feedback to their clinical teacher on what they have observed (Cox, 2002). Students prefer small group tutorials to formal classes for learning radiographic techniques (Whyke, 1985). The best results in spatial ability training are achieved when three to four sessions over a course of approximately four weeks are combined with test-specific training (Baenninger & Newcombe, 1989). According to Sorby and Baardmans (1996), the ideal situation would be if the sessions included two hours of formal lectures and two hours of practical work each week.

At the institution where this research was done, there are no specialised clinical instructor posts and the lecturers responsible for the formal training, are consequently involved in the clinical teaching and assessment of the students in the hospitals. The practical sessions (intervention) of this research, which were conducted over four weeks (one session of one hour per week), entailed mainly group work under supervision of the clinical lecturer (researcher), the manipulation of a concrete object (parts of a human skeleton), the drawing of cross-sections or two-dimensional pictures of the three-dimensional object, comparing the position of the object with the radiographic two-dimensional image and visa versa. These sessions also included mental image-generation exercises (mental rotation tasks, the mental separation of overlying structures and the recognition/correction of foreshortened structures) when interpreting complex radiographic projections. It entailed discussions of the technique and related images.

Table 3.3: Radiographic projections used in practical sessions and mental skills that had to be obtained by students

Radiographic projections	**Mental skills**
The left anterior oblique projection of the thorax	The skill to mentally “see” the changes in position and shape of anatomical structures in relation to the cassette and X-ray beam when rotating the thorax through 45°. The skill to mentally “see” the direction of the X-ray beam in relation to the anatomical structure (e.g., scapula) and cassette when projecting a structure “end on” or foreshortened (tube parallel to long axis of structure) or when projecting a structure to demonstrate it’s full width or length (tube perpendicular to long axis of structure). The aspect of the body in contact with the cassette had to be “seen”.
The lordotic projection of the thorax	The skill to mentally “see” the direction of the X-ray beam in relation to the anatomical structures and cassette with a 30°↑ (infero-superior) angulation of the X-ray tube during a thorax or any other infero-superior projection. Separation of the structures by the angulation of the tube from an AP aspect or by adjustment of the thorax, as well as the position of the images on the film, had to be “seen”.
The supine modified projection of the left scapula (with angulation of the tube)	The skill to mentally “see” the direction of the X-ray beam in relation to the anatomical structure and cassette when projecting the structure “end on” or foreshortened (tube parallel to long axis of structure) or when projecting the structure to demonstrate it’s full width or length (tube perpendicular to long axis of structure).

The left posterior oblique projection of the lumbar spine	The skill to mentally "see" the changes in position and shape of anatomical structures in relation to the cassette and X-ray beam when rotating the lumbar spine through 45°. The aspect of the body in contact with the cassette had to be "seen".
The Judet projection of the pelvis (left posterior oblique projection of the pelvis)	The skill to mentally "see" the changes in position and shape of anatomical structures in relation to the cassette and X-ray beam when rotating the pelvis through 15 - 45°. The skill to mentally "see" the direction of the X-ray beam in relation to the anatomical structure (e.g., iliac bone) and cassette when projecting a structure "end on" or foreshortened (tube parallel to long axis of structure) or when projecting a structure to demonstrate it's full width or length (tube perpendicular to long axis of structure). The aspect of the body in contact with the cassette had to be "seen".
The pelvic inlet projection	The skill to mentally "see" the direction of the X-ray beam in relation to the anatomical structures and cassette with a supero-inferior 30°↓ angulation of the X-ray tube during a pelvic or any other supero-inferior projection.
The postero-anterior 20°↓ projection of the skull	The skill to mentally "see" the direction of the X-ray tube in relation to the anatomical structures and cassette during a postero-anterior 20°↓ projection of the skull or similar projection of the skull. Separation of the structures by the angulation of the tube from a PA aspect or by adjustment of the skull, as well as the position of the images on the film, had to be "seen".
The lateral-oblique of the right mandible – with horizontal beam	The skill to mentally "see" the direction of the X-ray tube in relation to the anatomical structures and cassette during the lateral-oblique projection of the right mandible or similar projections. Separation of the structures by the angulation of the tube from a lateral aspect or by adjustment of the mandible, as well as the position of the images on the film, had to be "seen".

Figure 3.3: Participants of the 2006 trial group busy drawing a radiographic image during a practical session (photograph taken by researcher)

3.5.2 Example of a practical session (session one)

<u>Projection one: The left anterior oblique projection of the thorax</u>

The students had to:

- Perform the left anterior oblique projection of the thorax on the skeleton;
- Observe the rotation and position of the anatomical structures in relation to the cassette;
- Observe the direction of the X-ray beam in relation to the position of the anatomical structures;
- Observe the position and shape of the shadows of the structures on the cassette;
- Expose and develop the film;
- Observe the position of the anatomical structures on the image;
- Compare the position of the anatomical structures on the image with the position of the structures of the skeleton in relation to the cassette and the direction of the X-ray tube;
- Make a rough drawing of the transverse appearance of the thorax of the skeleton (from the feet) in relation to the cassette and X-ray tube (include spine, sternum, ribs and scapulae); and

- Make a rough drawing of the radiographic image of this projection (include spine, sternum, ribs and scapulae).
  (Refer to Figures 3.4 and 3.5)

<u>Projection two: The lordotic projection of the thorax</u>

The students had to:

- Perform the lordotic projection of the thorax on the skeleton;
- Observe the position of the anatomical structures in relation to the cassette;
- Observe the direction of the x-ray beam in relation to the position of the anatomical structures;
- Observe the position and shape of the shadows of the structures on the cassette;
- Expose and develop the film;
- Observe the position of the anatomical structures on the image;
- Compare the position of the anatomical structures on the image with the position of the structures of the skeleton in relation to the cassette and the direction of the x-ray tube;
- Make a rough drawing of the lateral appearance of the thorax of the skeleton (from the side) in relation to the cassette and the x-ray beam (include ribs, spine, sternum and specific clavicle); and
- Make a rough drawing of the radiographic image of this projection (include ribs, spine and clavicles).
  (Refer to Figures 3.6 and 3.7).

Bear in mind that this was the initial practical session. As previously mentioned, with each of the following practical sessions, a brief revision of the projections of the previous session was done. The radiographic images were discussed. The student had to recognise each projection and discuss the orientation of the X-ray beam to the anatomical structures, as well as to the cassette. The student had to point out directions, suggest methods to separate overlying structures, recognise foreshortening and suggest ways to set it right. The student had to show the positioning of each of the previous projections, using the parts of the skeleton, while comparing it to the specific image.

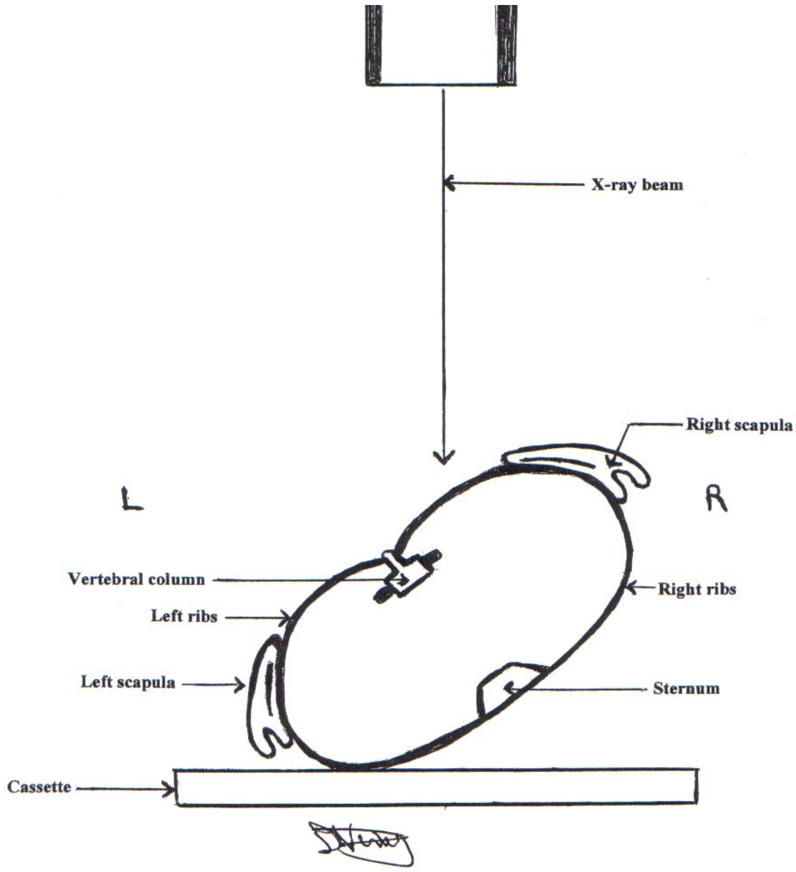

Figure 3.4: Cross-section of the left anterior oblique projection of the thorax seen from the feet (sketch drawn by researcher)

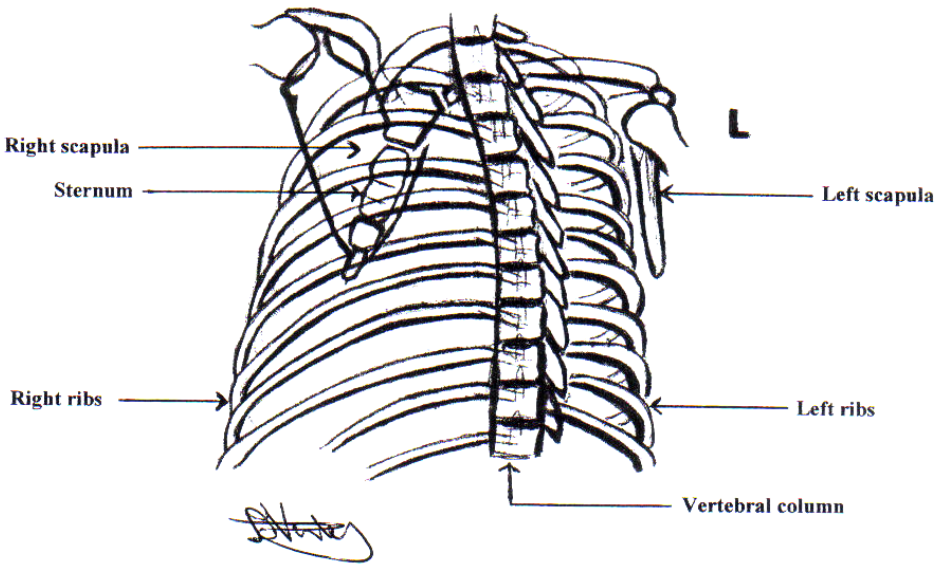

Figure 3.5: Radiographic image of the left anterior oblique projection of the thorax (sketch drawn by researcher)

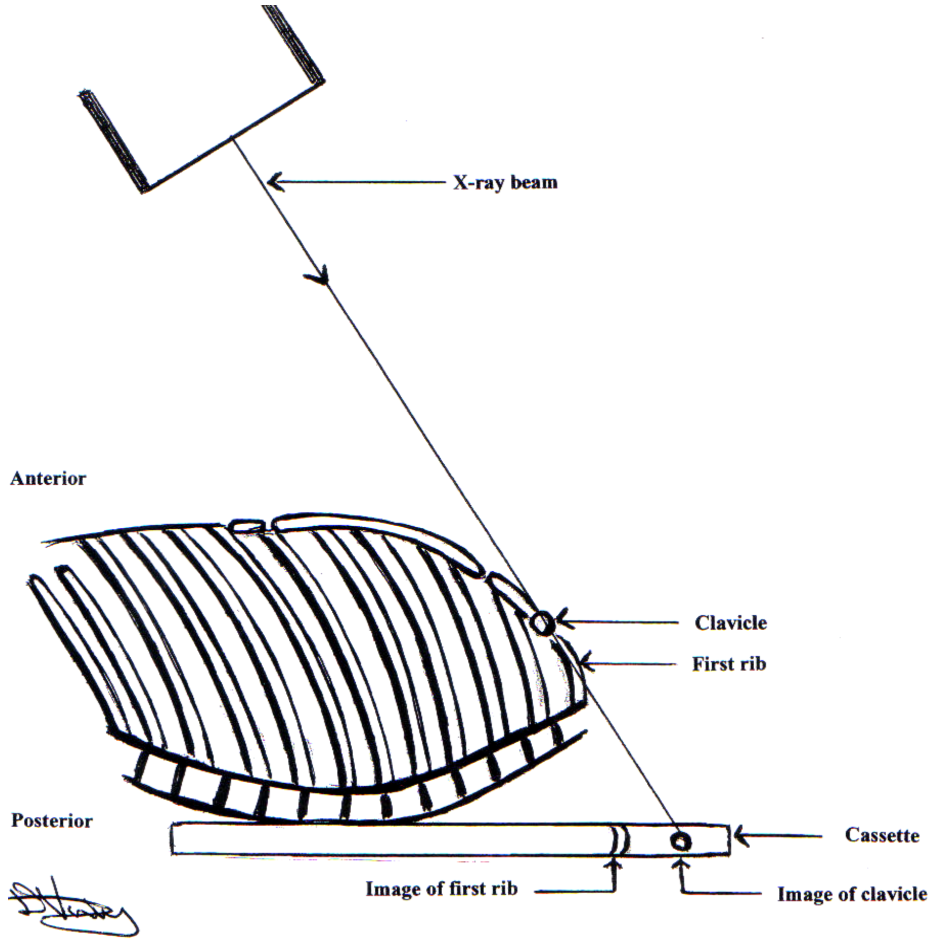

Figure 3.6: Lateral aspect of the lordotic projection of the thorax (sketch drawn by researcher)

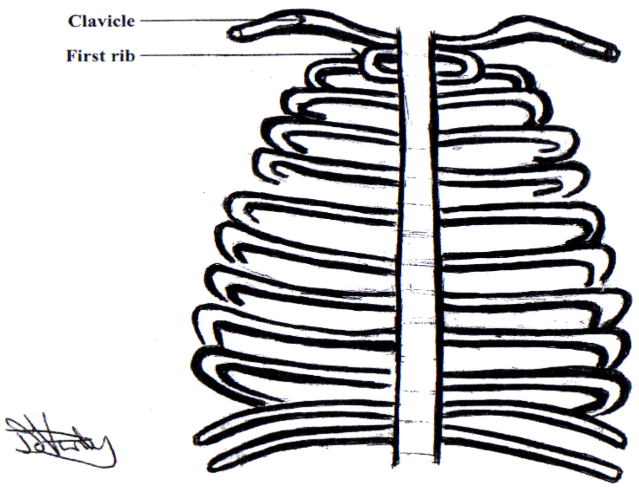

Figure 3.7: Radiographic image of the lordotic projection of the thorax (sketch drawn by researcher)

3.6 Data collection after intervention with intervention group

- **Second film-viewing assessment** (addresses sub-problem two).

  The control group, as well as the intervention group, subsequently wrote a second film-viewing assessment. Similar radiographic images as in the previous evaluation, as well as in the practical tutorials, were used. The intervention group should have been able to apply the knowledge and skills that they had gained. For ethical reasons, this additional film-viewing assessment did not count towards their annual film-viewing assessment mark.

  The outcomes of the film-viewing assessment were compared with the outcomes of the previous film-viewing assessment (baseline assessment), to determine if there were any improvements in performance pertaining to applied three-dimensional thinking.

3.7 Intervention with control group (addresses sub-problem two)

- For ethical reasons the same intervention took place with the control group, after the second film-viewing assessment.

3.8 Data collection after intervention with control group

- **Third film-viewing assessment** (addresses sub-problem two)

  A third film-viewing assessment was written by all the diagnostic second year students, which counted 40% towards their annual film-viewing assessment mark.
  These marks were compared with the marks of the baseline film-viewing assessment to evaluate the overall impact of the intervention on the performance of the class, pertaining to applied three-dimensional thinking.

  The marks of both the 2005 and 2006 classes (intervention classes) were compared to the marks achieved by former classes from 2000 to 2004 (control classes), at similar projections in film-viewing assessments to evaluate the role of the curricular intervention over the years.

- **Second three-dimensional test** (addresses sub-problems one and three).

  The students again completed the three-dimensional test, Spatial Perception (three-dimensional)(Owen & de Beer, 1997). These marks were compared with the marks of the first three-dimensional test to evaluate the impact of the intervention on the performance of the class, with regard to their general cognitive abilities, regarding three-dimensional thinking. These marks (three-dimensional test) were compared with the marks of the third film-viewing assessment, to determine if there was any correlation between the students' performances in the different tests.

3.9 Data analysis

The differences were described and analysed and recommendations were made with regard to future interventions. The computer-based data analysis software program, "STATISTICA", was used as the statistical method to analyse and present the data.

3.9.1 The mean and the median

Central tendency, the score that is the most typical of all the scores in a distribution, is measured by determining the mean or the median. The mean is the average score of the group of students (adding a list of scores and dividing the total by the number of scores), while the median is the middle score of a group of students when the percentages are ranked in order. If there is an uneven number of scores, the median is the midpoint in the distribution. If there is an even number of scores, the two middle scores are averaged to calculate the median (Brown & Dowling, 2001; Welman & Kruger, 2000; Berg & Latin, 2004). The median is the best measure to use when a sample size is small. It will represent the performance of a group better than the mean (Berg & Latin, 2004).

Since the sample size of this research was small, both the mean and the median were used to compare the performances of the groups, in order to determine the effect of the intervention.

3.9.2 Significance level versus intervention effect

A large sample will show statistical significance, even where the absolute differences between groups are insignificant. A large *n* reduces sampling error, which implies that the population is better represented (Berg & Latin, 2004; Brown & Dowling, 2001). Findings should however not be rejected if they do not achieve significance at the 0.05 ($p \leq$ as 0.05) level (Berg & Latin, 2004). The intervention effect could be huge, but if the sample size is small it may not achieve statistical significance (Berg & Latin, 2004; Brown & Dowling, 2001). The small sample size of this research made reaching significance (a real difference in performance) with the assessments of the small intervention and control groups of each class (2005 and 2006) almost impossible. It was therefore easier to reach significance when the overall impact of the intervention on the whole class group was assessed, as well as when both intervention groups' performances (2005 and 2006) were compared with those of previous years.

Statistically, significance between two groups is not likely to arise by probability (chance) alone (Brown & Dowling, 2001). The statistical power of research is the probability of discovering a result that really exists (Barker *et al.*, 2001). *Alpha* is the probability of discovering a result that does not exist (type 1 error or false positive), while *Beta* is the probability of not discovering a result that is present (type II error or false negative). If a researcher determined that data was caused by a sampling error and accepted the null hypothesis when it was a valid occurrence, a type II error has been made. The null hypothesis should have been rejected in favour of the research hypothesis (Barker *et al.*, 2001; Berg & Latin, 2004). With an adequate sample size any effect will become statistically significant. Results could therefore be statistically significant, but practically not significant (Barker *et al.*, 2001). For research to be statistically significant, the conventional criterion $p < 0.05$, which means that the results have to have a probability of less than one in twenty of happening by chance (Barker *et al.*, 2001).

Statistical significance refers to the possibility that a difference is real, whereas the "intervention effect" refers to the degree of the differences between groups (Berg & Latin, 2004). As earlier mentioned, the easiest way to determine the intervention effect is to compute the percentage difference between the means of two groups (Berg & Latin, 2004). Another way is to do the following calculation for effect size: $(M_e - M_c) \div SD$, where M_e is the mean of experimental group, M_c is the mean of control group and SD is the standard deviation of the control group. Cohen, reported in Berg and Latin (2004) states that an effect size of 0.2 indicates a small difference, 0.5 a reasonable difference, and 0.8 a large difference in results. According to Barker *et al.* (2001) effect sizes are more meaningful than p – values. A large effect size could however be caused by small standard deviations in the control and experimental groups rather than a significant distinction in the means themselves and would therefore not guarantee clinical significance (Barker *et al.*, 2001). Since it was difficult to achieve significance with the small intervention and control groups, the effect of the intervention was calculated, using the above-mentioned formula. Reasonable differences were shown between performances where significance was not achieved.

3.9.2.1 T-test versus ANOVA

To test a null hypothesis a *t* or *F* test statistic is used. The null hypothesis is the opposite of the research hypothesis and the research hypothesis will therefore be supported by rejection of the null hypothesis. The independent *t* test reveals whether a difference in the means of two groups of data is big enough to be accredited to a change in the dependent variable or if it could have occurred due to chance. An analysis of variance (ANOVA) is done to compare the mean scores of more than two groups. The *F* ratio is the statistic calculated in ANOVA (Welman & Kruger, 2000; Berg & Latin, 2004).

A larger *t* or *F* ratio increases the likelihood of statistical significance being achieved, where *t* or *F* = intervention variance/sampling error variance, or in other words, between-group variance/within-group variance. The between-group variance (numerator) shows variance in the dependent variable, which is caused by manipulation of the independent variable (intervention), while the within-group variance (denominator) shows the error-variance due to the influence of other variables. Measurement error is one of the sources of within-group variance and it can be caused by various other variables, causing the individuals' scores to be inaccurate (Welman & Kruger, 2000). A bigger sample group (*n*) will decrease the sampling error and therefore increases *t* or *F* (Berg & Latin, 2004; Welman & Kruger, 2000). The larger the *F* ratio is, therefore, the bigger the intervention variance. If the *F* ratio is 1.00 the intervention and error have an identical effect on causing results to vary. If the *F* ratio is less than 1.00, less than half of the variance is because of the intervention. If the *F* ratio is more than 5.00 it implies that the intervention variance was five times the error variance (Berg & Latin, 2004).

An ANOVA was done in this research to determine whether a change in the dependent variable (the three-dimensional skills of the students) caused the difference in the mean performances of the groups.

The mean scores of more than two groups (2000 – 2006) were compared and each of the intervention year groups (2005 and 2006) was assessed in three film-viewing assessments as well as in two three-dimensional tests. The *F* ratio was therefore calculated. The ratio could have been decreased by the small sample size used. Measurement errors caused by variables, such as anxiety or lack of motivation, could also have caused the F ratio to decrease.

3.9.3 Measures of variability

The range and the standard deviation are the most common measures of variety that describe the spreading of scores in a distribution. The range is calculated by subtracting the lowest score from the highest score. It is a weak method of determining variability because it depends on only two extreme scores. It therefore does not provide information on the spread of all the scores in a distribution. The standard deviation (SD), on the contrary, is the more common used and better measure. It provides information on the algebraic average distance of each score in a distribution from the mean. The standard deviations of two groups may only be compared if the groups have the same mean (M) (Berg & Latin, 2004).

In this research the range for each group of data was calculated. The standard deviations for most of the groups of data were calculated and, as previously explained, the standard deviations of the control groups were used in the formula that calculates the intervention effect. The standard deviations of the control and intervention groups' performances could not be compared, because the means of the groups differed after the interventions. The means of the two intervention groups of 2005 and 2006, as well as the means of the two control groups of these years, differed as well, after the interventions. The researcher chose subjects with similar levels of ability to reduce standard deviation within the group. The subjects in this research were all second year radiography students of more or less the same age (young adult phase). According to the researcher, a wide spread of scores after the intervention, especially very low and very high scores in the treatment group's data, could indicate that the intervention did not influence the performance of all the students in the same way and that the mean is not a true reflection of the group's performance.

3.9.4 The normal curve

The normal curve is represented by a bell-shape figure. It is a statistical model that is used to present data, to interpret distributions of scores and to make predictions using these data. The vertical mid-point represents the mean, median and mode. The curve is symmetrical. Positive values (values above the mean) are demonstrated on the right side and negative values (values below the mean) are demonstrated on the left side (Berg & Latin, 2004). It was important to compare the distribution of the students' marks before and after the intervention to determine if there was a change in the majority of the marks or in only a few marks, towards the positive side (more than the mean) or visa versa.

3.10 Validity of the research instruments

Validity means that a test or instrument (three-dimensional test or film-viewing assessment) precisely measures what it is supposed to measure (Berg & Latin, 2004).

3.10.1 Logical validity

This type of validity is qualitatively determined, since there is no statistical or numerical value to prove the accuracy of the instrument (Berg & Latin, 2004).

➢ **Content validity**

Content validity is very applicable to this research because a film-viewing assessment implies the evaluation of radiographic images, but also involves giving written answers to a questionnaire pertaining to these images. The questions should precisely measure the required information. For the instrument to be valid, a table of specifications could be used when setting the test, which would allow the researcher to calculate the number and type of the questions. The questions may also subsequently be evaluated by a panel of experts in the field, who will recommend alterations if necessary. "Again, there is no statistical value related to content validity. This is a bit stronger type of validity than the face type, since it employs both logic and authority opinion" (Berg & Latin, 2004: 163).

Pertaining to the instrument used in this research, each type of projection that would be used and the skill/s to be measured were tabled before the tests and moderated by the official moderator of the subject Clinical Radiographic Practice II (Refer to Appendices H & L). The questions that were set to measure these skills were also moderated. All the film-viewing assessments were prepared and marked by the researcher (lecturer of the subject Clinical Radiographic Practice II) and moderated by the internal moderator for this specific subject. Both the researcher and moderator had ample experience in offering/moderating this subject as well as many years of experience as radiographers in the clinical environment.

3.10.2 Statistical validity

Statistical measures are better than logical measures of validity. This type of validity is quantitatively determined because a numerical value is used to prove the accuracy of an instrument. The instrument would also be more statistically valid because it is compared to a standard test (Berg & Latin, 2004).

- **Criterion-based validity**

During the most accurate measurement of a variable, there is usually a gold standard present. The instrument or test can therefore be compared with the gold standard, which refers to standard criteria. These test results are compared to the results of another test where the specific criteria were applied and which has formerly been verified as valid. The results of these two tests should correlate statistically. Such a gold standard is unfortunately not always available (Berg & Latin, 2004; Brown & Dowling, 2001; Welman & Kruger, 2000).

In this research the students' three-dimensional abilities were tested by a standardised psychometric test. Their applied three-dimensional skills were evaluated in film-viewing assessments, for which no specific standard criteria were available. The tests were structured according to the film-viewing assessments of the previous years.

3.11 Experimental validity

"Researchers must design experiments in such a way that they have a high degree of confidence in the results" (Berg & Latin, 2004: 173). Experimental validity has to do with the way the intervention is conducted and it can be divided into two categories, namely internal and external validity.

3.11.1 Internal validity

There is no statistical value that can prove internal validity. The research conditions can only qualitatively be evaluated for internal validity. Internal validity is the degree to which the research condition is controlled so that changes in the dependent variable are caused by the independent variable alone. The researcher manipulates the independent variable to subsequently observe change in the affected dependable variable (Berg & Latin, 2004; Welman & Kruger, 2000).

The experimental design and randomisation of participants to groups would minimise threats to the internal validity of experiments (Berg & Latin, 2004). According to Benwell (1990) when using a control group, internal validity should be high and reliability good because unrelated variables will be prevented from changing the measuring instrument and influencing the results on consequent occasions. External validity, on the other hand, will be poor pertaining to ecological validity (generalisation of results to other surroundings) and population validity (generalisation of results to other groups of people) (Benwell, 1990).

The experimental design was mainly used in this research, which included randomisation of subjects into an intervention and a control group. Subjects with similar levels of ability (second year radiography students) participated in the research to reduce standard deviation within the group, which would increase internal validity of the intervention. The data of students repeating the subject, or with more clinical experience, were eliminated from the research. The intervention and control groups were statistically equivalent prior to the intervention, except for the spatial aptitude test results. The students were stratified according to their performances in the initial film-viewing assessments and afterwards randomly divided into two groups with an identical mean performance. The students were not involved in this assignment, which should eliminate the effect of selection bias.

As both groups' mean pre-tests scores were the same (62%), the threat, statistical regression, which means an extreme pre-test score of a group could decline to the mean, was eliminated. Students with various performances (high, average and low scores) were assigned to each group. The scores of individuals, who scored exceptionally well or badly in the pre-test, could still be influenced by this threat. The control group, as well as the intervention group, would then be influenced by this threat. The sample sizes were also small, which could have increased the influence of statistical regression to the mean. The larger the sample size, the more sampling and measurement errors will be eliminated. Executing the two trials over two years (using two classes) was an attempt to compensate for the small sample sizes.

In the first trial (2005) the initial post-test (the second film-viewing assessment test) was administered approximately four weeks after the pre-test. The reason for the four-week period was to exclude factors that would cause an increase in performance. In the second trial (2006), the initial post-test was administered approximately five weeks after the pre-test. According to Rafi *et al.* (2006) a five-week period would also exclude threats to internal validity, namely maturation and history. "Maturation" means that candidates become less nervous, more educated and better organised over time. "History" implicates factors outside the study influencing the dependent variable (Welman & Kruger, 2000; Berg & Latin 2004; Barker *et al.*, 2001). In this specific research it could have been their experiential training at the various practices. The skeletal content of their subject, Anatomy, which could have played a role, had been completed before the onset of the research. Randomisation would also have minimised the effects of history and maturation pertaining to the intervention and control groups and these factors should consequently not influence the results of the second film-viewing assessments. These effects would equally affect the performances of both these groups. Maturation and history could have influenced the results of the final film-viewing assessments, as well as the final three-dimensional tests (when compared to the pre-tests) because no control groups were used and as these tests were executed approximately two months after the pre-tests. The third film-viewing assessments' results were however subsequently also compared to the results of the film-viewing assessments of the previous year groups, which then acted as control groups. The assessments of the previous year groups (2000 - 2004) took place at approximately the same time of the year (last term, after completion of the academic content of the course) as the third film-viewing assessments of this research, which would reduce the effects of history and maturation.

The first three-dimensional tests and the first film-viewing assessments, which were compared for correlation, were executed at approximately the same time of the year (maximum a week apart). The final three-dimensional tests and final film-viewing assessments were also executed at more or less the same time of the year.

Another threat to internal validity is a faulty instrument, as discussed earlier. As explained in Chapter One, the film-viewing assessments were all structured assessments, done under exactly the same circumstances, which should objectively evaluate the performance of the students. All these film-viewing assessments were executed under the direct supervision of the researcher. The students also completed the three-dimensional tests under supervision of a psychologist and the same instrument was used over the two years. The circumstances (classroom setting for tests) were identical. Examination rules of the training institution were strictly applied with all assessments.

Fortunately no students dropped out of this study, therefore experimental mortality, where groups are not similar anymore, did not influence this research. Each film-viewing assessment was an objective structured clinical evaluation (OSCE), moderated by the official moderator, which would exclude the halo effect, namely the researcher expecting certain performances from certain subjects and as a result evaluating them subjectively. The Hawthorne effect, an increase in the performance of the subjects because they are being observed, could also not have played a noteworthy role in this study. The researcher did not directly observe the students' performances, as the assessments involved written answers to questionnaires.

3.11.2 External validity

Generalisation from the sample group to the target population is known as statistical inference. External validity is the ability to generalise the results to other settings or other populations (Berg & Latin, 2004; Benwell, 1990; Barker *et al.,* 2001). The random selection of subjects is compulsory for external validity, while the random assignment to groups promotes internal validity (Welman & Kruger, 2000). Selecting a homogeneous sample from a homogeneous population will reduce error and increase internal validity, but it will make the study less representative of the population and therefore decreases external validity (Barker *et al.*, 2001).

Only second year radiography students participated in this research, which decreases external validity, but a particular problem in a particular environment was investigated and generalisability was therefore not the main reason for performing the research.

The practical sessions were performed in the clinical setting namely, the practical X-ray room in a radiography department. A skeleton was used instead of a human being, to enlighten the students' on the positions and shapes of anatomical structures. As in the other X-ray rooms, viewing boxes were used to display the radiographic images. The circumstances during the practical sessions were therefore fairly realistic. The film-viewing assessments, as well as the three-dimensional tests, were executed in a classroom under examination circumstances. Viewing boxes were also used to display the images and the students had to execute the same type of mental tasks as during the practical sessions, but no patient or skeleton was present. The researcher would infer that although the practical sessions were done under fairly realistic circumstances, the circumstances during the assessments were not exactly realistic, but were, objective and well structured.

Artificial circumstances during assessments, for example, a classroom setting, will not be relevant to a real life situation, but it is not always possible to control this threat (Berg & Latin, 2004; Benwell, 1990). The advantage of such a venue is that it allows for maximum control over nuisance variables. Natural environments usually permit much less control (Welman & Kruger, 2000).

More emphasise was therefore placed on internal validity (structured objective assessments used) and less emphasise was placed on external validity. Unfortunately good internal validity results in poor external validity (Berg & Latin, 2004; Benwell, 1990). With experimental research, internal validity is extremely important, while external validity is not so important (Welman & Kruger, 2000).

3.12 Reliability

"Reliability is the consistency or repeatability of test scores or data" (Berg & Latin, 2004: 165). Test-retest reliability is obtained by repeating a test (usually within two weeks) to check if the results are consistent (Berg & Latin, 2004; Benwell, 1990; Stein & Cutler, 2000). This method would not have worked with this research.

If students were to execute exactly the same test, they would probably have done much better in the second one, because of the practice effect. Berg and Latin (2004) suggest that this method should not be used for knowledge or paper-and-pencil tests. According to Stein and Cutler (2000), in split half reliability, the test is divided into two equivalent components (e.g., ten items each) and correlated with each other.

Equivalence reliability is achieved if two different tests, using different items, are used to measure the same variable and if the results of these tests correlate with each other. Unfortunately it is difficult to compile similar tests, which would measure the same variable. Similar tests, using different items but measuring the same skills, can be used in knowledge or paper-and-pencil tests (Berg & Latin, 2004).

In this research three similar tests were conducted to measure the same three-dimensional skills in the students pertaining to film-viewing assessments. Different projections were used. The pre-tests and re-tests were compared to check that the same skills were measured and that similar questions and projections were used. Statistical correlation tests were performed on four film-viewing assessments (two used in 2005 and two in 2006). All four assessments correlated moderately, but the film-viewing assessments one and three of 2005 however did not achieve significance when tested separately (p = 0.1409). It could have been because different films or different projections were used to eliminate the practice effect. The format of these assessments was more or less the same as that of second year film-viewing assessments over the previous five years, which formed part of their annual clinical assessments and contributed towards their final mark.

The aptitude test Spatial Perception (three-dimensional) used in this research is a standardised test with a reliability coefficient of 0.87 (Owen & de Beer, 1997). Correlation tests were performed which showed a strong correlation among all these tests. The identical aptitude test was used for all the assessments.

3.13 Research ethics

A researcher should make sure that his/her subjects are adequately informed to make a sound decision about participating in a study. In this research informed consent was obtained from all the participants, as well as from all other parties involved (Refer to Appendix A).

3.13.1 Informed consent

"The right to give informed consent is one of the subject's most important rights" (Berg & Latin, 2004:17). The informed consent form is a written document, which provides background to the research and an invitation to the subject to participate. The document includes the detail of all the procedures, especially risks (physical and psychological) that are involved (Berg & Latin, 2004).

With experimental research there can be ethical concerns because of the intervention. The intervention should not be risky to the educational development of a group of students. The intervention, if valuable, should also not be withheld from other groups, for example, the control group for unlimited periods of time (Brown & Dowling, 2001). As previously mentioned, in this research a wait-listed control group was used, because the group was, for ethical reasons, only excluded from the initial experiment. After the second assessment they had the same intervention as the original intervention group. These procedures were thoroughly explained to the students. The students were reassured that the marks would be treated confidentially and that identification codes would be assigned to them.

Students were treated equally, because measurements were made during objective structured assessments. They were also familiar with film-viewing assessments as they had previous experience with formative assessments as well as with similar assessments in their first year of study. The practical sessions with all groups were also performed in a similar structured way according to specific guidelines (Refer to Appendices D, E, F and G).

They were informed that the extra practical assessments could be tiresome to some of them, especially if they did not like drawing. The students who had to travel from other practices were informed that their expenses would be remunerated. They were told that they could not withdraw from the initial and final film-viewing assessments because they formed part of their annual clinical assessments. The students were all very keen to participate and nobody withdrew from the study.

Possible benefits to the subject and society should be described, without misleading the subjects (Berg & Latin, 2004). In this research, it was explained to the students that the experience gained with the extra practical sessions, should equip them with additional skills, to apply in the last film-viewing assessment, which would count towards their annual mark. It was also explained to them that one of the objectives of this study was to improve the performance of future second year students in film-viewing assessments. The other objective of the study, to determine if three-dimensional cognitive abilities of students play a role in film-viewing assessments and if these abilities can be developed, were also discussed with them. They were informed that some radiography training institutions use psychometric tests (including three-dimensional tests) as part of their selection process.

They also knew that they were free to ask questions and to expect answers at any time during the research process. The researcher promised to give the students feedback on their performances, as well as on the results of the study.

3.14 Conclusion

The research methodology was applied as honestly, fairly, precisely and objectively as possible to achieve accurate results, which could be used in future to assist the second year students in film-viewing assessments. The research findings will be presented in the following chapter.

CHAPTER FOUR
THE RESULTS OF THE RESEARCH

In this chapter the main findings of the research are presented and described. Here follows an overview of the chapter.

4.1 Overview of the chapter

The quantitative data address the following three sub-problems:

- Correlation between the students' performances in three-dimensional tests and film-viewing assessments was investigated. Film-viewing assessments and three-dimensional tests, before and after the intervention, were compared and the results are presented.

- The impact of the curricular intervention on the applied three-dimensional skills of the students, with regard to film-viewing assessments, was investigated. Differences in the performances of the intervention and control groups, before and after the intervention, are demonstrated. Differences in the performance of the whole class, before and after the intervention, are demonstrated. Distribution of scores of the whole class, before and after the intervention, is displayed. The performances of the previous year groups, without the intervention, are compared to the two classes, with the intervention.

- The impact of the curricular intervention on students' general spatial cognitive abilities was investigated. Differences in the performance of the whole class in the spatial aptitude test, before and after the intervention, are demonstrated.

The role of gender in this research, with regard to three-dimensional thinking, is described.

The following qualitative data are subsequently presented:

- Feedback from the students on the intervention (practical sessions).

- Feedback from the students on the film-viewing assessments.

4.2 Quantitative data

This research is mainly quantitative research, because the design and variables had been determined before the data were collected. Measurement instruments (the film-viewing assessments and the three-dimensional test) were used. The data obtained are presented in numerical form and statistical calculation was done to determine and display true differences/correlation in performances of groups.

4.2.1 Addressing the problem statement

The focus of this research is second year radiography students' cognitive skills for relating the positions of anatomical structures on modified radiographic images, with the real positions in the human body. An evaluation methodology, which focused on a particular curricular intervention, was used. The following three sub-problems were investigated, and the findings are presented.

4.2.1.1 Investigation of sub-problem one: correlation between three-dimensional tests and film-viewing assessments

Correlation between the students' performances in three-dimensional tests and film-viewing assessments had to be determined. The students therefore wrote a three-dimensional test at the onset of the research at more or less the same time as the first and baseline film-viewing assessment (before the intervention). Both year groups (2005 and 2006) executed these tests. The marks of the first three-dimensional test were compared with the marks of the first film-viewing assessment to determine any correlation. After the whole class (in 2005 and 2006) had the intervention, the same three-dimensional test was written and a similar film-viewing assessment was done. The marks of these two assessments were also tested for correlation.

The following figures show that there is only a weak to moderate correlation between the marks that the students achieved in the three-dimensional tests and their marks in the film-viewing assessments (Refer to Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6).

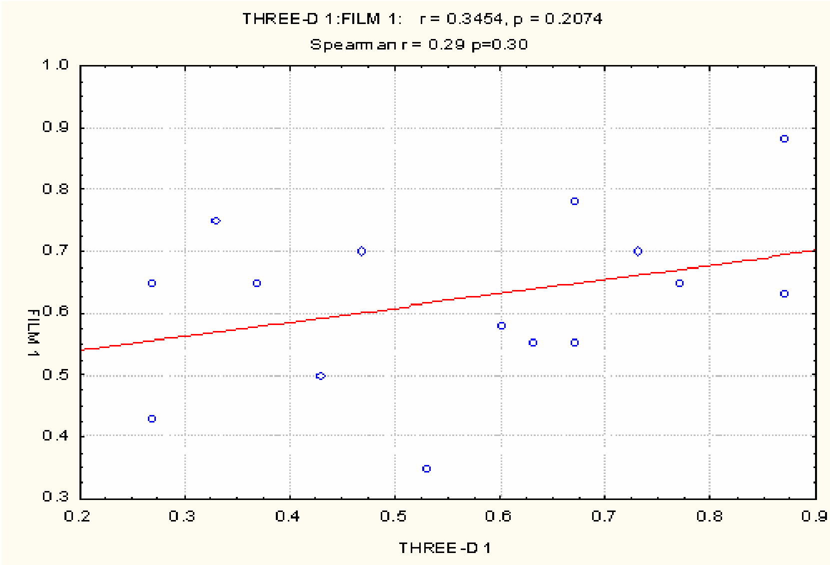

Figure 4.1: Correlation analysis between three-dimensional test 1 and film-viewing assessment 1
Results of tests before the intervention (2005)

Since $p = 0.207$ is more than 0.05, Pearson's coefficient of correlation $r = 0.345$ is not significant ($p > 0.05$), and the null hypothesis is accepted. There is only a moderate correlation (r = between 0.26 and 0.5) between the marks of the first three-dimensional test and the first film-viewing assessment in 2005.

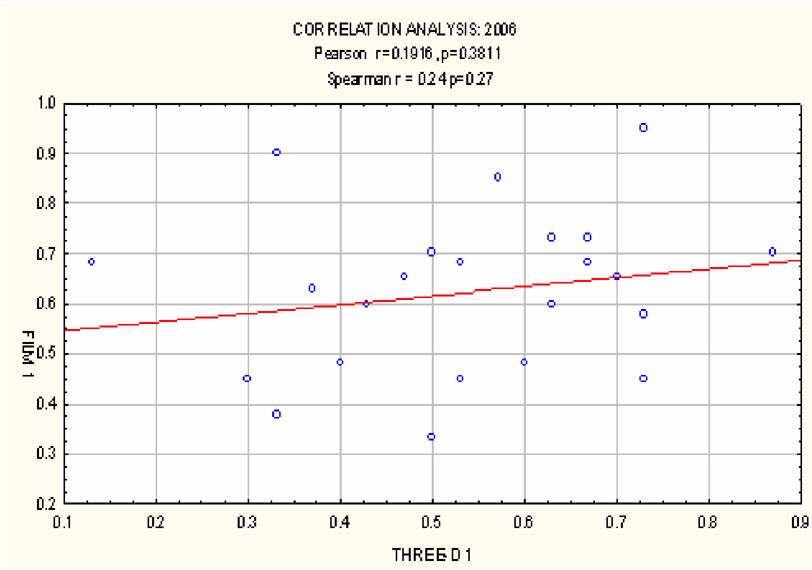

Figure 4.2: Correlation analysis between three-dimensional test 1 and film-viewing assessment 1
Results of tests before the intervention (2006)

Since $p = 0.381$ is more than 0.05, Pearson's coefficient of correlation $r = 0.192$ is not significant ($p > 0.05$), and the null hypothesis is accepted. There is a weak correlation (r = less than 0.25) between the marks of the first three-dimensional test and the first film-viewing assessment in 2006.

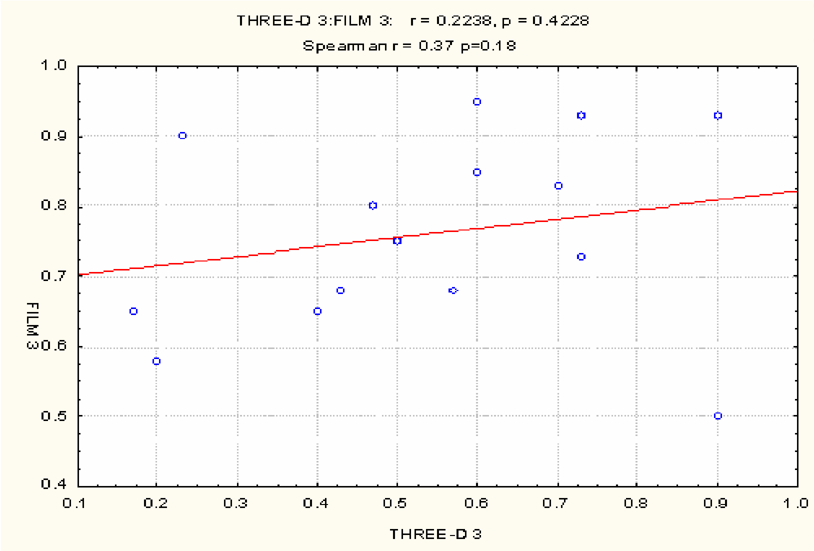

Figure 4.3: Correlation analysis between three-dimensional test 2 and film-viewing assessment 3
Results of tests after the intervention (2005)
(Three-D 3 means the second three-dimensional test done in the time period 3)

Since *p* = 0.423 is more than 0.05, Pearson's coefficient of correlation *r* = 0.224 is not significant ($p > 0.05$), and the null hypothesis is accepted. There is a weak correlation (*r* = less than 0.25) between the marks of the second three-dimensional test and the third film-viewing assessment in 2005.

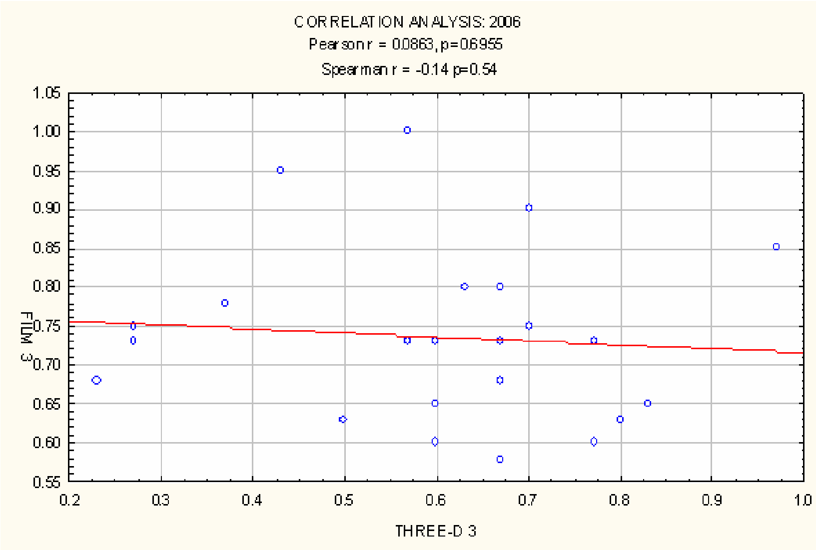

Figure 4.4: Correlation analysis between three-dimensional test 2 and film-viewing assessment 3
Results of tests after the intervention (2006)
(Three-D 3 means the second three-dimensional test done in the time period 3)

The following data refer to Figure 4.4: Since p = 0.696 is more than .05, Pearson's coefficient of correlation r = 0.086 is not significant (p > 0.05), and the null hypothesis is accepted. There is a weak correlation (r = less than 0.25) between the marks of the second three-dimensional test and the third film-viewing assessment in 2006.

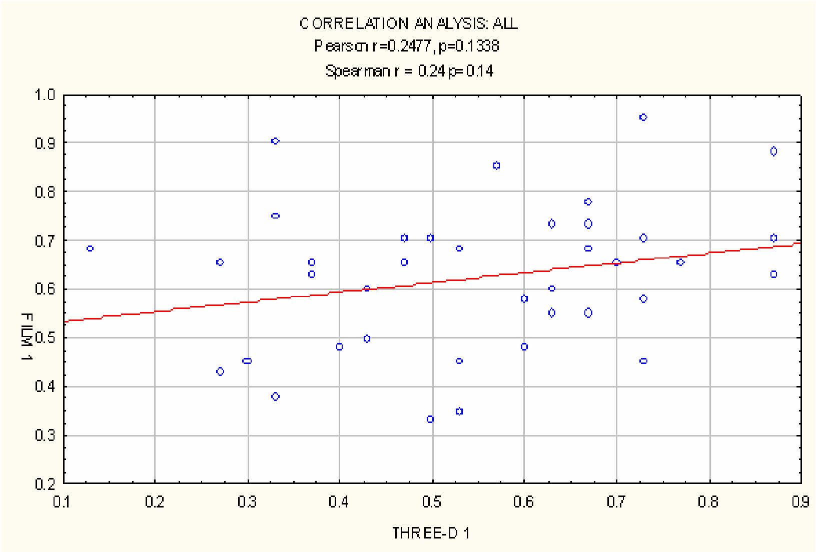

Figure 4.5: Correlation analysis between three-dimensional test 1 and film-viewing assessment 1
Results of tests before the intervention (2005 and 2006 groups)

The following data refer to Figure 4.5: Since p = 0.134 is more than 0.05, Pearson's coefficient of correlation r = 0.248 is not significant (p > 0.05), and the null hypothesis is accepted. There is a weak correlation (r = 0.25 or less than 0.25) between the marks of the first three-dimensional test and the first film-viewing assessment of both year groups of 2005 and 2006.

The following data refer to Figure 4.6: Since p = 0.760 is more than 0.05, Pearson's coefficient of correlation r = 0.051 is not significant (p > 0.05), and the null hypothesis is accepted. There is a weak correlation (r = less than 0.25) between the marks of the second three-dimensional test and the third film-viewing assessment of both year groups of 2005 and 2006.

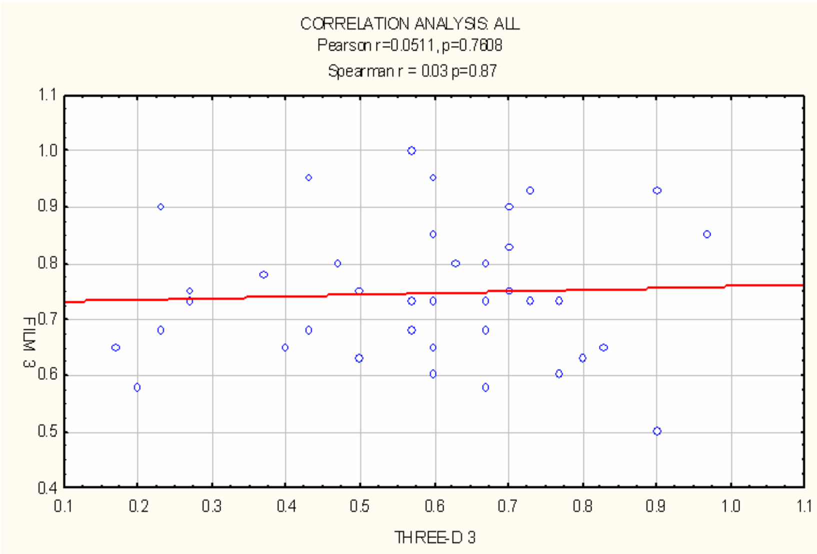

Figure 4.6: Correlation analysis between three-dimensional test 2 and film-viewing assessment 3
Results of tests after the intervention (2005 and 2006 groups)
(Three-D 3 means the second three-dimensional test done in time period 3)

4.2.1.2 Investigation of sub-problem two: impact of intervention on applied three-dimensional skills

A curricular intervention, which was intended to improve three-dimensional skills, pertaining to radiographic images, was developed and applied. A control group was used with the first intervention and second film-viewing assessment of both year groups (2005 and 2006). No control group was used with the third film-viewing assessment of both year groups. All the students in both classes had at that stage received the intervention. The third film-viewing assessments of the year groups 2005 and 2006 were compared to the film-viewing assessments of the previous year groups (2000 to 2004) without the intervention. Interesting patterns found in the data are the following:

- The intervention groups did not perform significantly better after the intervention.
- The whole class did exceptionally well after the intervention (both year groups).
- In the second film-viewing assessments (after intervention) the performances of the control groups decreased compared to their performance in the pre-tests, while the performances of the intervention groups increased (for both 2005 and 2006 groups).
- The intervention year groups also performed significantly better than the previous year groups (without the intervention).

Figure 4.7 shows an exact mean performance of 62% for both the class groups of 2005 and 2006 in the first film-viewing assessment, before the intervention took place (*n* of 2005 = 15 and *n* of 2006 = 23). Figure 4.8 shows a 2% difference in mean performance (76% for the class group of 2005 and 74% for the class group of 2006) for the third film-viewing assessment after the whole class had received the intervention. The smaller group performed better. The median for the class group of 2005 is 75% and the median for the class group of 2006 is 73%, therefore there is also a difference of 2% in favour of the smaller group.

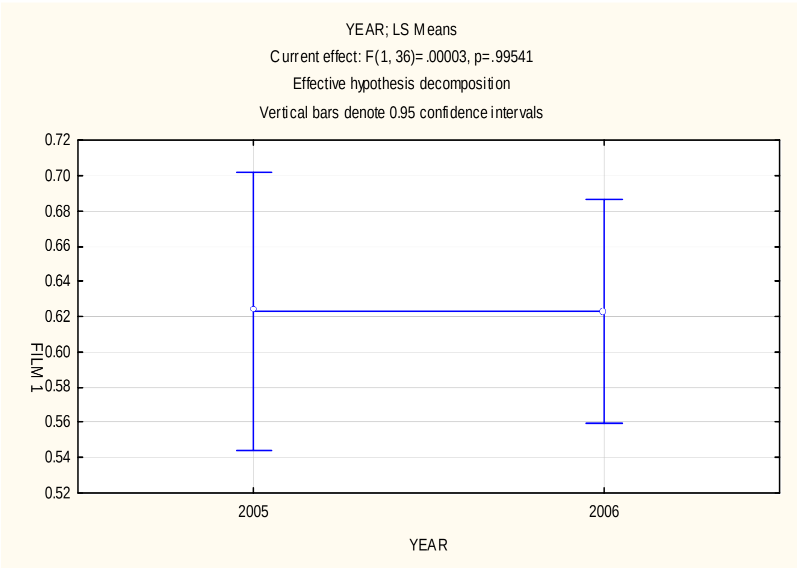

Figure 4.7: Mean performance of both groups (2005 and 2006) before the intervention
Results of first film-viewing assessments

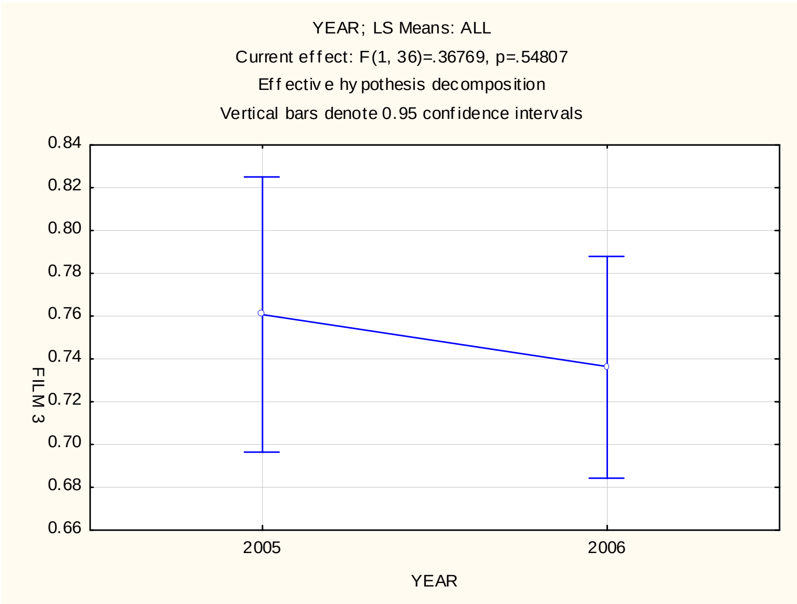

Figure 4.8: Mean performance of both groups (2005 and 2006) after the intervention
Results of third film-viewing assessments

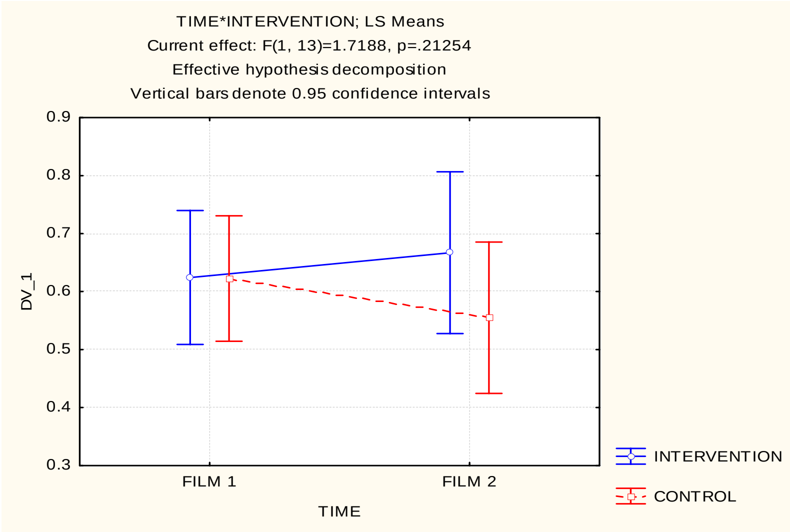

Figure 4.9: Difference in performances between intervention and control groups before and after the intervention
Results of film-viewing assessments 1 and 2 (2005)

Figure 4.9 demonstrates the effect of the practical sessions on the intervention group in comparison to the control group of 2005 (n = 15 for both intervention and control groups).

ANOVA

Since $p = 0.213$ is more than 0.05, $F = 1.719$ is not statistically significant ($p > 0.05$), and the null hypothesis is accepted.

Table 4.1: Central tendencies and standard deviations of the control and intervention groups during the second film-viewing assessment of 2005

Breakdown Table of Descriptive Statistics (2005 EXP VS CONTROL in DATA20080525.stw)
N=15 (No missing data in dep. var. list)

GROUP	F-V2 AFTER EP Means	F-V2 AFTER EP N	F-V2 AFTER EP Std.Dev.
INTERVENTION	0.667143	7	0.148067
CONTROL	0.555000	8	0.188225
All Grps	0.607333	15	0.174539

The standard deviation of the intervention group in the second film-viewing assessment is 0.148067 compared to the standard deviation of the control group of 0.188225 while the mean of the intervention group in the second film-viewing assessment is 0.667143 (67%) and that of the control group is 0.555000 (56%). The median of the intervention group in the second film-viewing assessment is 73% compared to the median of the control group of 53%.

The range for each group

Intervention group in first film-viewing assessment:	88% - 43% = 45%
Intervention group in second film-viewing assessment:	80% - 38% = 42%
Control group in first film-viewing assessment:	78% - 35% = 43%
Control group in second film-viewing assessment:	85% - 25% = 60%

Intervention effect

As already discussed, Barker *et al.* (2001) states that intervention effect sizes are more important than *p* – values. According to Berg and Latin (2004) the simplest way to state the effect size is to calculate the percentage difference between groups (mean/median), where the median would be the best measure when the sample size is small. The difference between the means is therefore 11% and the difference between the medians 20%, both favouring the intervention group. Another calculation for effect size: $(M_e - M_c) \div SD$ where M_e is the mean of experimental group, M_c is the mean of control group and SD is the standard deviation of the control group (Berg & Latin, 2004). The effect size: $(M_e - M_c) \div SD = (0.667 - 0.555) \div 0.188 = 0.59$ which is, according to Cohen reported in Berg and Latin (2004), a reasonable difference (more than 0.5). Cohen states that an effect size of 0.2 indicates a small difference, 0.5 a reasonable difference, and 0.8 a huge difference in results.

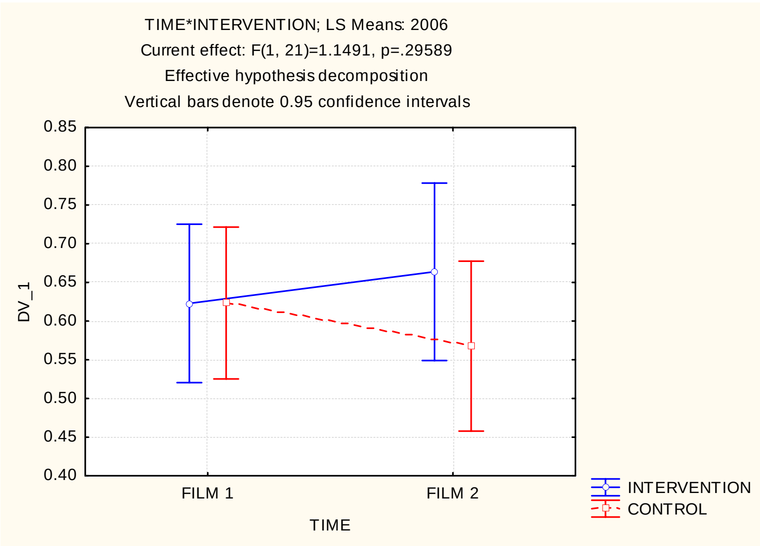

Figure 4.10: Difference in performances between intervention and control groups before and after the intervention Results of film-viewing assessments 1 and 2 (2006)

Figure 4.10 demonstrates the effect of the practical sessions on the intervention group in comparison to the control group of 2006 (*n* = 23 for both intervention and control groups).

ANOVA

Since *p* = 0.296 is more than 0.05, *F* = 1.149 is not statistically significant ($p > 0.05$), and the null hypothesis is accepted.

Table 4.2: Central tendencies and standard deviations of the control and intervention group during the second film-viewing assessment of 2006

Breakdown Table of Descriptive Statistics (2006 EXP VS CONTROL in DATA20080525.stw)
N=23 (No missing data in dep. var. list)

GROUP	F-V2 AFTER EP Means	F-V2 AFTER EP N	F-V2 AFTER EP Std.Dev.
INTERVENTION	0.663636	11	0.190907
CONTROL	0.567500	12	0.175195
All Grps	0.613478	23	0.185267

The standard deviation of the intervention group in the second film-viewing assessment (after experiment) is 0.190907 compared to the standard deviation of the control group of 0.175195, while the mean of the intervention group in the second film-viewing assessment is 0.663636 (66%) and that of the control group is 0.567500 (57%). The median of the intervention group in the second film-viewing assessment is 65% compared to the median of the control group of 55%.

The range for each group

Intervention group in first film-viewing assessment: 95% - 33% = 62%

Intervention group in second film-viewing assessment: 95% - 33% = 62%

Control group in first film-viewing assessment: 73% - 45% = 28%

Control group in second film-viewing assessment: 95% - 35% = 60%

Intervention effect

The difference between the means is therefore 9% and the difference between the medians 10%, both favouring the intervention group. Effect size = $(M_e - M_c) \div SD$ = $(0.664 - 0.568) \div 0.175 = 0.57$ which is a reasonable difference (more than 0.5).

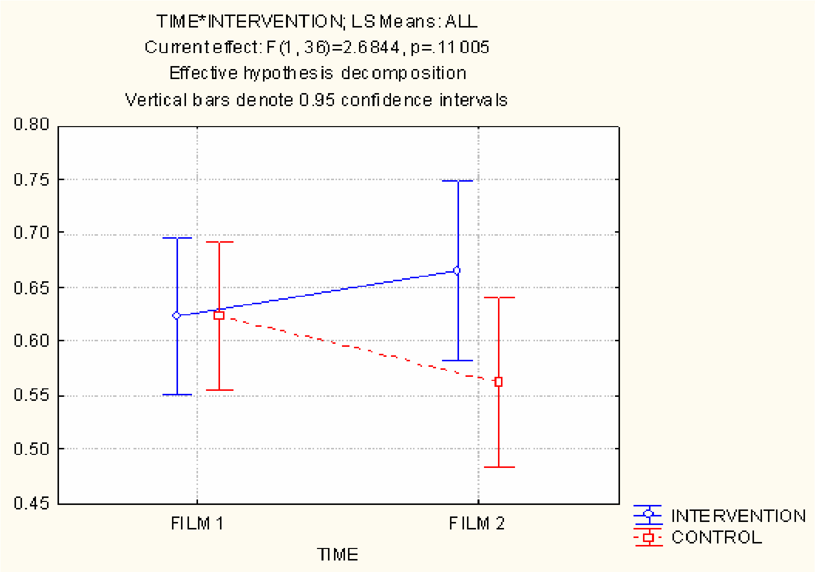

Figure 4.11: Difference in performances between intervention and control groups before and after the intervention
Results of film-viewing assessments 1 and 2 (2005 and 2006 groups)

Figure 4.11 demonstrates the effect of the practical sessions on both the intervention groups (2005 and 2006) in comparison to both the control groups (2005 and 2006). (*n* = 38 for both intervention and control groups).

ANOVA

Since $p = 0.110$ is more than 0.05, $F = 2.684$ is not statistically significant ($p > 0.05$), and the null hypothesis is accepted.

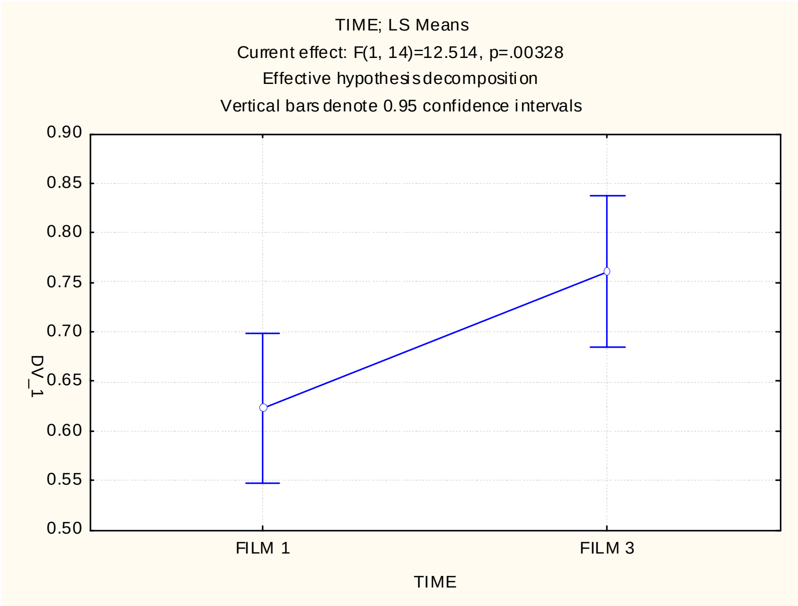

Figure 4.12: Difference in performances of whole class before and after the intervention
Results of film-viewing assessments 1 and 3 (2005)

Figure 4.12 demonstrates the effect of the practical sessions (intervention) on the whole class of 2005 ($n = 15$).

ANOVA

Since $p = 0.003$ is less than 0.01, $F = 12.514$ is statistically significant ($p < 0.01$), and the null hypothesis is rejected.

Table 4.3: Central tendencies and standard deviations of evaluations of 2005

Variable	Descriptive Statistics (2005 in DATA20080525.stw) Valid N	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
3-D 1	15	0.565	0.600	Multiple	2.000	0.270	0.870	0.370	0.730	0.203
3-D 2	15	0.542	0.570	Multiple	2.000	0.170	0.900	0.400	0.730	0.232
F-V1	15	0.623	0.650	.6500000	3.000	0.350	0.880	0.550	0.700	0.136
F-V 3	15	0.761	0.750	Multiple	2.000	0.500	0.950	0.650	0.900	0.138

The mean for film-viewing assessment 1 is 0.623 (62%) and the mean for film-viewing assessment 3 is 0.761 (76%), while the median for film-viewing assessment 1 is 0.650 (65%) and the median for film-viewing assessment 3 is 0.750 (75%). The standard deviation for film-viewing assessment 1 (before the intervention) is 0.136 and the standard deviation for film-viewing assessment 3 (after the intervention) is 0.138.

The range for the whole group

Film-viewing assessment 1: 88% - 35% = 53%

Film-viewing assessment 3: 95% - 50% = 45%

Intervention effect

The difference between the means is therefore 14% and the difference between the medians 10%, both favouring the intervention group. Effect size = $(M_e – M_c) \div SD$ = $(0.761 - 0.623) \div 0.136 = 1.03$ which is a huge difference.

Normal curves

The following two figures (4.13 and 4.14) represent the distribution of scores during film-viewing assessment 1 and film-viewing assessment 3 in 2005. The midpoint of the bell-shape figure represents the mean and the median.

Values above the mean are demonstrated on the right side and values below the mean on the left side (Berg & Latin, 2004). Figure 4.14 shows the shift of the median towards the right side, as well as the shift of a large number of scores towards the right side, in comparison with Figure 4.13.

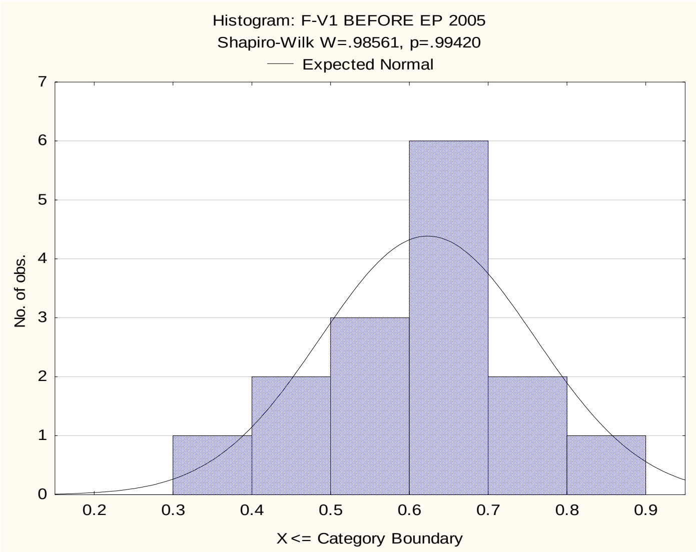

Figure 4.13: Spread of marks during film-viewing assessment 1 of 2005 (before the intervention)

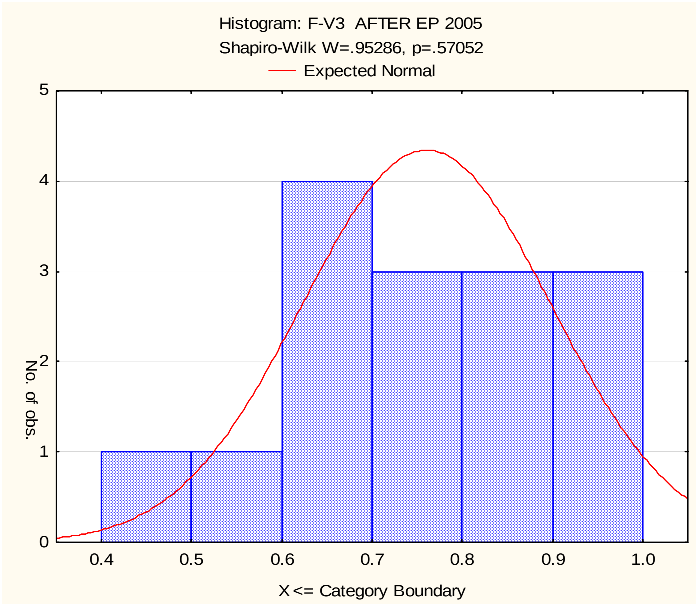

Figure 4.14: Spread of marks during film-viewing assessment 3 of 2005 (after the intervention)

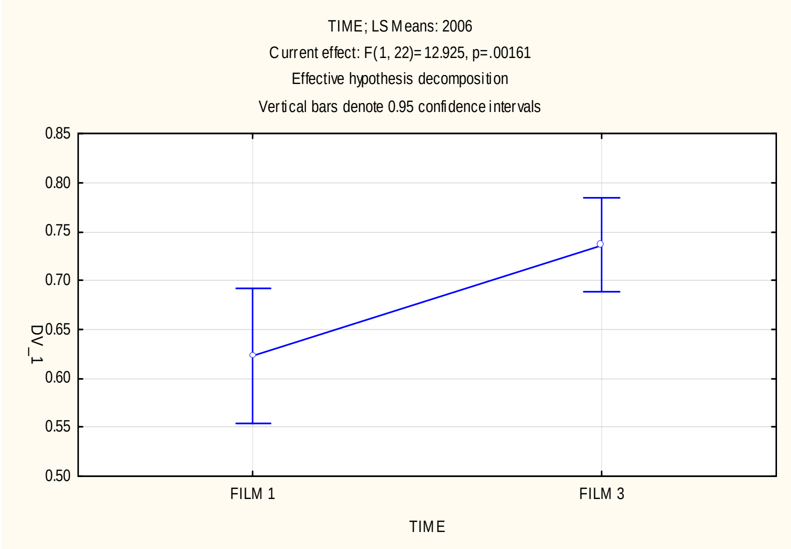

Figure 4.15: Difference in performances of whole class before and after the intervention
Results of film-viewing assessments 1 and 3 (2006)

Figure 4.15 demonstrates the effect of the practical sessions (intervention) on the whole class of 2006 (n = 23).

ANOVA

Since p = 0.002 is less than 0.01, F = 12.925 is statistically significant ($p < 0.01$), and the null hypothesis is rejected.

Table 4.4: Central tendencies and standard deviations of evaluations of 2006

	Descriptive Statistics (2006 in DATA20080525.stw)									
Variable	Valid N	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
3-D 1	23	0.537	0.530	.7300000	3.000	0.130	0.870	0.400	0.670	0.176
3-D 2	23	0.603	0.630	.6700000	4.000	0.230	0.970	0.500	0.700	0.188
F-V 1	23	0.623	0.650	Multiple	3.000	0.330	0.950	0.480	0.700	0.160
F-V 3	23	0.736	0.730	.7300000	5.000	0.580	1.000	0.650	0.800	0.111

The mean for film-viewing assessment 1 is 0.623 (62%) and the mean for film-viewing assessment 3 is 0.736 (74%), while the median for film-viewing assessment 1 is 0.650 (65%) and the median for film-viewing assessment 3 is 0.730 (73%). The standard deviation for film-viewing assessment 1 is 0.160 (before the intervention) and the standard deviation for film-viewing assessment 3 is 0.111 (after the intervention).

The range for the whole group

Film-viewing assessment 1: 95% - 33% = 62%

Film-viewing assessment 3: 100% - 58% = 42%

Intervention effect

The difference between the means is therefore 12% and the difference between the medians 8%, both favouring the intervention group. Effect size = $(M_e - M_c) \div SD$ = $(0.736 - 0.623) \div 0.160 = 0.69$ which is a reasonable difference.

Normal curves

The following two figures (4.16 and 4.17) represent the distribution of scores during film-viewing assessment 1 and film-viewing assessment 3 in 2006. The midpoint of the bell-shape figure represents the mean and the median. Values above the mean are demonstrated on the right side and values below the mean on the left side (Berg & Latin, 2004).

Figure 4.17 shows the shift of the mean towards the right side in comparison with Figure 4.16. A larger number of scores are demonstrated below the mean compared to that above the mean.

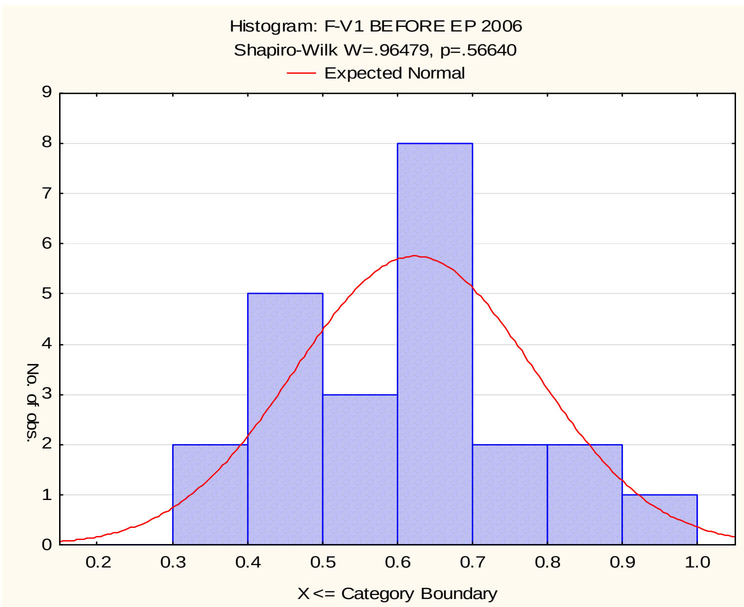

Figure 4.16: Spread of marks during film-viewing assessment 1 of 2006 before the intervention

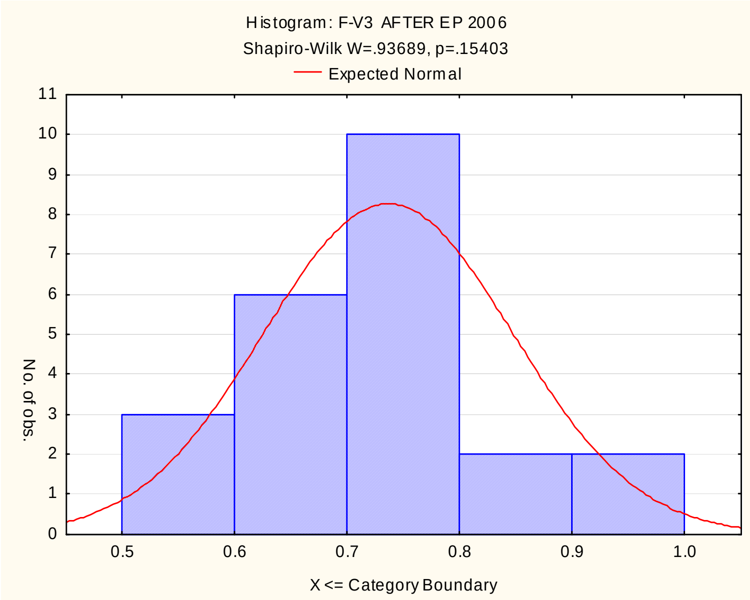

Figure 4.17: Spread of marks during film-viewing assessment 3 of 2006 after the intervention

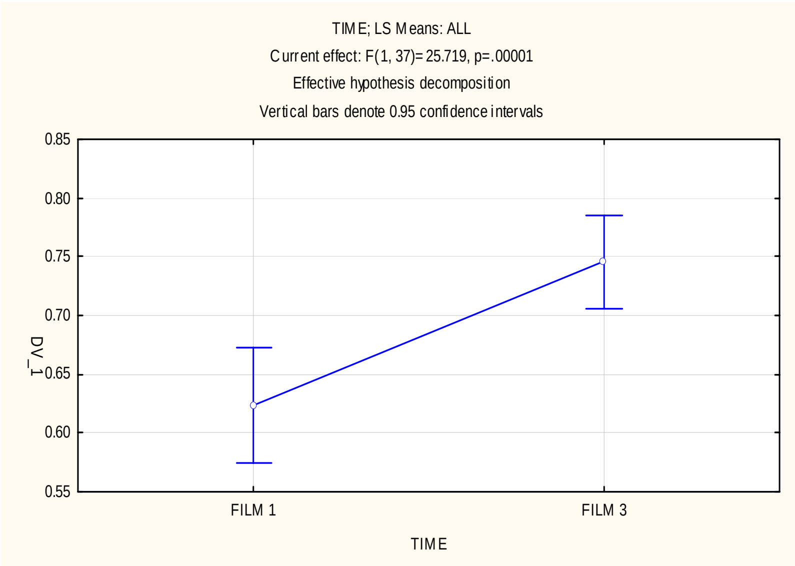

Figure 4.18: Difference in performances of whole class before and after the intervention
Results of film-viewing assessments 1 and 3 (2005 and 2006 groups)

Figure 4.18 demonstrates the effect of the practical sessions (intervention) on the whole classes of both 2005 and 2006 (n = 38).

ANOVA

Since p = 0.00001 is less than 0.01, F = 25.719 is statistically significant (p < 0.01), and the null hypothesis is rejected.

Table 4.5: Central tendencies and standard deviations of evaluations of both 2005 and 2006

Variable	Descriptive Statistics (ALL in DATA20080525.stw) Valid N	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
3-D 1	38	0.548	0.550	Multiple	4.000	0.130	0.870	0.400	0.670	0.185
3-D 2	38	0.579	0.600	.6000000	5.000	0.170	0.970	0.430	0.700	0.205
F-V 1	38	0.623	0.650	.6500000	5.000	0.330	0.950	0.500	0.700	0.149
F-V 3	38	0.746	0.730	.7300000	6.000	0.500	1.000	0.650	0.830	0.121

The mean for film-viewing assessments 1 is 0.623 (62%) and the mean for film-viewing assessments 3 is 0.746 (75%), while the median for film-viewing assessments 1 is 0.650 (65%) and the median for film-viewing assessments 3 is 0.730 (73%). The standard deviation for film-viewing assessments 1 is 0.149 (before the intervention) and the standard deviation for film-viewing assessments 3 is 0.121 (after the intervention).

Intervention effect

The difference between the means is therefore 13% and the difference between the medians 8%, both favouring the intervention group. Effect size = $(M_e - M_c) \div SD$ = $(0.746 - 0.623) \div 0.149 = 0.81$ which is a huge difference.

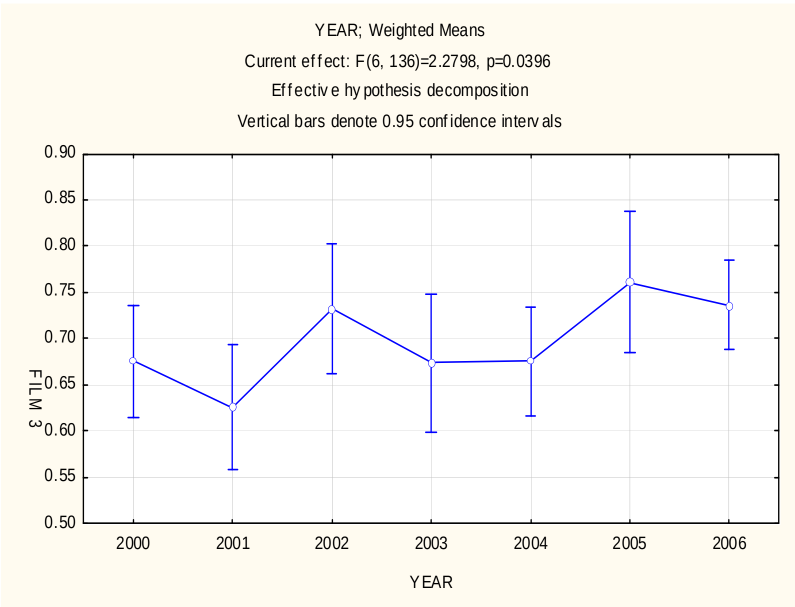

Figure 4.19: Differences in performances of classes of previous year groups without the intervention compared to classes of 2005 and 2006 with the intervention Results of final film-viewing assessment (2000 – 2006)

Figure 4.19 demonstrates the differences in performances in the final film-viewing assessments of the classes 2000 to 2006. The mean performance of only the class of 2002 comes close to that of the intervention groups.

Table 4.6: Demonstrates the central tendencies and ranges in final film-viewing assessments (2000 –2006)

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
N	20	24	16	17	28	15	23
Mean	68%	63%	73%	67%	68%	76%	74%
Median	70%	65%	77%	66%	69%	75%	73%
Range	85% - 45% = 40%	88% - 33% = 55%	90% - 50% = 40%	87% - 30% = 57%	93% - 37% =56%	95% - 50% = 45%	100% - 58% = 42%

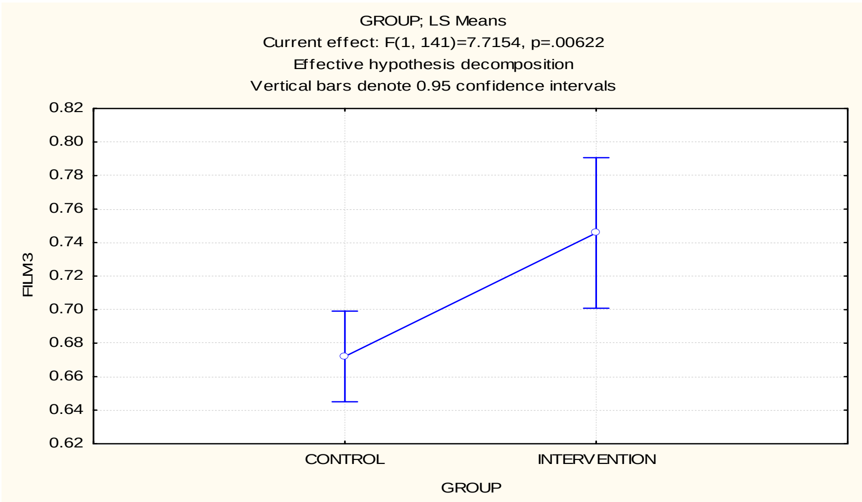

Figure 4.20: Differences in performances of classes of previous year groups without the intervention (control), compared to classes of 2005 and 2006 with the intervention (intervention)
Results of final film-viewing assessment (2000 – 2006)

Figure 4.20 demonstrates the effect of the practical sessions (intervention) on the intervention classes of 2005 and 2006, compared to the control classes of 2000 to 2004.

ANOVA

Since $p = 0.006$ is less than 0.01, $F = 7.715$ is statistically significant ($p < 0.01$), and the null hypothesis is rejected.

Intervention effect

The mean of control groups (2000 – 2004) for the final film-viewing assessments = 0.678 (68%), while the mean of the treatment groups (2005 – 2006) for third and final film-viewing assessments = 0.746 (75%).   The difference between the means is therefore 7%.

4.2.1.3 Investigation of sub-problem three: impact of intervention on general three-dimensional cognitive abilities

The impact of the curricular intervention on students' general spatial cognitive abilities was evaluated. The following figures display the performances of the students in the three-dimensional tests before and after the intervention.

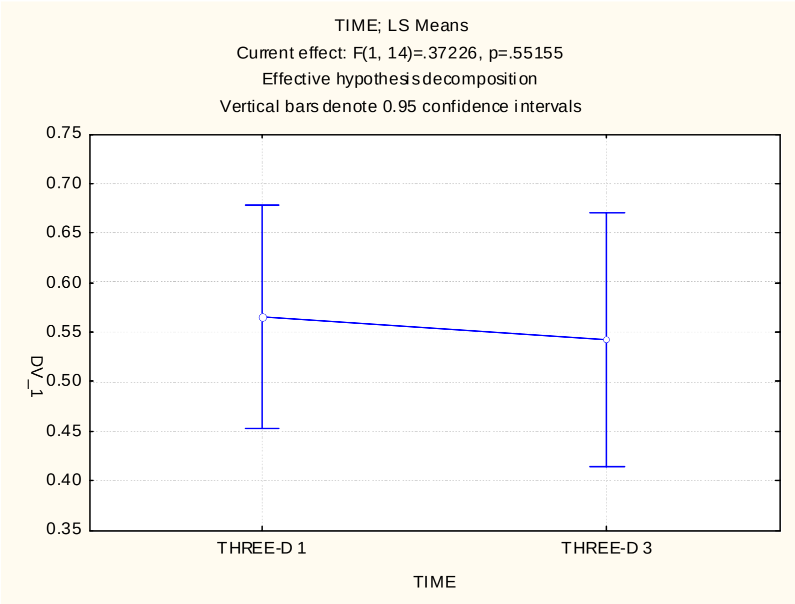

Figure 4.21: Difference in performances of whole class before and after the intervention
Results of three-dimensional tests 1 and 2 (2005)
(Three-D 3 means second three-dimensional test done in time period 3)

Figure 4.21 demonstrates the difference in performance pertaining to general three-dimensional abilities, before and after the intervention, of the whole class of 2005 ($n = 15$).

ANOVA

Since $p = 0.552$ is more than 0.05, $F = 0.372$ is not statistically significant ($p > 0.05$), the null hypothesis is accepted.

The mean of three-dimensional test 1 is 0.565 (57%) and the mean of three-dimensional test 2 is 0.542 (54%). The median of three-dimensional test 1 is 0.600 (60%) and the median of three-dimensional test 2 is 0.570 (57%). The standard deviation of three-dimensional test 1 is 0.203 and the standard deviation of three-dimensional test 2 is 0.232 (Refer to Table 4.3).

The range for each group

Three-dimensional test 1: 87% - 27% = 60%

Three-dimensional test 2: 90% - 17% = 73%

Intervention effect

There is a 3% difference in the means, as well as a 3% difference in the medians, both favouring the group without the intervention.

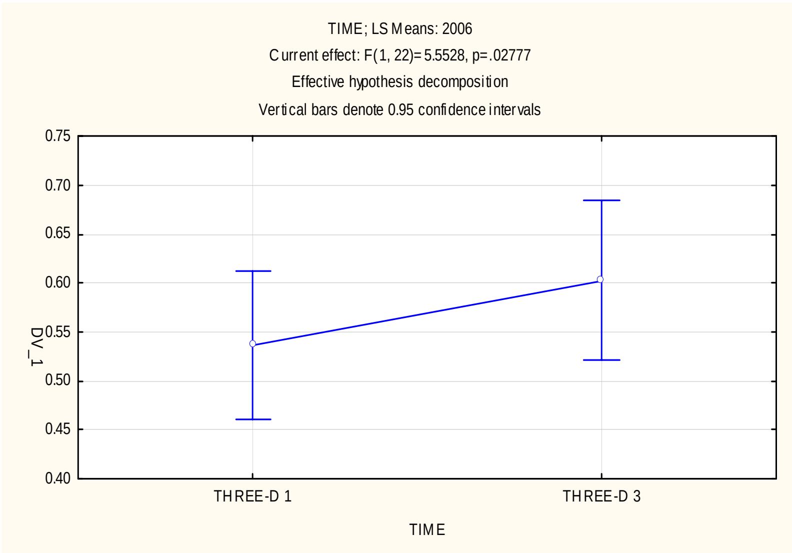

Figure 4.22: Difference in performances of whole class before and after the intervention
Results of three-dimensional tests 1 and 2 (2006)
(Three-D 3 means second three-dimensional test done in time period

Figure 4.22 demonstrates the difference in performance pertaining to general three-dimensional abilities, before and after the intervention, of the whole class of 2006 (n = 23).

ANOVA

Since $p = 0.028$ is less than 0.05, $F = 5.553$ is statistically significant ($p < 0$ .05), and the null hypothesis is rejected.

The mean of three-dimensional test 1 is 0.537 (54%) and the mean of three-dimensional test 2 is 0.603 (60%). The median of three-dimensional test 1 is 0.530 (53%) and the median of three-dimensional test 2 is 0.630 (63%).

The standard deviation of three-dimensional test 1 (before the intervention) is 0.176 and the standard deviation of three-dimensional test 2 (after the intervention) is 0.188 (Refer to Table 4.4).

The range for each group

Three-dimensional test 1: 87% - 13% = 74%

Three-dimensional test 2: 97% - 23% = 74%

Intervention effect

There is a 6% difference in the means, as well as a 10% difference in the medians, both favouring the intervention group.

Effect size = $(M_e - M_c) \div SD = (0.603 - 0.537) \div 0.176 = 0.4$ which is a small difference.

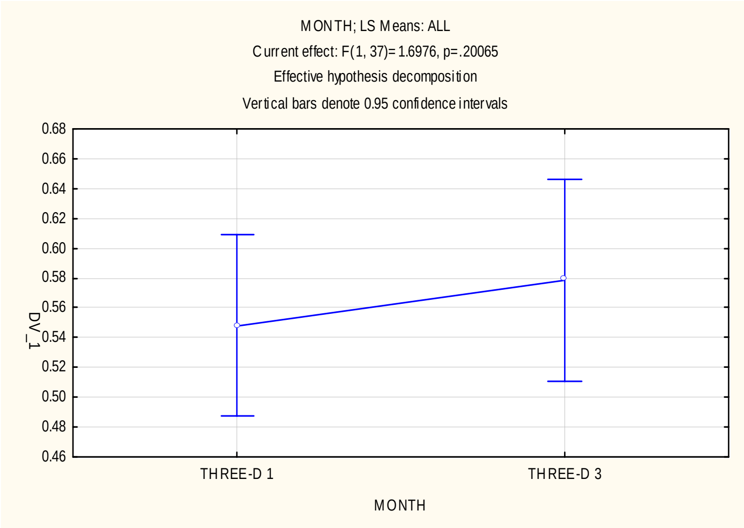

Figure 4.23: Difference in performances of whole class before and after the intervention
Results of three-dimensional tests 1 and 2 (2005 and 2006 groups)
(Three-D 3 means second three-dimensional test done in time period 3)

Figure 4.23 demonstrates the difference in performance pertaining to general three-dimensional abilities, before and after the intervention, of both classes of 2005 and 2006 ($n = 38$).

ANOVA

Since $p = 0.201$ is more than 0.05, $F = 1.698$ is not statistically significant ($p > 0.05$), and the null hypothesis is accepted.

The mean of three-dimensional tests 1 is 0.548 (55%) and the mean of three-dimensional tests 2 is 0.579 (58%). The median of three-dimensional tests 1 is 0.550 (55%) and the median of three-dimensional tests 2 is 0.600 (60%). The standard deviation of three-dimensional tests 1 is 0.185 and the standard deviation of three-dimensional tests 2 is 0.205 (Refer to Table 4.5).

Intervention effect

There is a 3% difference in the means, as well as a 5% difference in the medians, both favouring the group with treatment.

Effect size = $(M_e - M_c) \div SD = (0.579 - 0.548) \div 0.185 = 0.16$ which is a small difference.

There is therefore not really a pattern between the data of the year group of 2005 and the year group of 2006. The performance in general three-dimensional thinking of the group of 2006 improved after the intervention, but the performance of the group of 2005 worsened.

4.2.1.4 The influence of gender

The minimum and maximum percentages of males per second year radiography class (2000 to 2004) at the specific training institution used for this research, were 0% (2000) and 25% (2004). The average results for second year radiography film-viewing assessments (2001 to 2004), where spatial skills were involved in executing the tasks, were calculated separately for the male and female students. The average percentage for the males was 70%, compared to the lower average score of 67% for the women.

In 2005 four out of the group of fifteen students were male participants (27%), while in 2006 only one out of the group of twenty-three students was a male participant (4%). In 2005 the mean in the final film-viewing assessment for the female students was 79% compared to the mean of 69% for the four male students. In 2006 the mean for the females was 74% compared to the score of 68% for the one male student. In the final three-dimensional test in 2005 the four male students achieved a mean of 65% in comparison with the mean of 50% for the female students. In the final three-dimensional test in 2006, the only male student achieved 67% in comparison with the mean of 60% for the female students.

It seems that when applying three-dimensional skills in film-viewing assessments, the female students performed better than the male students after the intervention (2005 and 2006 groups) than before the intervention (2001 - 2004 groups), but when using general three-dimensional abilities in three-dimensional tests (after the intervention), the males outperformed the females.

The average results of the males would probably be different and also more valuable, with a higher percentage of males participating in the assessments.

4.3 Qualitative data

A qualitative research design is much more flexible than a quantitative design. It depends on environmental factors, as well as the input from the participants. Qualitative research involves a holistic approach to situations. The data are not presented in numbers and do not require statistical calculation (Berg & Latin, 1994). Quantitative data were mainly obtained in this research. Qualitative data (feedback) were however obtained from the 2006 participants on the intervention, as well as from both the 2005 and 2006 groups on the film-viewing assessments.

4.3.1 Feedback from students on practical sessions

Feedback on the research activities was requested from the participants of 2006. Here follows some of the positive feedback that was received:

- “Excellent. Really helped me a lot!” (Student 6.23).
- “I think the practicals helped to a great extent.” (Student 6.21).
- “Thank you for the classes. The practicals were worthwile. We have really learned a lot.” (Student 6.20).
- “The practical sessions have helped a great deal. Thanx!” (Student 6.6).
- “It really helped me a lot!” (Student 6.13).
- “Small mistakes that count marks in the film evaluations were sorted out. It has helped very much. Thank you.” (Student 6.3).
- “It helped a great deal, I think it must be done every year. Thank you.” (Student 6.7).

- “Extra practicals have helped to a large extent. Understand the oblique projections much better.” (Student 6.14).
- “Practicals have helped a lot, especially with rotation of PA and AP.” (Student 6.16).
- “After the extra classes I now know how to correct my films when needed.” (Student 6.9).
- “Thank you very much. The classes were very interesting and I have learned a lot.” (Student 6.4).

Out of 23 students, 22 reacted positively with a “yes” on all the questions of the questionnaire (Refer to Appendix Q). Only one student responded at one question with “slightly” (to recognise the position and shape of structures with supero-inferior/infero-superior projections and to identify direction for example, anterior or posterior).

4.3.2 Feedback from students on film-viewing assessments

Feedback, as with all the OSCE s at this institution, was requested from the students on each of the film-viewing assessments. Due to the fact that the feedback was anonymous, the data of the three students with extra clinical experience could not be excluded. Although they participated in the research activities, their data were excluded from all the other experiments.

4.3.2.1 Feedback from the 2005 group

Even with the excellent performance of the students in the third film-viewing assessment, 16% still found the questions difficult compared to the 12.5% who found it difficult in the first film-viewing assessment. Only 6% of them found the questions difficult in the second film-viewing assessment. They gradually had fewer problems with time from the first to the third film-viewing assessment. They however experienced increased anxiety from the first to the third film-viewing assessment. A number of students (47%) commented that they did not prepare enough for the first film-viewing assessment and even more of them (62.5%) mentioned that they did not prepare enough for the second film-viewing assessment. Preparation time was less of a problem in the last film-viewing assessment (Refer to Table 4.6).

Table 4.7: Feedback received on certain questions regarding film-viewing assessments in 2005

	Film assessment 1			**Film assessment 2**			**Film assessment 3**		
Question	Yes	No	None /other answer	Yes	No	None /other answer	Yes	No	None /other answer
Were the assignments clear?	97%	3%		91%	9%		97%	3%	
Were the assignments too difficult for you?	12.5%	75%	12.5%	6%	88%	6%	16%	78%	6%
Was the time enough to complete the assignments?	62.5%	37.5%		81%	19%		87.5%	12.5%	
Were you abnormally tense/anxious during the examination?	34%	66%		44%	56%		50%	50%	
Did you prepare yourself enough for the examination?	53%	47%		37.5%	62.5%		91%	9%	

4.3.2.2 Feedback from the 2006 group

Students of the 2006 group found the questions progressively less difficult from film-viewing assessment 1 to film-viewing assessment 3.

They however still experienced difficulties with time in the third film-viewing assessment. Time was however less of an issue in the second film-viewing assessment. More of them (18%) were tense in the third film-viewing assessment compared to the 14% in the first film-viewing assessment. Fewer students were anxious in the second film-viewing assessment compared to the other two assessments. According to the students, their preparation time increased gradually from the first to the third film-viewing assessment (Refer to Table 4.7).

Table 4.8: Feedback received on certain questions regarding film-viewing assessments in 2006

	Film assessment 1			**Film assessment 2**			**Film assessment 3**		
Question	Yes	No	None /other answer	Yes	No	None /other answer	Yes	No	None /other answer
Were the assignments clear?	96%		4%	96%	4%		100%		
Were the assignments too difficult for you?	10%	78%	12%	4%	96%		0%	100%	
Was the time enough to complete the assignments?	84%	16%		92%	8%		84%	16%	
Were you abnormally tense/anxious during the examination?	14%	86%		8%	92%		18%	82%	
Did you prepare yourself enough for the examination?	76%	20%	4%	83%	17%		92%	8%	

4.3.2.3 Patterns in the data of the feedback (both groups)

The number of students who experienced anxiety, increased from the first to the third film-viewing assessments for both year groups (24% in the first film-viewing assessment, 26% in the second film-viewing assessment and 34% in the third film-viewing assessment). In all three, the film-viewing assessments over the two years (2005 and 2006) an average of 28% of students experienced anxiety. In 2006 however a fewer number experienced anxiety in the second film-viewing assessment. Their feedback was anonymous therefore it could not be compared with their specific results.

Questionnaires completed by the students after the film-viewing assessments in 2001 to 2004 (groups without intervention), reveal that about 39% of students tended to be extremely anxious before evaluations, compared to the 34% of students who experienced anxiety in the final assessments in 2005 and 2006 (groups with intervention). It seems that the questions in the film-viewing assessments (2005 and 2006) were all fairly comprehensible to the students, although 9% of them found it difficult to understand some questions in film-viewing assessment 2 of 2005.

Conflicting feedback were obtained between these two groups (2005 and 2006) with regard to some questions of the questionnaires.

4.4 Conclusion

The next step is to declare whether the hypothesis, after exploration, can be accepted or has to be rejected.

4.4.1 The research hypothesis versus the null hypothesis

The research hypothesis of this research entails the following statements:

- There is a relationship between students' perceived limited three-dimensional thinking abilities and the difficulties they experience in the evaluation of two-dimensional radiographic images.

- There will be a difference in the skills of students who received in-depth training sessions aimed at developing critical thinking skills to interpret radiographic images and those students who did not receive the training.

The null hypothesis of this research therefore involves the following opposite statements:

- There will be no statistically significant relationship between students' perceived limited three-dimensional thinking abilities and the difficulties they experience in the evaluation of two-dimensional radiographic images.

- There will be no statistically significant differences in the skills of students who received in-depth training sessions aimed at developing critical thinking skills to interpret radiographic images and those students who did not receive the training.

Hypothesis accepted or rejected?

- In the case of the first statement, the hypothesis is rejected in favour of the null hypothesis. The radiography students do not experience problems in the evaluation of two-dimensional radiographic images due to their limited three-dimensional thinking abilities.

- The second statement is however more complicated to reject or accept. After the initial interventions with the intervention groups and the students' performances in the second film-viewing assessments, the null hypothesis has to be accepted. However, the significant impact on the performance of the whole group (both classes of 2005 and 2006) in the final film-viewing assessments (after the interventions with the control groups), as well as the positive feedback from the students, show that the hypothesis can be accepted. Data of these two intervention groups (classes of 2005 and 2006) were also compared with that of previous years (control groups), which also show significant improvement in performance pertaining to film-viewing assessments after the intervention. The general three-dimensional abilities of the group of 2006 also improved significantly after the intervention (but not that of the 2005 group). In conclusion the null hypothesis is rejected in favour of the alternative hypothesis. In-depth training sessions can develop spatial skills in radiography students, which should enable them to interpret these images.

The data presented in this chapter will be discussed and compared to the research literature, in Chapter Five.

CHAPTER FIVE
THE INTERPRETATION OF THE RESEARCH RESULTS

5.1 Quantitative data

The quantitative data, obtained in this research, were examined and compared to the research literature. Patterns found in the data are discussed below.

5.1.1 Investigation of sub-problem one: correlation between three-dimensional tests and film-viewing assessments

Correlation between the students' performance in three-dimensional tests and film-viewing assessments was determined. Only a weak to moderate correlation between the marks that the students achieved in the three-dimensional tests and the marks achieved in the film-viewing assessments, was found. It shows that there is a difference in item type between these two tests and that they do not measure the same type of skill. Dean and Morris (2003) agree that there is a difference between questionnaires which force subjects to generate and manipulate colourful mental pictures of objects (previously seen) and spatial tests, which require the manipulation of abstract geometrical shapes (usually not previously seen). Real life objects are created from information stored in the long-term memory, while geometrical shapes are perceived and temporarily stored or manipulated in the short-term memory. The film-viewing assessments forced the students to recall mental pictures of familiar anatomical structures (previously seen), while the items of the three-dimensional test consisted of abstract geometrical forms, which were unfamiliar to them.

According to Hegarty *et al.* (2007) spatial abilities, which are measured by spatial tests, are relatively general cognitive abilities that are related to the performance of tasks in a variety of medical professions. More important, the results also reveal that extensive practice and experience develop task specific skills.

Film-viewing assessments also require task specific skills (applied three-dimensional skills), which can therefore be developed by practice. Rochford (1985), however, posits a relationship between spatial ability and the acquiring of spatial skills. According to Rochford (1985), about seven to ten percent of subjects with low spatial abilities will not acquire anatomical spatial skills with practice. In this research (2005 to 2006) seven out of thirty-eight students (18%) achieved lower marks in the final film-viewing assessments (after the intervention) compared to the initial film-viewing assessments (before the intervention). Four of these seven students achieved between 67% and 90% in the final three-dimensional tests. Not all of them were therefore students with weak spatial abilities.

Students' performances in the film-viewing assessments do not correlate highly with their performances in the three-dimensional tests. The results of this research therefore show that even students with low spatial abilities can achieve high marks in film-viewing assessments (Refer to Table 5.1).

Table 5.1: Examples of huge differences between performances in the second three-dimensional tests and in the third film-viewing assessments (2005 and 2006) Assessments done after the intervention

Student code	Three-dimensional test 2	Film-viewing assessment 3
5.1	17%	65%
5.3	47%	80%
5.9	23%	90%
5.12	50%	75%
6.4	43%	95%
6.11	27%	73%
6.14	27%	75%
6.21	37%	78%

5.1.2 Investigation of sub-problem two: impact of intervention on applied three-dimensional skills

A curricular intervention that was intended to improve three-dimensional skills, pertaining to radiographic images, was developed and applied. The impact of the curricular intervention on students' applied three-dimensional skills was evaluated.

5.1.2.1 The intervention and applied three-dimensional skills

Interesting patterns found in the data of the film-viewing assessments are the following:

(a) Pattern one: reasonable differences achieved, but significance not achieved by intervention groups

The intervention groups did not perform significantly better after the intervention ($p = 0.213$ in 2005 and $p = 0.296$ in 2006). In both the 2005 and 2006 second film-viewing assessments (after the intervention) the performances of the intervention groups did not achieve significance compared to that of the control groups (Refer to Figure 4.9 and Figure 4.10). The sample group (*n*) consisted of fifteen second year diagnostic radiography students in 2005 (seven in the intervention group and eight in the control group) and twenty-three second year diagnostic radiography students in 2006 (eleven in the intervention group and twelve in the control group). The sample sizes used in this research were therefore very small. According to Berg and Latin (2004) and Brown and Dowling (2001), the intervention effect could be notable, but if the sample size is small, it may not achieve statistical significance. The fact that the second film-viewing assessments did not count towards their year mark could have influenced the performances of both groups (control and intervention) negatively, but should not contribute to the differences between the groups after the intervention.

Findings should however not be discarded if they do not attain significance at the 0.05 ($p \leq$ as 0.05) level (Berg & Latin, 2004). As already discussed, Barker *et al.* (2001) state that intervention effect sizes are more crucial than *p* – values.

Intervention effect for the 2005 group

The difference between the means is 11% and the difference between the medians 20%, both favouring the intervention group. The effect size = 0.59 which is, according to Cohen reported in Berg and Latin (2004), a reasonable difference (more than 0.5).

Intervention effect for the 2006 group

The difference between the means is 9% and the difference between the medians 10%, both favouring the intervention group. The effect size = 0.57 which is according to Cohen, reported in Berg and Latin (2004), also a reasonable difference (more than 0.5).

In the first trial (2005), the initial post-test (the second film-viewing assessment test) was administered approximately four weeks after the pre-test, while in the second trial (2006), the initial post-test was administered approximately five weeks after the pre-test. The reason for the four-to-five-week period was to exclude factors causing an increase in performance (Welman & Kruger, 2000; Berg & Latin 2004; Barker *et* *al.*, 2001). The control groups would, however, also eliminate these factors (Benwell, 1990).

It must be mentioned that one of the students (5.2) in the intervention group of 2005, had motivational problems regarding the whole radiography course at the time of the second film-viewing assessment. Her mark decreased from 65% in the first film-viewing assessment to 38% in the second film-viewing assessment. A student (6.1) in the intervention group of 2006 had emotional problems and her mark also decreased from 85% to 33% in the similar assessment. The notable decrease in performance of both students was in contrast with the performance of the rest of these intervention groups. Logie (1995) states that it is statistically legal to omit the data of participants who are totally different from the rest of the group, from an analysis. The data of these two students were however not omitted from the analysis and this could have influenced the performances of the intervention groups.

The reasonable differences as a result of the intervention are of enough importance for the researcher to apply the same intervention in future to assist students in assessing radiographic images. The small sample sizes could be the reason for not attaining statistical significance.

(b) Pattern two: contrasting performance of intervention and control groups

In the second film-viewing assessments (after the intervention) the performance of the control groups decreased compared to their performance in the pre-test, while the performance of the intervention groups increased (for both the 2005 and 2006 groups).

Table 5.2: Differences in the means of the intervention and control groups of 2005 and 2006 (before and after intervention)

2005		**2006**	
Mean of control group before intervention	Mean of control group after intervention	Mean of control group before intervention	Mean of control group after intervention
62%	56%	62%	57%
Mean of intervention group before intervention	Mean of intervention group after intervention	Mean of intervention group before intervention	Mean of intervention group after intervention
62%	67%	62%	66%

The researcher and moderator used different radiographic projections in the re-tests that measured the same skills as in the pre-tests, in an attempt to prevent the students from anticipating the answers in the re-tests. It could be possible that the intervention groups could apply their skills obtained in the intervention to the alternative projections. These projections could also have been more difficult than the projections in the first film-viewing assessment, resulting in the weaker performance of the control groups.

(c) Pattern three: significance achieved by both class groups after the intervention

Statistical significance was achieved with both year groups after the whole class had received the intervention (p = 0.003 in 2005 and p = 0.002 in 2006). The data were obtained at the third film-viewing assessments after the control groups had received the intervention. Figure 4.12 demonstrates the effect of the intervention on the whole class of 2005 (n = 15) and Figure 4.15 demonstrates the effect of the intervention on the whole class of 2006 (n = 23).

Intervention effect for the 2005 group

The difference between the means is 14% and the difference between the medians is 10%, both favouring the group after the intervention. The effect size = 1.03 which is, according to Cohen reported in Berg and Latin (2004), a significant difference (more than 0.8).

Intervention effect for the 2006 group

The difference between the means is 12% and the difference between the medians is 8%, both favouring the group after the intervention. Effect size = 0.69 which is according to Cohen, reported in Berg and Latin (2004) a reasonable difference (more than 0.5).

The smaller group of 2005 (n = 15) therefore performed somewhat better than the group of 2006 (n = 23). The distribution of marks after the intervention of the group of 2005 (displayed in Figure 4.14) shows an increase of the mean, as well as a shift of the scores to the right side (above the mean). The distribution of marks after the intervention of the 2006 group (displayed in Figure 4.17) shows an increase of the mean, but a larger number of scores are demonstrated below the mean compared to that above the mean. An explanation for the better performance of the smaller class could be the bigger ratio of lecturer to students (1:15 instead of 1:23). The smaller class could also have been more motivated.

Significance might have been attained because of the bigger groups in contrast with the small groups of the second film-viewing assessments. The data of the whole class were included. There were no control groups used (data of the whole class after the intervention, were compared to the data of the whole class before the intervention). Maturation and history could however have influenced the results of the final film-viewing assessments, because no control groups were used and the assessments were executed approximately two months after the pre-tests (Welman & Kruger, 2000; Berg & Latin 2004; Barker *et al.,* 2001). As discussed earlier, the skeletal part of the subject Anatomy was already completed before the onset of this research. Only clinical experience in certain modified radiographic projections (which are not done daily by second year students) could have played a role regarding history effects. The effect of re-testing could also have influenced the results (Berg & Latin, 2004). As previously mentioned, different radiographic projections/films were used in the re-tests, in an attempt to eliminate this effect.

The final (third film-viewing) assessments also counted towards the students' year mark. This could have motivated them, more than in the second film-viewing assessment, to perform well. They, however, would also have given their best in the first film-viewing assessments (which also counted towards their year mark), which acted at that stage as control assessments to determine the difference in performance of the whole class before and after the intervention. The researcher considers the notable increase in the performance of some "weaker" students of both year groups as a worthwhile effect (Refer to Table 5.3).

Table 5.3: Examples of huge differences between performances in the first film-viewing assessments and in the third film-viewing assessments (2005 and 2006)

Student code	**Film-viewing assessment 1**	**Film-viewing assessment 3**
5.3	43%	80%
5.6	55%	73%
5.12	35%	75%
6.2	38%	68%
6.14	45%	75%
6.23	48%	75%

An interesting finding, which is applicable to this research, although not part of the analysis of this research, has to do with the same intervention with the class group of 2007. They however executed only one film-viewing assessment (after the intervention), which was similar to the first film-viewing assessments of 2005 and 2006 (before the intervention). No control and intervention groups were involved.

The single assessment eliminated the re-testing effect. The class achieved a mean of 71% (after the intervention), compared to the mean of 62% of both the 2005 and 2006 groups (before the intervention), for the similar "stations". The intervention therefore could have played a role in the 9% performance difference. The 2005 and 2006 intervention groups achieved an average mean of 67% in the second film-viewing assessments (after the intervention), but the whole class groups however performed much better after the intervention in the third film-viewings assessment (mean for both groups = 75%), where re-testing could have influenced the results.

(d) Pattern four: significance achieved by intervention year groups compared to previous years

The intervention year groups also performed significantly better ($p = 0.006$) than the previous year groups (without the intervention). These groups (2000 – 2004) then acted as control groups. Figure 4.20 demonstrates the effect of the intervention on the intervention classes of 2005 and 2006 compared to the control classes of 2000 to 2004.

Intervention effect for both 2005 and 2006 groups

The mean of the control groups (2000 – 2004) for the final film-viewing assessments = 0.678 (68%), while the mean of the intervention groups (2005 – 2006) for the third and final film-viewing assessments = 0.746 (75%). The difference between the means is therefore 7%.

Significance could have been attained because of the bigger sample group ($n = 38$) in contrast to the small sample groups of the second film-viewing assessments. Data for both classes (2005 and 2006) were included.

The assessments of the previous years' groups (2000 - 2004) took place at approximately the same time of the year as the third film-viewing assessments of this research, which would reduce the effects of history and maturation, but not the effects of re-testing. Only one final film-viewing assessment was executed by each of the previous year groups in contrast with the three film-viewing assessments of the research groups.

5.1.2.2 Discussion of patterns during film-viewing assessments

The above-mentioned patterns confirm the results of previous research that the effects of cognitive abilities on performance, decrease with practice (and the gaining of skills). People with different abilities can acquire these practical skills (Hegarty *et al.*, 2007; Keehner *et al.*, 2004; Ackerman, 1988; Sidhu *et al.*, 2004).

According to Ackerman (1988), skill acquisition will only be possible when practising consistent tasks. Ackerman (1988) also mentions that complex tasks will rely heavily on general cognitive abilities, even after intensive practice. The alternative projections used in the second and third film-viewing assessments could have been more difficult for some students than those used in the initial film-viewing assessments, which could also have influenced their performance negatively. Correlation studies of the different film-viewing assessments were however done.

5.1.2.3 Correlation analysis of film-viewing assessments

To achieve content validity pertaining to the instrument used in this research, each type of projection that was used and the skill/s that were measured, were tabled before the tests and moderated. The questions set to measure these skills, were also moderated. This procedure was intended to ensure that the film-viewing assessment measured what it was suppose to measure.

To achieve reliability or consistency between the different film-viewing assessments, three similar tests were conducted to measure the same three-dimensional skills in the students pertaining to film-viewing assessments. The researcher and moderator, to check that the same skills were measured and that similar questions and projections were used, compared the pre-tests and re-tests. The students could not carry out identical tests, because they would probably have performed much better in the re-tests, due to the practice effect (Berg & Latin, 2004; Benwell, 1990). Statistical correlations were performed on four of the film-viewing assessments (two used in 2005 and two in 2006). All these assessments correlated moderately, but the correlation test of film-viewing assessments one and three of 2005, however, did not achieve significance when tested separately (p = 0.1409). This could be because different films or different projections were used to eliminate the practice effect and some of the projections could have been slightly more difficult to interpret.

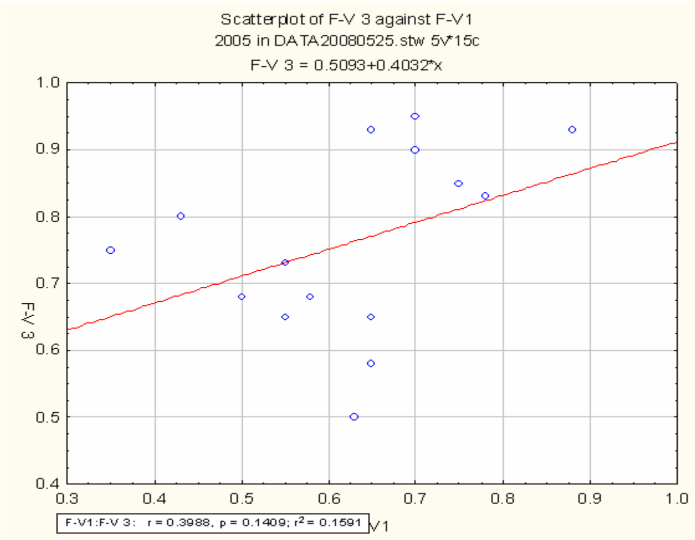

Figure 5.1: Correlation study between data of film-viewing assessments 1 and 3 of 2005

Since *p* = 0.1409 is more than 0.05, *r* = 0.3988 is not significant (*p* > 0.05). The marks of the first film-viewing assessment and the third film-viewing assessment of year group 2005 correlate only moderately. According to Berg and Latin (2004) the correlation is weak if *r* is 0.25 or less than 0.25, it is moderate if *r* is between 0.26 to 0.50, it is fair if *r* is between 0.51 and 0.75 and it is high if *r* is above 0.75.

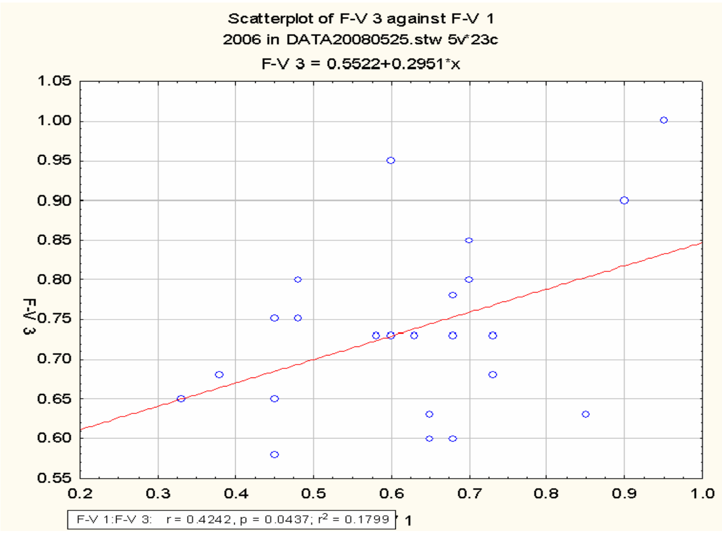

Figure 5.2: Correlation study between data of film-viewing assessments 1 and 3 of 2006

The following data refer to Figure 5.2:

Since $p = 0.0437$ is less than 0.05, $r = 0.4242$ is significant ($p < 0.05$). The marks of the first film-viewing assessment and the third film-viewing assessment of year group 2006 correlate moderately.

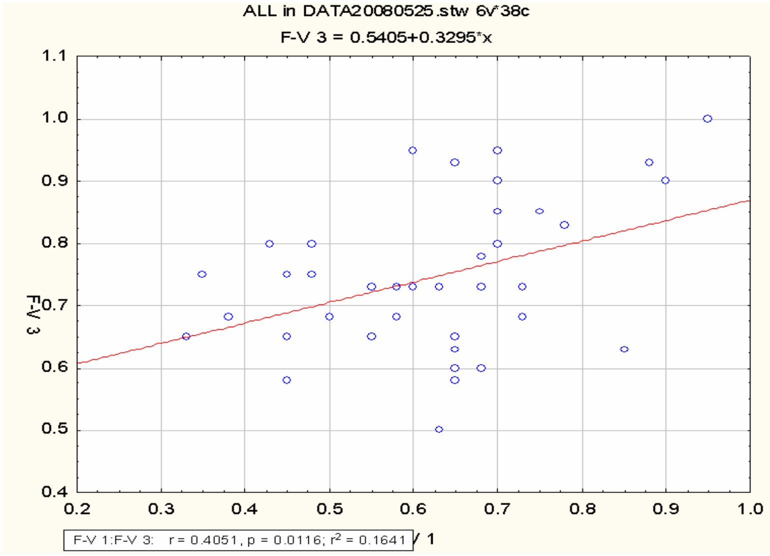

Figure 5.3: Correlation study between data of film-viewing assessments 1 and 3 of 2005 and 2006

The following data refer to figure 5.3:

Since $p = 0.0116$ is less than 0.05, $r = 0.4051$ is significant ($p < 0.05$). The marks of the first film-viewing assessments and the third film-viewing assessments of both year groups of 2005 and 2006 correlate moderately.

5.1.3 Investigation of sub-problem three: impact of intervention on general three-dimensional cognitive abilities

The impact of the curricular intervention on students' general cognitive abilities, pertaining to three-dimensional thinking, was evaluated. The students completed a three-dimensional test on two occasions (before and after the intervention) measuring mental rotation abilities. This basic test shows the general intelligence of the students pertaining to three-dimensional thinking (Owen & de Beer, 1997).

5.1.3.1 The intervention and general three-dimensional abilities

There is no evident pattern between the data of the year group of 2005 and the year group of 2006. The performance in the general three-dimensional thinking of the group of 2006 improved significantly after the intervention ($p = 0.028$), but the performance of the group of 2005 declined ($p = 0.552$). Maturation and history could have influenced the results of the final three-dimensional tests (when compared to the pre-tests) because no control groups were used and the re-tests were executed approximately two months after the pre-tests (Welman & Kruger, 2000; Berg & Latin 2004; Barker *et al.,* 2001). The results after intervention with the whole class were compared to the results before the intervention. The threat of re-testing could also have influenced the students' performance in the final assessments, because this threat could have equipped the students with skills in executing these tests (Berg & Latin, 2004). Maturation, history and re-testing effects, however, did not influence the performance of the 2005 group positively. It is thus very unlikely that these effects could have played a major role in the better performance of the 2006 group, since the academic and practical experience was more or less similar for both year groups. The bigger sample group ($n = 23$) of the 2006 class could have played a role in achieving significance after the intervention.

Intervention effect of 2005 group

There is a 3% difference in the means, as well as a 3% difference in the medians, both favouring the group without the intervention.

Intervention effect of 2006 group

There is a 6% difference in the means, as well as a 10% difference in the medians, both favouring the intervention group. Effect size **=** 0.4 which is according to Cohen, reported in Berg and Latin (2004) a small difference (more than 0.2 but less than 0.5).

According to Olkun (2003) and Strong and Smith (2001), there are contradictory research findings regarding the possibility of developing spatial abilities.

Professionals in engineering graphics believe spatial visualisation skills can be developed by experience (Strong & Smith, 2001). Please note that "skills" are mentioned, which is different from inheritable cognitive "abilities". Several researchers however state that through thorough training and the use of suitable learning material spatial ability can be developed (Ben-Chaim *et al.*, 1988; Lord, 1985). The contrasting evidence between the data of the two groups (2005 and 2006) and the small intervention effect on the performance of the group of 2006 makes the intervention not applicable for the increase of general spatial abilities in future.

5.1.3.2 Correlation analysis of three-dimensional tests

The three-dimensional test used in this research is a standardised test used for evaluating the performance of various groups of students in the past and should therefore be a reliable test. Correlation tests were performed which showed a strong correlation among all these tests. The identical test was used for all the measurements.

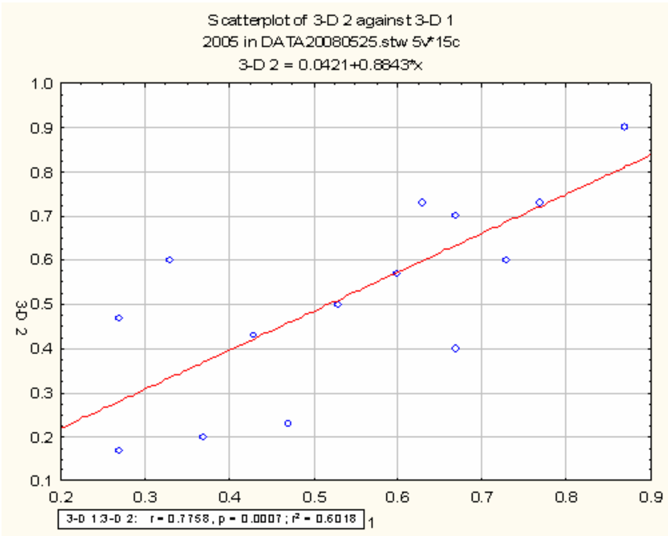

Figure 5.4: Correlation study between data of three-dimensional tests 1 and 2 of 2005

Since $p = 0.0007$ is less than 0.01, $r = 0.7758$ is significant ($p < 0.01$). The marks of the first three-dimensional test and the second three-dimensional test of year group 2005 correlate highly.

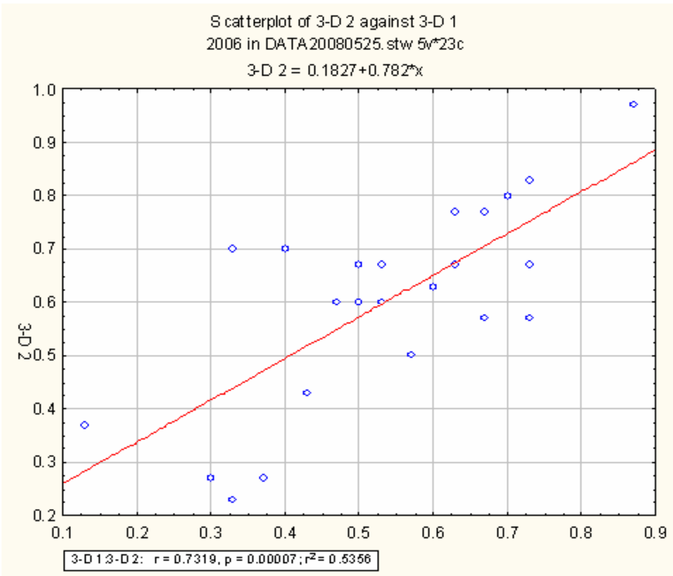

Figure 5.5: Correlation study between data of three-dimensional tests 1 and 2 of 2006

Since p = 0.00007 is less than 0.01, r = 0.7319 is significant ($p < 0.01$). The marks of the first three-dimensional test and the second three-dimensional test of year group 2006 correlate fairly (Refer to figure 5.5).

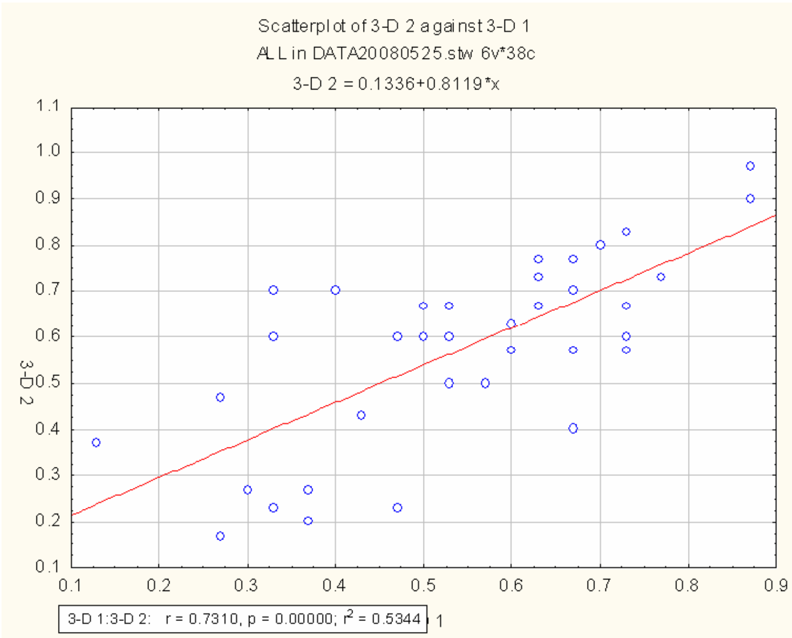

Figure 5.6: Correlation study between data of three-dimensional tests 1 and 2 of 2005 and 2006

Since p = 0.0000 is less than 0.01, r = 0.7310 is significant ($p < 0.01$). The marks of the first three-dimensional tests and the second three-dimensional tests of year groups 2005 and 2006 correlate fairly.

5.1.4 The influence of gender

The research done by Garg *et al.* (1999) and many more researchers, show that men perform significantly better on a generic spatial ability test than women.

The average results for second year radiography film-viewing assessments (2001 to 2004), where applied spatial skills were involved to execute the tasks, were calculated separately for the female and male students. The average percentage for the males was 70%, compared to the lower average score of 67% for the women. In 2005 the mean in the final film-viewing assessment for the female students was 79% compared to the mean of 69% for the four male students. In 2006 the mean, in the same assessment, for the females was 74% compared to the score of 68% of the one male student. However, in the final three-dimensional test in 2005 the four male students achieved a mean of 65% in comparison with the mean of 50% for the female students. In the final three-dimensional test in 2006, the only male student achieved 67% in comparison with the mean of 60% for the female students.

It seems that pertaining to general three-dimensional abilities, the males outperformed the females, which confirms previous research. Pertaining to applied three-dimensional skills, the female students of the intervention year groups (2005 and 2006) performed better than the male students, compared to the female students of the previous year groups (2001 to 2004) without the intervention, who performed worse than the males. The average results of the males would probably be different, and also more significant, with a bigger sample group and a higher percentage of males participating in the research.

5.1.5 The influence of attitude on performance in assessments

A considerably widespread range of results, pertaining to spatial orientation tests, might have been caused by motivational factors (Kosslyn, 1980; McGee, 1979). The weak correlation of the three-dimensional tests with the film-viewing assessments could also have been influenced by the motivation of the students because the three-dimensional tests did not count towards their annual mark. Contrasting results were however achieved between the 2005 and 2006 groups in these three-dimensional tests. The anxiety that a group of students experienced throughout all the film-viewing assessments could also have influenced their performance negatively.

5.2 Qualitative data

The qualitative data, obtained in this research, will be scrutinized and compared to the research literature. Patterns found in the data will be discussed.

5.2.1 Feedback from students on practical sessions (2006)

Out of 23 students, 22 reacted positively to all the questions of the questionnaire (Refer to Appendix Q). Only one student responded to the question (pertaining to comprehending the images of axial projections) that the intervention benefited him only “slightly”. It is thus clear, according to the feedback of the students, that they experienced the practical sessions as valuable to their training.

5.2.2 Feedback from students on film-viewing assessments (2005 and 2006)

In the final film-viewing assessments of the intervention year groups (2005 and 2006), 34% of students experienced anxiety, compared to the 39% of students who experienced anxiety in the film-viewing assessments of the previous year groups (2001 to 2004) without the intervention. The anxiety effect therefore decreased slightly after the intervention.

An unusual pattern was found with the intervention groups. The number of students who experienced anxiety increased from the first to the third film-viewing assessments for both the intervention year groups (2005 and 2006). The anxiety should have decreased with more practice. It could be that they tried harder to perform towards the end of the year, or that they found the alternative projections in the second and the third film-viewing assessments more difficult to interpret. In 2005, more students complained in film-viewing assessment 3, than in film-viewing assessment 1, with regard to finding the assignment difficult. In 2006 less students experienced anxiety in the second film-viewing assessment. A reason could be that the assessment did not count towards the students' annual mark. According to Baddeley *et al.* (1995), people who are anxious during assessments, may either perform better, or fail in their memory tasks. Eye tension will influence the observation and interpretation of images negatively (McKim, 1980).

Figure 5.7: Radiography student doing a film-viewing assessment (Sketch drawn by researcher)

Although the researcher tried to create a relaxed atmosphere during the film-viewing assessments, there is a limit to relaxation, taking into account that these assessments are always executed under strict examination circumstances. Breathing exercises just before the onset of the assessments can be incorporated in future. Some of the students' scores in this research could have been influenced by their emotional state.

Contradictory data were obtained from the two groups (2005 and 2006) across some questions of the questionnaire (students' feedback on film-viewing assessments). According to their feedback, some of them were unable to complete the assignments in the given time. Tarr and Pinker (1989) state that students need more time to recognise complicated objects, for example, objects when foreshortened and especially objects with a large number of units. Participants will use mental rotation to recognise unfamiliar shapes. They also note that with increased training, and the learning of certain characteristics or cues, participants will recognise these objects independently of the mental rotation task (match it with stored representations). According to Kosslyn (1980), larger and more complex images also require more time to rotate than smaller, less complex images. These images will therefore fade more with time than smaller images. More time is also needed to rotate an image or object farther from the original position (Rock, 1983; Kosslyn, 1980). The differences in the projections, could therefore have influenced the time for interpretation of an image, for example, a 45° oblique projection of the lungs will be more difficult to interpret than a slightly rotated AP projection of the lungs.

The nature of verbal description received before commencement of a mental task, may also influence the mode of image generation (e.g., it may increase or decrease the time for generating an image). For example, participants will not be able to recognise a tilted object if they have not been informed that the object may be in a strange position, or if there are no cues available (Kosslyn, 1980; Kosslyn, 1994; Tarr & Pinker, 1989; Rock, 1983). It seems that the questions were all generally comprehensible to the students, although some of them found it difficult to understand some questions in the second film-viewing assessment of 2005. It is thus important that enough cues are present in images, or that appropriate verbal descriptions are included in the assignments.

Despite the excellent performance of the students in the third film-viewing assessment of 2005, 16% found the assignments difficult compared to the 12.5% who found the first film-viewing assessment difficult. The projections used in the various film-viewing assessments differ, but all measured the same skills. It could be that some of the projections in the third film-viewing assessment were more difficult to interpret than those in the first film-viewing assessment. According to Joliceur (1992) students may find it difficult to apply skills that they have obtained to alternative, more complex images. Keep in mind that the correlation analysis done does not show a significant correlation between the two film-viewing assessments of 2005.

5.2.3 Discussion of practical sessions

According to Cox (2002) the clinical lecturer should be present when students practice their skills in order to identify and solve perceptual gaps. Students also prefer small group tutorials for learning practical skills (Whyke, 1985). In this research, the researcher (clinical lecturer) was present during the practical sessions (which consisted of groups of four to five students) to assist students in the interpretation of the radiographic images.

One of the practical assignments was to draw a cross-section of the thorax of the skeleton (skeleton in oblique position on X-ray table). The researcher noticed that some students did not understand the term “cross-section”. For example, they drew a cross-section of the thorax combined with the exterior features of the skeleton (Refer to Figure 5.9). Figure 5.8 demonstrates the correct presentation of this cross-section. In research done by Cohen *et al.* (2003) and Russell-Gebbett (1985), some of the subjects made exactly the same error. In the current research, the researcher could have explained the term “cross-section” in detail to the participants before they made the drawings. The researcher assisted the students with the corrections when wrong sketches were drawn. Provo *et al.* (2002) mention that students should be well informed on how to relate a cross-section to the entire body.

The student (6.14), who drew Figure 5.9, obtained 30% in the first three-dimensional test and 27% in the second three-dimensional test (after the intervention). She however increased her performance from 45% in the first film-viewing assessment to 75% in the third film-viewing assessment.

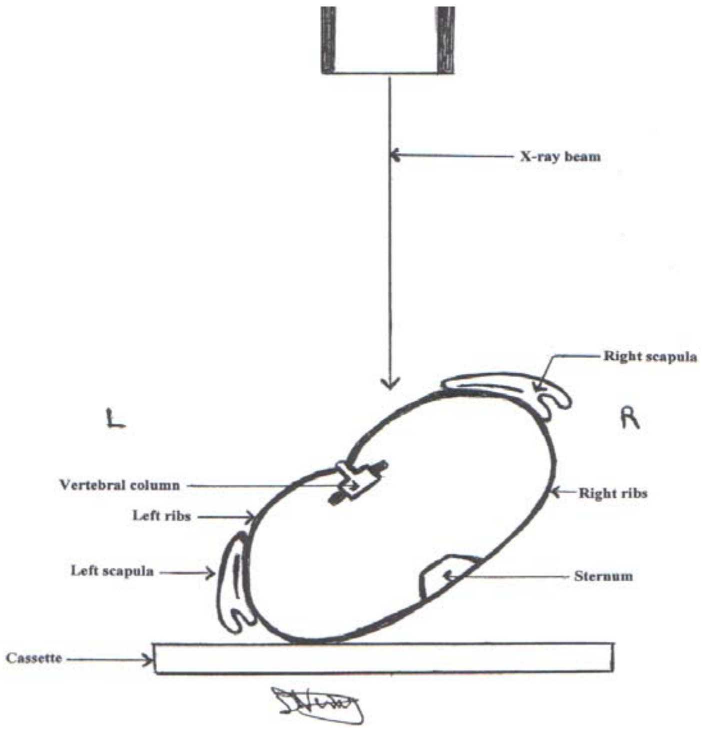

Figure 5.8: Cross section of the thorax seen from feet. Thorax in left anterior oblique position (sketch drawn by researcher)

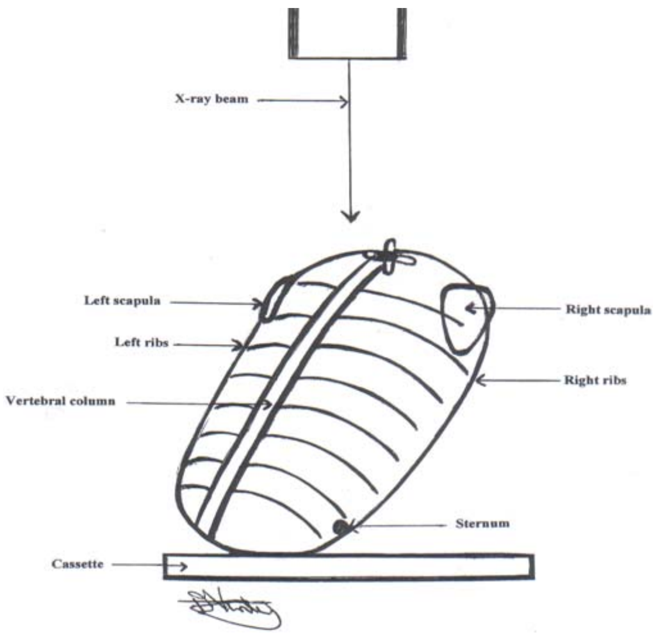

Figure 5.9: "Cross section" of the thorax seen from feet. Thorax in left anterior oblique position (sketch drawn incorrectly by student 6.14 and redrawn by researcher)

In the film-viewing assessments as well as during the practical sessions, the researcher noticed that the students found it difficult to recognise anatomical structures or identify directions (anterior/posterior) when the structures were tilted on their axes in space (structures seen "end on"). Rock (1983) also mentions that if subjects are suddenly confronted with an "end on" view of a complex object they will experience difficulties in recognising it, especially if there are no cues present. Russell-Gebbett (1985) suggests that teachers should encourage learners to search for cues. The researcher encouraged the students to look for patterns to identify structures seen "end on" in a radiographic image (e.g., a dense and foreshortened appearance of a structure, such as the iliac bone). McKim (1980) posits that awareness of the spatial cue of foreshortening is a prerequisite for accurate perception of a three-dimensional form (especially in a two-dimensional plane). McKim (1980) suggests drawing exercises for comprehending this cue. During the practical sessions in this research students drew anatomical structures in "end on" positions, as well as the radiographic images of these structures. Tarr and Pinker (1989) argue that only a few image attributes in the observed object are enough to match it with stored representations. Another example of a cue could be the image of the lateral or "end on" (thin/dense) scapula on a PA oblique projection of the thorax, which tells that a specific side of the thorax is in contact with the film (and subsequently the name of the projection would be identified). Previous research done by Joliceur (1992), also found that practice and the availability of cues would enhance recognition of objects in different orientations.

Logie (1995) states that there is enough evidence from previous research to show that if two objects are visually similar to one another, visual perplexity may occur when a person tries to remember one of these objects. This information is especially important in radiographic film-viewing assessments, where students have to identify oblique projections, which can appear very similar to one another, such as a right anterior oblique projection of the lungs versus a left anterior oblique projection of the lungs. It was also observed during the practical sessions that students found it difficult to distinguish between these two oblique projections. The previously mentioned cues could also be applied to solve this problem.

It is important to mention that according to Garg *et al.* (1999) demonstrating multiple projections using a concrete model to students, may handicap students with weaker spatial abilities. The brain can only remember and focus on key views (two-dimensional mental views) for example, one side of the body (anterior aspect/lateral aspect, etc.) and only afterwards rotate the information to form a three-dimensional mental view (oblique), if requested. A possible reason could be that these key or basic views display the biggest differences in the features of an object. Any extra information, such as presenting anatomical objects in rotated positions will not be remembered. Galton (1919) agrees that people will remember only the first view that they have observed of an object, instead of multiple views. The memories of multiple views will blend together and form a vague mental picture. People with stronger spatial abilities would be able to manoeuvre their mental images in any way. During this research the students focused on only two projections per practical session (eight projections in total for all the sessions). It could have been limited to lesser projections.

In research done by Harman *et al.* (1999) and James *et al.* (2002), participants rotated the object slightly from the key positions, into semi-oblique positions. These continuous small deviations from side to side seemed to provide enough information on the characteristics of all intermediate (oblique) views. The main advantage of active control of an object is the fact that it gives the participant the opportunity to envisage the modified view of the object, before rotating it in a specific direction and then checking his/her prediction after rotating the object. Garg *et al.* (2001) also emphasise the active control of models as a prerequisite for gaining spatial abilities. It is important that students, during practical sessions, have the opportunity to actively manipulate a model themselves, as was done in this research. They should be able to first focus on, for example, a basic AP projection of a pelvis and then afterwards slightly rotate the pelvis on their own from the AP (key view) to semi-oblique positions and back, comparing the positions of the anatomical structures with the relative radiographic image. In this research, because of time constraints, the students directly rotated the skeleton from the basic (key position) into the specific oblique position. The students could have spent more time on manoeuvring the skeleton.

Sketching/drawing inspires creativity and develops mental image-generation skills (McKim, 1980; Olkun, 2003; Sorby, 1999; Arvold, 1993). McKim (1980) claims that if observation, image-generation and drawing interact in tasks, visual thinking will be at its best. According to Sorby (1999) and Olkun (2003), in order to encourage meaningful learning, students should start with observing familiar concrete models then, secondly, proceed to the semi-concrete by drawing pictorial sketches of these models and, thirdly, proceed to the abstract, by visualising multiple views of the models and creating multi-view sketches. To achieve spatial skills, tasks should therefore be arranged from easy to more complex. Mental transformation from the second to the third dimension can be especially effective in developing spatial visualisation skills. The procedure during the practical sessions of this research followed more or less the same steps. The students positioned the skeleton for a specific projection and then observed the relations of the anatomical structures with the X-ray beam, as well as with the cassette. They then drew the skeleton in that position. Cross-sectional drawings were made of oblique projections, as well as drawings of the two-dimensional radiographic images of these three-dimensional structures. They therefore had to relate the position of a specific structure with its image on the film. At the abstract level, the students observed and interpreted the radiographic images at the follow-up sessions (using their image-generation skills). The researcher found the drawings beneficial, but extremely time-consuming. Some students struggled with the drawings and had to be guided by the researcher.

As previously discussed, radiographers have to develop the skill to mentally visualise the movement of anatomical structures, especially when interpreting an image of an oblique projection or when removing structures superimposed on the region of interest (Carlton & Adler, 1992). It was noticed, during the practical sessions, that students found the projection of shadows (of the anatomical structures of the skeleton) by the light beam of the X-ray tube, very informative. The researcher showed them the position of the shadows of the clavicles, in relation to the position of the shadows of the upper ribs, on the cassette, when the X-ray beam is angulated 30° cranially (clavicles projected more cranially than the ribs). This exercise could have assisted them in interpreting an AP apical projection, a lordotic projection of the lungs, as well as an infero-superior projection of the clavicle.

According to Du Toit (1995) image-generation skills can be practised and developed. Guided image-generation exercises, according to Bishop (1978), should make use of spatial visualisation. The lecturer should assist the students in these exercises. Mental image generation will interfere with visual input (and the other way around) if these processes are simultaneously executed (Ishai & Sagi, 1997; Kirby & Kosslyn, 1992). This information is important for radiography film-viewing assessments, where students inspect radiographic images on films and simultaneously execute mental manipulations of these images. They should first observe the radiographic images, then close their eyes and focus on the mental images. In this research, the researcher could have placed more emphasis on these image-generation techniques during the practical sessions.

In order to assist students in recognising radiographic projections, regardless of their spatial ability, considerable practice is required. Joliceur (1992) mentions that skills obtained by practice cannot be applied in general to other objects/situations. However, the students should be able to recognise certain cues/features (e.g., the cues of foreshortening) in unfamiliar images, if they had them seen before in familiar images.

As previously discussed, the best results in training spatial skills, are achieved when three to four sessions (each session includes two hours of formal lectures and two hours of practical work) over a course of approximately four weeks, are combined with test-specific training (Baenninger & Newcombe, 1989; Sorby & Baardmans, 1996). Due to time constraints, the intervention during the current research only consisted of a one-hour practical session per week per group of students for the duration of four weeks. Test-specific training was done, because the sessions focused on the adaptation of certain skills. The formal lectures regarding the specific projections had already been completed before the onset of the research.

5.3 Conclusion

In conclusion, the researcher gained a great deal of insight during the practical sessions on the students’ way of reasoning and on the specific areas that they experience difficulties with, in the interpretation of radiographic images. The researcher will be more equipped in future to assist the students with their problems.

CHAPTER SIX
THE CONCLUSION

6.1 Important findings in quantitative data

The most significant results of the investigation of the sub-problems are summarised in order to suggest recommendations for future training of student radiographers.

6.1.1 Investigation of sub-problem one

Only a weak to moderate correlation between the marks of the students achieved in the three-dimensional tests and the marks achieved in the film-viewing assessments, was found. The results are in contrast to what the researcher and many other radiographers have anticipated. It is generally assumed that radiographers require inherited three-dimensional abilities to interpret radiographic images. Certain radiography training institutions use psychometric testing in their selection processes, but this research shows that even students with low spatial abilities can achieve high marks in film-viewing assessments and that psychometric testing therefore would discriminate against them. Film-viewing assessments require task-specific skills, which can be developed by practice, such as the intervention used in this research.

6.1.2 Investigation of sub-problem two

The impact of the curricular intervention on students' applied three-dimensional skills was evaluated. Students did not perform significantly better after the interventions ($p = 0.213$ in 2005 and $p = 0.296$ in 2006). The small sample sizes could be the reason for not attaining statistical significance. The intervention effect size for the 2005 group = 0.59, which is a reasonable difference. The difference between the means is 11% and the difference between the medians 20%, both favouring the intervention group. The intervention effect size for the 2006 group = 0.57, which is also a reasonable difference. The difference between the means is 9% and the difference between the medians 10%, both favouring the intervention group. The reasonable differences as a result of the training indicate that the same educational intervention can be applied in future to assist students with assessing radiographic images.

Statistical significance was achieved with both year groups after the whole class received the intervention (*p* = 0.003 in 2005 and *p* = 0.002 in 2006). The intervention effect size for the 2005 group = 1.03 which is a significant difference. The difference between the means is 14% and the difference between the medians 10%, both favouring the intervention group. The intervention effect size for the 2006 group = 0.69 which is a reasonable difference. The difference between the means is 12% and the difference between the medians 8%, both favouring the intervention group. Maturation, history and re-testing could have influenced the results of the final film-viewing assessments as they were executed approximately two months after the pre-tests.

The intervention groups (2005 and 2006) performed significantly better (*p* = 0.006) than the previous five year groups (without the intervention). The mean of the control groups (2000 – 2004) for the final film-viewing assessments = 68%, while the mean of the intervention groups (2005 – 2006) for the final film-viewing assessments = 75%. The assessments of the previous groups (2000 - 2004) took place at approximately the same time of the year as the final film-viewing assessments of this research, which would reduce the effects of history and maturation, but not the effects of re-testing. Only one film-viewing assessment was executed by each of the previous year groups, as opposed to the three film-viewing assessments of the research groups. In 2007 the intervention was repeated and only one film-viewing assessment was executed, which was similar to the first film-viewing assessments of 2005 and 2006 (before the intervention). A 9% difference in performance was achieved favouring the group (2007) with the intervention. The effect of re-testing was as a result excluded.

The above-mentioned patterns confirm the results of previous research, that with intensive practice, people with different cognitive abilities can acquire the necessary spatial skills (Hegarty *et al.*, 2007; Keehner *et al.*, 2004; Ackerman, 1988; Sidhu *et al.*, 2004). Ackerman (1988), however states, that this will only be possible for consistent tasks. Complex tasks will still rely heavily on general cognitive abilities, even after intensive practice.

6.1.3 Investigation of sub-problem three

The impact of the curricular intervention on students' general cognitive abilities, pertaining to three-dimensional thinking, was evaluated.

The performance in general three-dimensional abilities of the group of 2006 improved significantly after the intervention ($p = 0.028$), while the performance of the group of 2005 decreased ($p = 0.552$). Maturation, history and re-testing did not influence the performance of the 2005 group positively. It is thus very unlikely that these could have played a major role in the better performance of the 2006 group. The bigger sample group ($n = 23$) of the 2006 class could have played a role in achieving significance after the intervention. There is a 3% difference in the means, as well as a 3% difference in the medians, of the 2005 group (before and after the intervention), both favouring the group without the intervention. In 2006, however, there was a 6% difference in the means, as well as a 10% difference in the medians, both favouring the group with the intervention. The intervention effect size of the 2006 group = 0.4 which is only a small difference.

There is conflict in research findings regarding the possibility of developing spatial abilities. The researcher therefore did not anticipate a significant difference in performance after the intervention. The contrasting evidence between the data of the two groups (2005 and 2006) makes this intervention not appropriate for increasing general spatial abilities.

6.1.4 The influence of gender

The males outperformed the females in the generic spatial ability tests, which confirms previous research. However, in the film-viewing assessments, where applied three-dimensional skills were tested, the female students performed better than the male students. The female students of the intervention year groups (2005 and 2006) also performed better compared to the female students of the previous groups (2001 to 2004), without the intervention, who performed worse than the males (of these groups). The number of males who participated in this research is too small to make any predictions regarding the data. Nevertheless, the research results do show that women are able to develop the skills (through training) that are required for interpreting radiographic images.

6.1.5 The influence of attitude on performance in assessments

The weak correlation of the three-dimensional tests with the film-viewing assessments could have been influenced by motivational factors, because the three-dimensional tests did not count towards the annual mark. The research results, regarding film-viewing assessments, could also have been influenced negatively by the anxiety that a group of students experienced throughout these assessments.

6.2 Important findings in qualitative data

The most significant feedback of the students and observations made by the researcher, are summarised in order to suggest recommendations for future training of student radiographers.

6.2.1 Feedback from students on practical sessions (2006)

Written feedback on how the students experienced the research activities was only obtained from the 2006 group. Their feedback with regard to the educational value of the practical sessions was positive.

6.2.2 Feedback from students on film-viewing assessments (2005 and 2006)

The anxiety effect decreased slightly over the years from 39% of students who reported anxiety in 2000 to 2004 (before the intervention) to 34% of students who reported anxiety in 2005 and 2006 (after the intervention). The number of students who experienced anxiety increased from the first film-viewing assessments (before the intervention) to the third film-viewing assessments (after the intervention) for both the treatment year groups (2005 and 2006). The researcher had expected that the anxiety effect would decrease with more practice. According to the feedback of the students, some of them were unable to complete the assignments on time, and some of them found the assignments of the third film-viewing assessment in 2005 difficult. According to the literature, students need more time to recognise complicated objects (Kosslyn, 1980; Kosslyn, 1994; Tarr & Pinker, 1989; Rock, 1983). It could be that they found it difficult to apply the skills that they had obtained to the alternative, and maybe more complicated, images.

6.3 Recommendations regarding training of spatial skills (based on data and literature)

The researcher strongly agrees with Cox (2002) that the clinical lecturer should be present when students practice their skills, in order to identify and solve perceptual gaps. Small group tutorials should be held for learning radiographic techniques. The lecturer-student relationship would be improved with a small group. According to the researcher, the group should not consist of more than six students.

6.3.1 Practice makes perfect

Sorby (1999) and Hegarty *et al.* (2007) define spatial ability as a cognitive ability that a person is born with, compared to spatial skills that are task specific and acquired through formal training. Practice also reduces the problems of recognition of objects in different orientations (Joliceur, 1992; Barlow & Mollon, 1982; Cox, 2002).

This research demonstrated the importance of practice regarding film-viewing assessments. The extra practical sessions, as well as the re-testing (extra film-viewing assessments) enhanced the students' spatial skills in interpreting radiographic images of specialised and modified technique. A two-hour practical session per group per week, instead of a one-hour session per week, would however have been more valuable to exercise these specific skills.

6.3.2 The correct sequence during training

Tasks should be arranged from easy to more complex in order to develop spatial skills (Olkun, 2003). The procedure during the practical sessions of this research followed the following steps: The students positioned the skeleton for a specific projection and subsequently observed the location and form of the anatomical structures. They then drew the skeleton in that position. Cross-sectional drawings were made of oblique projections, as well as drawings of the radiographic images of these projections. At the abstract level, the students observed and interpreted the radiographic images at the follow-up sessions.

6.3.3 Computer models versus real life models

Hegarty *et al.* (2007) and Provo *et al.* (2002) state that external visualisations such as computer models or other real life models, can aid individuals, with low spatial abilities, to understand internal visualisations, especially regarding cross-sections of objects (Refer to 2.4.3). Nevertheless, subjects with high levels of experience in spatial visualisation, when using a computerised program, performed much better than subjects with low spatial experience (Rafi *et al.*, 2006).

McKim (1980) and Petroski (2000) both agree that the interaction of students with hand-held models, which they are able to perceive and simultaneously touch and manoeuvre, will stimulate the visual perception part of their brain more than perceiving computer images only, resulting in the developing of spatial skills. In this research, students were actively involved in the manipulation of the skeleton. However, because of time constraints, the students directly rotated the skeleton from the basic (key position) into a specific oblique position. The students should spend more time on moving the skeleton from a basic position into semi-oblique positions and back.

6.3.4 Key projections versus multiple projections

Memories of multiple views tend to blend together and form a vague mental picture (Galton, 1919). Lecturers should therefore keep in mind that demonstrating multiple projections to students, may handicap students with weaker spatial abilities. The researcher suggests that lecturers start off with one key projection (PA projection of the thorax) and then proceed to only one oblique projection (left anterior oblique projection of the thorax) instead of exercising all four oblique projections.

6.3.5 Shadows

Scholnick *et al.* (1982), in order to demonstrate three-dimensional form, suggest creating shadows of objects against a wall, while rotating these objects in different positions. Arvold (1993) describes a similar type of activity that entails the manoeuvring of three-dimensional objects on an overhead projector.

It was noticed during the practical sessions that students found the projection of anatomical shadows by the light beam of the X-ray tube, very informative (e.g., clavicles projected more cranial than the upper ribs). "Separation" of these structures by the light beam, can only be demonstrated when using a skeleton (even an artificial model), because of the visibility of the bones.

6.3.6 Drawing

Drawing exercises are suggested to comprehend three-dimensional form, for example, drawing different perspectives of simple familiar objects (e.g., an apple) and subsequently a cross-section thereof (McKim, 1980). According to Provo *et al.* (2002), students should be well informed on how to relate a cross-section to the entire body. During the current research, students made cross-sectional drawings of the skeleton in oblique projections.

McKim (1980) suggests drawing exercises for comprehending the spatial cue of foreshortening. Pairs of objects can be drawn, for example, two bottles, where the one is in an upright position and the other one lying on its side, in an "end on" position to the observer. Students, participating in this research, drew anatomical structures in "end on" positions, as well as the radiographic images of these three-dimensional structures.

6.3.7 Image-generation exercises

People use mental rotation to recognise unfamiliar forms. With increased training, participants will become more familiar with the objects and will either rotate these objects very quickly or recognise them independently of the mental rotation task. If the participants are suddenly confronted with unfamiliar perspectives, they will be forced to use the mental rotation task again (Bethell-Fox & Shephard, 1988; Tarr & Pinker, 1989).

Mental image-generation will interfere with visual input (and the other way around) if these processes are simultaneously executed (Ishai & Sagi, 1997; Kirby & Kosslyn, 1992). Students should therefore first observe the radiographic images, then close their eyes and subsequently focus on manipulating their mental images.

Arvold (1993) posits that practice in mental transformation from the second to the third dimension can develop spatial visualisation skills. She suggests simple spatial activities to be executed by students (e.g., drawing two circles on a paper, the smaller one inside the bigger one, then first visualising the smaller circle as closer to oneself, and subsequently visualising it as further away from oneself) (Refer to 2.4.2.1).

Seymour and Beardslee (1990) also propose activities, which might improve image-generation skills in students, for example, the mental decoding of reflected sentences, the matching of various (reflected or rotated) figures, guessing the hidden faces of cubes, the mental "folding" of a two-dimensional sheet into a three-dimensional configuration, and so forth (Refer to 2.4.9).

With more time available, the researcher could have placed more emphasis during the practical sessions on image-generation techniques. Mental rotation was however exercised when interpreting the postero-anterior oblique projection of the thorax. Lecturers should try to improve the image-generation skills of students by assisting them in these exercises.

6.3.8 Providing cues and proper task instructions

It is important that the questions during film-viewing assessments are clear and contain enough information regarding the images for the students to execute the mental tasks. The clinical lecturer must also ensure that the students are well prepared, with regard to cues that can be searched for, to identify a projection, to locate the anatomical structures in the human body, to mentally move these structures and to recognise and rectify positioning mistakes. It is very important that these cues are visible in the images that are used in the assessments, for example, the position of the petrous bones in an image of the facial bones, would indicate the position of the radiographic baseline or the angulation of the X-ray beam. McKim (1980) posits that awareness of the spatial cue of foreshortening is a prerequisite for accurate perception of a three-dimensional form (especially in a two-dimensional plane). In identifying structures seen "end on" in a radiographic image, the researcher suggests that students should search for a dense and foreshortened appearance of a structure (e.g., axial calcaneus projection).

During the practical sessions, the researcher noticed that the students found it difficult to recognise anatomical structures or directions (e.g., anterior or posterior) when the structures were tilted according to their axes in space (e.g., pelvic inlet projection). The researcher guided them to search for a familiar anatomical structure, which was situated anterior or posterior in identifying the other directions on the image. It was also emphasised that the direction of the X-ray beam (supero-inferior for the above-mentioned projection) could never be observed on the image.

6.3.9 Provide enough time to complete assessments

Subjects need more time to recognise objects when foreshortened, especially when unique features are obscured with severe foreshortening (Kosslyn, 1994). Larger and more complex images also require more time to rotate than smaller or less complex images. More time is also needed to rotate an image or object farther from the original position (Rock, 1983; Kosslyn, 1980). During this research students complained about having too little time to accomplish the tasks. Lecturers compiling assignments, which include similarly complicated tasks, should keep the time factor in mind.

6.3.10 Activities to relieve stress during assessments

McKim (1980) states that deep muscle relaxation and motivation are both prerequisites for creating mental pictures. Listening to music will also enhance spatial reasoning performance (Rauscher *et al.*, 1994; Sprenger, 1990).

In this research, students experienced anxiety throughout the film-viewing assessments. The researcher therefore suggests that breathing exercises be performed by the students immediately before an assessment and that soft background music be played during an assessment.

6.3.11 Spatial aptitude tests

Provo *et al.* (2002) suggest that a spatial aptitude test should be used to identify students with low spatial abilities in order to assist them with extra training to develop these skills. The researcher does not think that executing spatial aptitude tests are absolutely essential for identifying the weaker students, because the results of this research show only a weak to moderate correlation between the film-viewing assessments and the spatial aptitude tests. Students with low spatial abilities can achieve excellent marks in film-viewing assessments.

Researchers question the use of a single aptitude test to predict the competence of future surgeons (Keehner *et al.*, 2004; Graham & Deary, 1991; Ghiselli, 1973).
Psychological literature argues that the importance of general cognitive spatial ability will fade with increased experience and the acquirement of skills. Taking the results of the current research into account, the researcher would not recommend the inclusion of a spatial aptitude test in the selection process of radiography students.

6.4 Limitations of research

The experiment and instrument of this research could be improved through the following suggestions. A bigger sample group could be used to achieve statistical significance, as it was not achieved with the first film-viewing post-tests.

Re-testing, maturation and history effects could have influenced the results of the final film-viewing assessments. The results of these assessments were, however, compared to the results of previous groups (without the intervention), which were obtained at the same time of the year. A significant difference was achieved, favouring the intervention groups. Maturation and history effects were therefore eliminated, but not the effect of re-testing. Only one final film-viewing assessment was executed by each of the previous groups in contrast to the three film-viewing assessments of the research groups. In an attempt to control this effect, different radiographic projections were used in the re-tests, which measured the same skills as in the pre-tests. The use of a control group eliminated the re-testing effect in the second film-viewing assessments. In 2007, the intervention was repeated and only one film-viewing assessment was executed after the whole class had had the intervention, which was similar to the first film-viewing assessments of 2005 and 2006 (before the intervention). A 9% difference in performance was achieved favouring the group of 2007 (with the intervention). The effect of re-testing was as a result excluded.

The emotional state of the students and the amount of preparation for the film-viewing assessments could have influenced their performances in the final assessments. The performance of the students in both the three-dimensional tests could have been influenced by a lack of motivation, because the results did not contribute towards their year mark. Maturation, history and re-test effects could have influenced the final three-dimensional tests positively. However, the contrasting results of the two research groups in the three-dimensional tests make the influence of these fore-mentioned effects debatable.

Leakage of information might have occurred between the intervention and control groups regarding the content of the practical sessions, which could have influenced the results of the control groups positively. According to the researcher, this was unlikely, since these groups were competing with one another.

The sample group in this research did not represent all the people in the medical field who are involved in the interpretation of medical radiographic images. A variety of people in the medical field, such as radiographers, students, radiologists, etcetera, should be included to achieve external validity. More men would then also form part of the sample group. Berg and Latin posit: "Technically, the only fully justified application of the results of a single study is to the subjects of that particular investigation" (2004: 246).

When more than one level of a variable is investigated, multiple intervention interference is possible, which could also influence external validity negatively (Berg & Latin, 2004). Different types of mental skill were researched namely, the rotation skills in recognising an oblique projection, the skills in recognising a foreshortened object, the skills in localising structures in the image of an axial projection, as well as the skills to mentally remove superimposed anatomical structures from one another. Using more than one intervention group to research the various skills would have prevented the possibility of interference.

As already explained, this research placed emphasis on internal validity and not on external validity therefore the external validity would be poor.

6.5 The need for future research

This project identified several areas that need additional research. Those areas are explained below.

6.5.1 Anatomy correlation

There is evidence, according to Sidhu *et al.* (2004) that some additional anatomical training can enhance the performance of students pertaining to the interpretation of angiographic two-dimensional images, independent of their spatial abilities. The results of the research of Provo *et al.* (2002) also reveal a statistically significant correlation between the performance of the students in the spatial aptitude test and the anatomy tests. A correlation analysis between students' film-viewing assessment marks and their marks achieved in the subject Anatomy should be done in future.

6.5.2 Visual image-generation exercises

Future research could determine the effect of in-depth training of, for example, only one skill, namely mental rotation on film-viewing assessments. The students could perform various activities to enhance this skill (Refer to 6.3.7).

6.5.3 The influence of stress

Feedback from the students on film-viewing assessments should not be done anonymously. The students who experience anxiety would then be identified and the influence of this effect on their performance in these assessments could be investigated.

6.5.4 Develop an applied spatial aptitude test for radiography

Kali and Orion (1996) developed a Geological Spatial Aptitude Test (GeoSAT). Subjects had to draw cross-sections of three-dimensional block diagrams. These block diagrams consisted of multiple complex layers, representing the layers of the earth. The items of the test were therefore familiar to the learners and therefore did not only test general abilities, but “applied” skills as well. A spatial skills test, which includes mental rotation activities, such the mental rotation of radiographic images, instead of abstract block figures, could be compiled. A correlation analysis could be done to compare the performance of the students in film-viewing assessments with their performance in this test. If the correlation is found to be significant, then the test could be used in future to identify and assist students with low spatial skills.

6.6 Conclusion

Several researchers state that through training and the use of suitable learning material spatial abilities can be developed (Ben-Chaim *et al.*, 1988; Lord, 1985), although there is disagreement in the literature in this regard. This research has not demonstrated a significant increase in the general spatial abilities of students following an intervention. The researcher agrees with Sorby (1999) and Hegarty *et al.* (2007) that spatial ability is an inherited cognitive ability, while spatial skills are task specific and are acquired through formal training. In order to assist students in interpreting the images of specialised and modified radiographic projections, regardless of their spatial ability, the main solution would therefore be “practice”. Joliceur (1992) mentions that skills obtained by practice cannot be applied in general to other objects/situations. The researcher anticipates that certain cues such as the “end on” cue (structure foreshortened and dense) could, with in-depth training, be transferred from the familiar object to another object, or to an unfamiliar object.

Valuable information was obtained during the practical sessions with regard to the difficulties that the students experienced in the interpretation of radiographic images. Clinical lecturers therefore have to be equipped to assist students appropriately, for example, by providing them with additional clues to recognise images, encouraging them to search for cues in the images and making more use of the valuable aid of shadows and alternative techniques to improve spatial skills.

This research shows that radiography students with low spatial abilities could, with intensive training, develop spatial skills regarding the interpretation of specialised and modified radiographic images. They could develop excellence in recognising positioning errors and in suggesting technique modifications to rectify these errors. Intensive training, however, requires dedicated students and a great deal of patience on the side of the clinical lecturer. Most important, intensive and appropriate training would lead to the production of superior images. These images would contribute to the correct diagnosis and subsequently the appropriate treatment or referrals for patients.

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APPENDICES

APPENDIX A: EXAMPLES OF INFORMED CONSENT FORMS

PARTICIPANT CONSENT

STUDY TITLE: An Investigation into the Role of Three-dimensional Thinking in Radiography.

RESEARCHER: Dalene Venter, Diagnostic Radiography Lecturer, Cape Peninsula University of Technology, Tygerberg Hospital Satellite Campus.

I, (full name) ……………………………………………… hereby consent to participate in a research study to improve the teaching methods and therefore the practical skills (pertaining film analysis) of students in the subject Clinical Radiographic Practice II.

I understand that:

- My participation is voluntary.
- The research activities will involve two three-dimensional tests, four additional practical tutorials (including drawing exercises), as well as two additional film-viewing assessments on modified radiographic technique.
  The first additional film-viewing assessment will not contribute towards my annual film-viewing assessment mark. The second additional film-viewing assessment will however count 40% of my annual film-viewing assessment mark.
- I will be kept informed of the results of the research activities.
- Confidentiality of all data gathered will be maintained during the analysis of this research.

Signature of the participant: …………………………………………….

Position: ………………………………………………………………

Date: ……………………………………………………………………….

Institution: ………………………………………………………………….

Witnesses: 1. ……………………………………………………………….

2. ……………………………………………………………….

INFORMED CONSENT

STUDY TITLE: An Investigation into the Role of Three-dimensional Thinking in Radiography.

RESEARCHER: Dalene Venter, Diagnostic Radiography Lecturer, Cape Peninsula University of Technology, Tygerberg Hospital Satellite Campus.

I, (full name) ………………………………………………………… hereby consent that the private practice students may participate in the research study.

I understand that:

- The research activities will involve additional practical sessions on phantoms with the second year Radiography students.
- The practical sessions will be conducted under supervision of the researcher.
- The students will be withdrawn in groups from the Department on a Tuesday afternoon between 15:00 and 16:00 for September and October. Each group will consist of four students and the duration per group session will be one hour.

Signature: …………………………………………………………………………

Position: ………………………………………………………………………….

Date: …………………………………………………………………………..

Institution: …………………………………………………………………………

INFORMED CONSENT

STUDY TITLE: An Investigation into the Role of Three-dimensional Thinking in Radiography.

RESEARCHER: Dalene Venter, Diagnostic Radiography Lecturer, Cape Peninsula University of Technology, Tygerberg Hospital Satellite Campus.

I, (full name) ………………………………………………………… hereby consent that the X-ray facilities on third floor in Tygerberg Hospital may be used in the research study.

I understand that:

- The research activities will involve additional practical sessions on phantoms with the second year Radiography students.
- The practical sessions will be conducted under supervision of the researcher.
- The students will be withdrawn in groups from the Department on a Wednesday afternoon between 14:00 and 16:00 for September and October. Each group will consist of four students and the duration per group session will be one hour.

Signature: ………………………………………………………………………………

Position: ……………………………………………………………………………….

Date: ……………………………………………………………………………………..

Institution: ………………………………………………………………………………

INFORMED CONSENT

STUDY TITLE: An Investigation into the Role of Three-dimensional Thinking in Radiography.

RESEARCHER: Dalene Venter, Diagnostic Radiography Lecturer, Cape Peninsula University of Technology, Tygerberg Hospital Satellite Campus.

I, (full name) ………………………………………………………… hereby consent that the two parts of the skeleton, the rib cage and pelvis, may be borrowed from the ossuary of the University of Stellenbosch to be used in the research study.

I understand that:

- The research activities will involve practical sessions using the material as indicated above.
- No photographs of the material will be taken.
- X-ray images will be taken of the material as part of the research study, but the X-ray images will not be published.
- The practical sessions will be conducted under supervision of the researcher.
- The material will be locked up in the practical X-ray room on the third floor (C3B) in Tygerberg Hospital.
- Record of this material will be kept.

Signature: ……………………………………………………………………………

Position: …………………………………………………………………………….

Date: ……………………………………………………………………………..

Institution: ……………………………………………………………………………

APPENDIX B: RESEARCH ACTIVITIES PROGRAM 2005

M TECH DEGREE (RADIOGRAPHY) MRS D VENTER

<u>FILM-VIEWING ASSESSMENT 1</u>: TUESDAY 6 SEPTEMBER 2005

<u>THREE-DIMENSIONAL TEST 1:</u> THURSDAY 8 SEPTEMBER 2005

INTERVENTION GROUP	CONTROL GROUP
Subject 5.1	Subject 5.8
Subject 5.2	Subject 5.9
Subject 5.3	Subject 5.10
Subject 5.4	Subject 5.11
Subject 5.5	Subject 5.12
Subject 5.6	Subject 5.13
Subject 5.7	Subject 5.14
Subject 5.X	Subject 5.15

<u>PRACTICAL SESSION DATES WITH INTERVENTION GROUP</u>:

Wednesday :	14 September 2005	(14:00 – 15:00 or 15:00 – 16:00)
Tuesday:	20 September 2005	(14:00 – 15:00 or 15:00 – 16:00)
Wednesday :	21 September 2005	(14:00 – 15:00 or 15:00 – 16:00)
Tuesday:	4 October 2005	(14:00 – 15:00 or 15:00 – 16:00)

<u>FILM-VIEWING ASSESSMENT 2</u>: THURSDAY 6 OCTOBER 2005

<u>PRACTICAL SESSION DATES WITH CONTROL GROUP</u>:

Wednesday :	19 October 2005	(14:00 – 15:00 or 15:00 – 16:00)
Tuesday:	25 October 2005	(14:00 – 15:00 or 15:00 – 16:00)
Wednesday :	26 October 2005	(14:00 – 15:00 or 15:00 – 16:00)
Tuesday:	1 November 2005	(14:00 – 15:00 or 15:00 – 16:00)

<u>FILM-VIEWING ASSESSMENT 3</u>: THURSDAY 3 NOVEMBER 2005

<u>THREE-DIMENSIONAL TEST 2:</u> THURSDAY 10 NOVEMBER 2005

APPENDIX C: RESEARCH ACTIVITIES PROGRAM 2006

M TECH DEGREE (RADIOGRAPHY) MRS D VENTER

<u>THREE-DIMENSIONAL TEST 1:</u> **THURSDAY 24 AUGUST 2006**

<u>FILM-VIEWING ASSESSMENT 1</u>: **TUESDAY 29 AUGUST 2006**

INTERVENTION GROUP	CONTROL GROUP
Subject 6.1	Subject 6.12
Subject 6.2	Subject 6.13
Subject 6.3	Subject 6.14
Subject 6.4	Subject 6.15
Subject 6.5	Subject 6.16
Subject 6.6	Subject 6.17
Subject 6.7	Subject 6.18
Subject 6.8	Subject 6.19
Subject 6.9	Subject 6.20
Subject 6.10	Subject 6.21
Subject 6.11	Subject 6.22
Subject 6.X	Subject 6.23
	Subject 6.Y

<u>PRACTICAL SESSION DATES WITH INTERVENTION GROUP</u>:

Monday: 4 September 2006 (15:00 – 16:00)
(LouisLeipoldt and Van Wageningen students)

Wednesday: 6 September 2006 (14:00 – 15:00 or 15:00 – 16:00)
(TBH and Panorama hospital students)

Monday: 11 September 2006 (15:00 – 16:00)
(Louis Leipoldt and Van Wageningen students)

Wednesday: 13 September 2006 (14:00 – 15:00 or 15:00 – 16:00)
(TBH and Panorama hospital students)

Monday: 18 September 2006 (15:00 – 16:00)
(Louis Leipoldt and Van Wageningen students)

Wednesday: 20 September 2006 (14:00 – 15:00 or 15:00 – 16:00)
(TBH and Panorama students)

Monday: 2 October 2006 (15:00 – 16:00)
(Leipoldt and Van Wageningen students)

Wednesday: 4 October 2006 (14:00 – 15:00 or 15:00 – 16:00)
(TBH and Panorama students)

Thursday: 5 October 2006 (additional practical sessions if necessary)

<u>FILM-VIEWING ASSESSMENT 2</u>: **MONDAY 9 OCTOBER 2006**

PRACTICAL SESSION DATES WITH CONTROL GROUP:

Wednesday:	11 October 2006 (TBH students)	(11:00 - 12:00, 14:00 – 15:00 or 15:00 – 16:00)
Wednesday:	18 October 2006 (TBH students)	(11:00 - 12:00, 14:00 – 15:00 or 15:00 – 16:00)
Wednesday:	25 October 2006 (TBH students)	(11:00 - 12:00, 14:00 – 15:00 or 15:00 – 16:00)
Wednesday:	1 November 2006 (TBH students)	(11:00 - 12:00, 14:00 – 15:00 or 15:00 – 16:00)
Thursday:	2 November (additional practical sessions if necessary)	

FILM-VIEWING ASSESSMENT 3: MONDAY 6 NOVEMBER 2006

THREE-DIMENSIONAL TEST 2: THURSDAY 9 NOVEMBER 2006

APPENDIX D: PRACTICAL SESSION 1

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 1

NAME OF STUDENT: ………………………………………………

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

THE LEFT ANTERIOR OBLIQUE PROJECTION OF THE THORAX

1. PERFORM THE LEFT ANTERIOR OBLIQUE PROJECTION OF THE THORAX ON THE SKELETON.

1.1 OBSERVE THE ROTATION AND POSITION OF THE ANATOMICAL STRUCTURES IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE ANATOMICAL STRUCTURES.

1.3 OBSERVE THE POSITION AND SHAPE OF THE SHADOWS OF THE STRUCTURES ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKELETON IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.

2. **MAKE A ROUGH DRAWING OF THE TRANSVERSE APPEARANCE OF THE THORAX OF THE SKELETON (FROM THE FEET) IN RELATION TO THE CASSETTE AND X-RAY TUBE (INCLUDE SPINE, STERNUM AND RIBS).**

3. **MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE SPINE, STERNUM AND RIBS).**

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 1

NAME OF STUDENT: ……………………………………………….

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

THE LORDOTIC PROJECTION OF THE THORAX

1. PERFORM THE LORDOTIC PROJECTION OF THE THORAX ON THE SKELETON.

1.1 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE ANATOMICAL STRUCTURES.

1.3 OBSERVE THE POSITION AND SHAPE OF THE SHADOWS OF THE STRUCTURES ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKELETON IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.

2. **MAKE A ROUGH DRAWING OF THE LATERAL APPEARANCE OF THE THORAX OF THE SKELETON (FROM THE SIDE) IN RELATION TO THE CASSETTE AND THE X-RAY BEAM (INCLUDE RIBS, SPINE, STERNUM AND SPECIFIC CLAVICLE).**

3. MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE RIBS, STERNUM AND CLAVICLES).

APPENDIX E: PRACTICAL SESSION 2

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 2

NAME OF STUDENT: ……………………………………………………

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

REVISION OF PREVIOUS PROJECTIONS

1. **OBSERVE THE IMAGE OF THE ANTERO-POSTERIOR OBLIQUE PROJECTION OF THE THORAX ON THE VIEWING BOX AND THEN IMMOBILISE THE THORAX OF THE SKELETON IN THE SAME POSITION.**

2. **SUGGEST THREE WAYS OF ACHIEVING A LORDOTIC PROJECTION OF THE THORAX, AS WELL AS THREE WAYS TO RECTIFY A LORDOTIC PROJECTION OF THE THORAX.**

THE SUPINE MODIFIED PROJECTION OF THE LEFT SCAPULA

1. **PERFORM THE SUPINE MODIFIED PROJECTION OF THE LEFT SCAPULA ON THE SKELETON, BY RECTIFYING THE TECHNIQUE OF THE IMAGE OF THE LATERAL SCAPULA ON THE VIEWING BOX (DO NOT ROTATE THE SKELETON).**

1.1 OBSERVE THE POSITION OF THE SCAPULA IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE SCAPULA.

1.3 OBSERVE THE POSITION AND SHAPE OF THE SHADOW OF THE SCAPULA ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKELETON IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.

2. **MAKE A ROUGH DRAWING OF THE TRANSVERSE APPEARANCE OF THE THORAX OF THE SKELETON (FROM THE FEET) IN RELATION TO THE CASSETTE AND X-RAY TUBE (INCLUDE SPINE, STERNUM, RIBS AND SCAPULAE).**

3. **MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE LEFT UPPER RIBS, LEFT HUMERUS AND SCAPULA).**

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 2

NAME OF STUDENT: ……………………………………………….

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

THE LPO PROJECTION OF THE LUMBAR SPINE

1. PERFORM THE LEFT POSTERIOR OBLIQUE PROJECTION OF THE LUMBAR SPINE.

1.1 OBSERVE THE ROTATION AND POSITION OF THE VERTEBRAE IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE VERTEBRAE.

1.3 OBSERVE THE POSITION AND SHAPE OF THE SHADOWS OF THE VERTEBRAE ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKELETON IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.

2. **MAKE A ROUGH DRAWING OF THE TRANSVERSE APPEARANCE OF ONE OF THE VERTEBRAE OF THE SKELETON (FROM THE FEET) IN RELATION TO THE CASSETTE AND X-RAY TUBE (INCLUDE SPINOUS PROCESS, BODY AND TRANSVERS PROCESSES OF VERTEBRA).**

3. MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE ONE VERTEBRA = "SCOTTISH DOG")

APPENDIX F: PRACTICAL SESSION 3

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 3

NAME OF STUDENT: …………………………………………………

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

REVISION OF PREVIOUS PROJECTIONS

1. **OBSERVE THE IMAGE OF THE POSTERO-ANTERIOR OBLIQUE PROJECTION OF THE THORAX ON THE VIEWING BOX AND THEN IMMOBILISE THE THORAX OF THE SKELETON IN THE SAME POSITION. IDENTIFY THE NAME OF THE PROJECTION.**

2. **EXPLAIN THE ANGULATION OF THE X-RAY TUBE TO ACHIEVE AN "END ON" (FORESHORTENED) IMAGE OF AN ANATOMICAL STRUCTURE. ALSO EXPLAIN THE ANGULATION OF THE X-RAY TUBE FOR RECTIFYING THE FORESHORTENING OF AN ANATOMICAL STRUCTURE.**

3. **IDENTIFY THE NAME OF THE ANTERO-POSTERIOR OBLIQUE PROJECTION OF THE LUMBAR SPINE ON THE VIEWING BOX. MOTIVATE YOUR ANSWER.**

THE JUDET PROJECTION OF THE PELVIS (LPO OBLIQUE PELVIS)

1. **PERFORM THE LEFT POSTERIOR OBLIQUE PROJECTION OF THE PELVIS.**

1.1 **OBSERVE THE ROTATION AND POSITION OF THE ANATOMICAL STRUCTURES IN RELATION TO THE CASSETTE.**

1.2 **OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE ANATOMICAL STRUCTURES.**

1.3 **OBSERVE THE POSITION AND SHAPE OF THE SHADOWS OF THE ANATOMICAL STRUCTURES ON THE CASSETTE.**

1.4 **EXPOSE AND DEVELOP THE FILM.**

1.5 **OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.**

1.6 **COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKELETON IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.**

2. **MAKE A ROUGH DRAWING OF THE TRANSVERSE APPEARANCE OF THE PELVIS OF THE SKELETON (FROM THE FEET) IN RELATION TO THE CASSETTE AND X-RAY TUBE (INCLUDE SACRUM, ILIUM BONES, PUBIC AND ISCHIUM BONES).**

3. **MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE ILIUM BONES, SACRUM, OBTURATOR FORAMINA, PUBIC AND ISCHIUM BONES).**

M TECH DEGREE   D VENTER 2005

PRACTICAL SESSION 3

NAME OF STUDENT: ……………………………………………….

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

THE PELVIC INLET PROJECTION

1. PERFORM THE PELVIC INLET PROJECTION.

1.1 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE ANATOMICAL STRUCTURES.

1.3 OBSERVE THE POSITION AND SHAPE OF THE SHADOWS OF THE ANATOMICAL STRUCTURES ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKELETON IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE (IDENTIFY DIRECTION E.G. ANTERIOR AND POSTERIOR).

2. **MAKE A ROUGH DRAWING OF THE LATERAL APPEARANCE OF THE PELVIS OF THE SKELETON (FROM THE LEFT SIDE) IN RELATION TO THE CASSETTE AND X-RAY TUBE (INCLUDE ILIUM BONE, SACRUM, ACETABULUM, PUBIC BONE AND ISCHIUM BONE).**

3. **MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE ILIUM BONES, SACRUM, ACETABULA AND PUBIC BONES).**

APPENDIX G: PRACTICAL SESSION 4

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 4

NAME OF STUDENT: ……………………………………………….

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

REVISION OF PREVIOUS PROJECTIONS

1. **OBSERVE THE IMAGE OF THE POSTERO-ANTERIOR OBLIQUE PROJECTION OF THE THORAX ON THE VIEWING BOX AND THEN IMMOBILISE THE THORAX OF THE SKELETON IN THE SAME POSITION.**
2. **OBSERVE THE IMAGE OF THE ANTERO-POSTERIOR OBLIQUE PROJECTION OF THE PELVIS (JUDET) ON THE VIEWING BOX AND THEN IMMOBILISE THE PELVIS OF THE SKELETON IN THE SAME POSITION.**
3. **IDENTIFY THE DIRECTIONS INDICATED BY THE ARROWS ON THE PELVIC INLET PROJECTION ON THE VIEWING BOX.**

THE POSTERO-ANTERIOR 20°↓ PROJECTION OF THE SKULL

1. **PERFORM THE POSTERO-ANTERIOR 20°↓ PROJECTION OF THE SKULL.**

1.1 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE ANATOMICAL STRUCTURES.

1.3 OBSERVE THE POSITION OF THE SHADOWS OF THE MARKERS ATTACHED TO THE ANATOMICAL STRUCTURES (OUTER CANTHUS OF LEFT ORBIT AND LEFT E.A.M.) ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKULL IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.

2. **MAKE A ROUGH DRAWING OF THE LATERAL APPEARANCE OF THE SKULL (FROM THE LEFT SIDE) IN RELATION TO THE CASSETTE AND X-RAY TUBE (INCLUDE RBL, E.A.M. AND ORBIT).**

3. **MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (INCLUDE ORBITS AND PETROUS BONES).**

M TECH DEGREE D VENTER 2005

PRACTICAL SESSION 4

NAME OF STUDENT: ……………………………………………….

ASSIGNMENT TO SECOND YEAR RADIOGRAPHY STUDENT

THE LATERAL-OBLIQUE PROJECTION OF THE RIGHT MANDIBLE – WITH HORIZONTAL BEAM

1. PERFORM THE LATERAL-OBLIQUE PROJECTION OF THE RIGHT MANDIBLE.

1.1 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES IN RELATION TO THE CASSETTE.

1.2 OBSERVE THE DIRECTION OF THE X-RAY BEAM IN RELATION TO THE POSITION OF THE ANATOMICAL STRUCTURES.

1.3 OBSERVE THE POSITION AND SHAPE OF THE SHADOWS OF THE ANATOMICAL STRUCTURES ON THE CASSETTE.

1.4 EXPOSE AND DEVELOP THE FILM.

1.5 OBSERVE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE.

1.6 COMPARE THE POSITION OF THE ANATOMICAL STRUCTURES ON THE IMAGE WITH THE POSITION OF THE STRUCTURES OF THE SKULL IN RELATION TO THE CASSETTE AND THE DIRECTION OF THE X-RAY TUBE.

2. **MAKE A ROUGH DRAWING OF THE LATERAL APPEARANCE OF THE MANDIBLE (FROM THE LEFT SIDE) IN RELATION TO THE CASSETTE AND X-RAY TUBE (ONLY INCLUDE MANDIBLE).**

3. **MAKE A ROUGH DRAWING OF THE RADIOGRAPHIC IMAGE OF THIS PROJECTION (ONLY INCLUDE THE MANDIBLE).**

APPENDIX H: RADIOGRAPHIC PROJECTIONS USED IN ASSESSMENTS (2005)

M TECH D VENTER

FILM-VIEWING ASSESSMENTS 2005

SKILLS TESTED	FILM-VIEWING ASSESMENT 1 (BASELINE)	FILM-VIEWING ASSESSMENT 2	FILM-VIEWING ASSESSMENT 3
The student should be able to:	**Projection**	**Projection**	**Projection**
Suggest tilting of the X-ray tube or adjusting the position of the skull to project structures of the skull (e.g. petrous bones) in the correct position (from an AP or PA aspect). Suggest ways to rectify rotation or other positioning mistakes.	Occipito-frontal 20°↓ skull.	Reversed occipito-mental 0° facial bones.	Sitting occipito-mental 0° facial bones.
Suggest tilting of the X-ray tube or adjusting the patient's body to separate overlying (remove unwanted) structures (from a lateral aspect).	Lateral-oblique projection of the mandible.	Lateral projection of the femoral neck.	Lateral projection of the cervical-thoracic region ("Swimmer's").
Recognise the position of structures with a 30°↑ tilt of the X-ray tube/patient leaning 30° backwards during a chest projection. Suggest ways to rectify mistakes.	Lordotic projection of the chest.	Infero-superior projection of the clavicle.	Antero-posterior 30°↑ projection of the apices.
Recognise the position and shape of structures when rotating the chest through 45°. Identify the name of the projection (which aspect is in contact with the film).	Postero-anterior oblique projection of both lungs.	Postero-anterior oblique projection of the sterno-clavicular joints.	Postero-anterior oblique projection of the left ribs.
Recognise the position and shape of structures when rotating the pelvis through 15 - 45°. Identify the name of the projection (which aspect is in contact with the film).	Left posterior oblique projection of the pelvis ("Judet").	Left posterior oblique projection of the bladder.	Posterior oblique projection of the left s.i. joint.
Recognise the position and shape of structures with supero-inferior/ infero-superior projections. Identify direction e.g. anterior or posterior.	Pelvic inlet projection.	Supero-inferior projection of the shoulder.	Modified infero-superior projection of the shoulder ("Westpoint").
Recognise the position and shape of structures when rotating the lumbar spine/abdomen through 45°. Identify the name of the projection (which aspect is in contact with the film).	Left posterior oblique projection of the lumbar spine.	Posterior oblique projection of the kidneys.	Anterior oblique projection of the lumbar spine.
Suggest modifications in angulation of the tube to project a structure "end on" or foreshortened (tube parallel to axis of structure) or to project a structure to demonstrate it's full width or length (tube perpendicular to axis of structure).	Modified supine lateral projection of the scapula.	Infero-superior ("Skyline") projection of both patella.	Axial projection of the calcaneus.

- The above-mentioned projections of the different film-viewing assessments test similar skills.

Examiner: ....(Mrs. D. Venter) Date: 1/9/2005

Moderator: V Daries .... (Mrs. V. Daries) Date: 1/9/2005

APPENDIX I: FILM-VIEWING ASSESSMENT 1 (2005)

<u>FILM-VIEWING ASSESSMENT 1</u>

<u>CLINICAL RADIOGRAPHIC PRACTICE II</u>

6 SEPTEMBER 2005

(ONLY THE TWO STATIONS APPLICABLE TO RESEARCH INCLUDED)

FILM-VIEWING ASSESSMENT

SECOND YEAR RADIOGRAPHIC (DIAG.) STUDENTS

DATE:	**6 SEPTEMBER 2005**
VENUE:	**RADIOTHERAPY LECTURE ROOM**
DURATION:	**6 MIN. PER STATION x 4 STATIONS = 24 MIN. 24 MIN. + 11 MIN. ROTATION TIME = ± 35 MIN. PER GROUP 35 MIN. x 4 GROUPS = TOTAL DURATION = 2 HOURS 20 MIN. = ± 13:00 – 15:20**
FILMS:	**1 - 5 FILMS ON EACH VIEWING BOX**
VIEWING BOXES:	**4 VIEWING BOXES**
NUMBER OF STUDENTS:	**16 (4 GROUPS OF 4 STUDENTS)**

ROTATION LIST:

Grouping done by lecturer from middle of alphabetical class list.
No suitcases/bags or cell phones are allowed in lecture room (not before or during evaluation)!
Students must already be seated at 12:45 in the Second years' lecture room.

Group 1: (13:00-13:35)
B Johnson
U Horn
D Kotze
V Francke

Group 2: (13:35-14:10)
N Lerm
E Deyzel
M Molde
M Cloete

Group 3: (14:10-14:45)
A Rabe
L Cloete
J Roberts
D Cloete

Group 4: (14:45-15:20)
E Smith
M Booys
D van Wyk
I Appel

OBJECTIVES

The student is tested regarding the **IDENTIFICATION** of the following on radiographic images:

- Abnormal appearances
- Possible pathology
- Modified/special radiographic images (specific name of projection/position of patient)
- Technique/exposure faults (also correction thereof)
- Film artefacts
- Radiographic anatomy

NECESSARIES

Answer sheet (per station)	x 16 (+2)
Instructions to invigilator	x 1
Viewing box	x 4
Stopwatch	x 1
X-ray film	x 14
Pen	x 2
Adhesive tape roll	x 1
Memorandum (per station)	x 1
Extension cord	x 2
Double power socket	x 2

INSTRUCTIONS TO INVIGILATOR

1. Check that the films are placed in the correct sequence on the viewing boxes before each assessment.

2. Place the correct answer sheet at each viewing box before each assessment.

3. Check that the students fill in their names on the answer sheets.

4. Set the stopwatch for 6 min. and press “start”, when the students are standing ready next to the viewing boxes.

5. No assistance regarding the questions may be rendered to the students.

6. Put the completed answer sheets in the specific X-ray envelopes.

7. Check that there are 16 x 4 answer sheets in the envelopes at the end of the film-viewing assessment.

8. The invigilator has to complete an evaluation form at the end of the film-viewing assessment.

9. Let each student complete an evaluation form at the end of each round.

STATION 1: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………………

FILM 1
Judet projection of the pelvis

(a) Which **aspect** of the pelvis is in contact with the film?

………..…………………………………………………………………..…… (1)

(b) **Give three reasons** for your answer.

…………………………………………………………………………………… (1)

…………………………………………………………………………………… (1)

……………………………………………………………………………………. (1)

FILM 2
Postero-anterior projection of the lungs

(a) **Give** the **correct name** of this projection …………………………………… (1)

(b) **Give one reason** for your answer.

……………………………………………………………………..………… (1)

FILM 3
Supine lateral-oblique projection of the right mandible
- done with horizontal central ray (cervical spine reported as normal)

(a) **Describe two methods** whereby this **critical positioning fault can be corrected.**

(i) ……………………………………..………. ……………………………… (1)

(ii) ……………………………..…………………………………………… (1)

FILM 4
Supine modified lateral projection of the scapula
(patient has spine injuries)

(a) **Identify** the **positioning fault** that you observe at the scapula.

………………………………………………………………. …………………. (1)

(b) **Name one way** to **correct** this mistake.

………………. …………..………………………………………………… (1)

[10]

STATION 1: MEMORANDUM

FILM 1

Judet projection of the pelvis

(a) Which **aspect** of the pelvis is in contact with the film?
Left posterior…………………………………………………………………….. (1)

(b) **Give three reasons** for your answer.
3 Of the following: Left iliac bone is broad/right iliac bone is thin/right obturator foramen is open/right pubic bone is elongated/left pubic bone is foreshortened/left obturator foramen is closed/medial part of left acetabulum is demonstrated/right s.i. joint is slightly open……………………………… (3)

FILM 2

Postero-anterior projection of the lungs

(a) **Give** the **correct name** of this projection.
Right anterior oblique………………………………………………………… (1)

(b) **Give one reason** for your answer.
Spine rotated towards the right side/left side of chest or ribs is broad………. (1)

FILM 3

Supine lateral-oblique projection of the right mandible
- done with horizontal ray (cervical spine reported as normal)

(a) **Describe two ways** whereby this **critical positioning fault can be corrected.**
(i) Tilt the skull more towards the cassette ...……………………………… (1)
(ii) Angle more cranially …………………………………………………… (1)

FILM 4

Supine modified lateral projection of the scapula
(patient has spine injuries)

(a) **Identify** the **positioning fault** that you observe at the scapula.
The scapula is not perpendicular to the film (not lateral) ……………………. (1)

(b) **Name one way** to **correct** this mistake.
Adjust the tube angulation to direct it parallel with the body of the scapula … (1)

[10]

STATION 2: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………

FILM 1

Pelvic inlet projection

(a) **Identify** the **direction of displacement** of the **left pubic bone.**

……..…………………………………………………………………….. (1)

FILM 2

Occipito-frontal 20°↓ projection of the skull

(a) **Identify two critical positioning faults** that were made when performing this projection.

(i) ………………………..……………………………………………….… (1)

(ii)…………………………………………………………………………… (1)

FILM 3

Antero-posterior sitting projection of the lungs

(a) **Identify** the **most critical positioning fault/appearance** that you observe on this projection (letter excluded).

………………………….…………………………………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance at (a).

……………………………………………………………………………….. (1)

……………………………………………………………………………….. (1)

FILM 4

Antero-posterior projection of the lumbar spine

(a) **Give** the **correct name** of this projection ……………………………………. (1)

(b) **Give one reason** for your answer at (a).

……………………………………………………………………………. (1)

(c) Was the patient **more** or **less** than 45° rotated? (too Lat or too AP?)

……………………………………………………………………………. (1)

(d) **Motivate** your answer at (c).

……………………………………………………………………………….. (1)

[10]

STATION 2: MEMORANDUM

FILM 1

Pelvic inlet projection

(a) **Identify** the **direction of displacement** of the **left pubic bone.**

Anteriorly ………………………………………………………………….. (1)

FILM 2

Occipito-frontal 20º↓ projection of the skull

(a) **Identify two critical positioning faults** that were made when performing this projection.

(i) Skull was rotated towards the left side…………………………………….…(1)
(ii) RBL was not perpendicular to the film (chin raised) or tube was more than 20º↓ (caudally angled) …………………………………………………… (1)

FILM 3

Antero-posterior sitting projection of the lungs

(a) **Identify** the **most critical positioning fault/appearance** that you observe on this projection (letter excluded).
The chest is lordotic ……..…………………………………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance at (a).
2 Of the following:
The patient was reclining.
The tube was not caudally angled.
The centring was too low.
(2)

FILM 4

Antero-posterior projection of the lumbar spine

(a) **Give** the **correct name** of this projection.
Left posterior oblique projection of the lumbar spine ………………………. (1)

(b) **Give one reason** for your answer at (a).
One of the following:
"Scottish dog" looks towards side nearest to film/Left iliac bone is flattened …(1)

(c) Was the patient **more** or **less** than 45º rotated? (too Lat or too AP?)
Less/too AP ………………………………………………………………. (1)

(d) **Motivate** your answer at (c).
The transverse processes ("muzzles" of "dogs") project across the sides of the vertebrae ……………………………………………………………….. (1)

[10]

APPENDIX J: FILM-VIEWING ASSESSMENT 2 (2005)

FILM-VIEWING ASSESSMENT 2

(Not part of year mark)

CLINICAL RADIOGRAPHIC PRACTICE II

10 OCTOBER 2005

FILM-VIEWING ASSESSMENT

SECOND YEAR RADIOGRAPHIC (DIAG.) STUDENTS

DATE:	**10 OCTOBER 2005**
VENUE:	**ULTRASOUND LECTURE ROOM**
DURATION:	**6 MIN. PER STATION x 2 STATIONS = 12 MIN. 12 MIN. + 3 MIN. ROTATION TIME = ± 15 MIN. PER GROUP 15 MIN. x 8 GROUPS = TOTAL DURATION = 2 HOURS = ± 08H00 – 10H00**
FILMS:	**4 FILMS ON EACH VIEWING BOX**
VIEWING BOXES:	**2 VIEWING BOXES**
NUMBER OF STUDENTS:	**16 (8 GROUPS OF 2 STUDENTS)**

ROTATION LIST:

Grouping done by students (number of group drawn by each student). No suitcases/bags or cell phones are allowed in lecture room (not before or during evaluation)! Students must already be seated at 07:50 in the Second years' lecture room.

Group 1: (08:00-08:15)
A Rabe
V Francke

Group 2: (08:15-08:30)
J Roberts
I Appel

Group 3: (08:30-08:45)
L Cloete
D Kotze

Group 4: (08:45-09:00)
U Horn
M Booys

Group 5: (09:00-09:15)
N Lerm
E Deysel

Group 6: (09:15-09:30)
M Molde
E Smith

Group 7: (09:30-09:45)
D Cloete
B Johnson

Group 8: (09:45-10:00)
D van Wyk
M Cloete

OBJECTIVES

The student is tested regarding the **IDENTIFICATION** of the following on radiographic images:

- Modified/special radiographic images (specific name of projection/position of patient)
- Technique faults (also correction thereof)
- Radiographic anatomy

NECESSARIES

Answer sheet (per station)	x 16 (+2)
Instructions to invigilator	x 1
Viewing box	x 2
Stopwatch	x 1
X-ray film	x 8
Pen	x 2
Adhesive tape roll	x 1
Memorandum (per station)	x 1
Extension cord	x 1
Double power socket	x 1

INSTRUCTIONS TO INVIGILATOR

1. Check that the films are placed in the correct sequence on the viewing boxes before each assessment.

2. Place the correct answer sheet at each viewing box before each assessment.

3. Check that the students fill in their names on the answer sheets.

4. Set the stopwatch for 6 min. and press "start", when the students are standing ready next to the viewing boxes.

5. No assistance regarding the questions may be rendered to the students.

6. Put the completed answer sheets in the specific X-ray envelopes.

7. Check that there are 16 x 2 answer sheets in the envelopes at the end of the film-viewing assessment.

8. The invigilator has to complete an evaluation form at the end of the film-viewing assessment.

9. Let each student complete an evaluation form at the end of each round.

STATION 1: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………………

FILM 1

Antero-posterior projection of the bladder

(a) **Give** the **full name** of this projection.

…………..……………………………………………………..…………… (1)

(b) **Give two reasons** for your answer.

……………………………………………………………………………… (1)

……………………………………………………………………………… (1)

FILM 2

Postero-anterior projection of the sterno-clavicular joints

(a) **Give** the **full name** of this projection.

……………………………………………………………………………. (1)

(b) **Give one reason** for your answer.

…………..…………………………………………………………………….. (1)

(c) Which sterno-clavicular joint is demonstrated open? …………..……………… (1)

FILM 3

Lateral projection of the left femoral neck
- done with horizontal central ray

(a) **Describe two ways** whereby this **critical positioning fault can be rectified** (letter excluded).

(i) ……………………………………...………………………………… (1)

(ii) ...……………………………………………………………………… (1)

FILM 4

Sitting infero-superior ("skyline") projection of the knees

(a) **Identify** the **critical positioning fault** that you observe at the patellae (letter excluded).

……………………………………………………………………………… (1)

(b) **Name one way** to rectify this mistake.

…………………………………………………………………………….(1)

[10]

STATION 1: MEMORANDUM

FILM 1
Antero-posterior projection of the bladder

(a) **Give** the **full name** of this projection.
Left posterior oblique bladder ………………………………………………… (1)

(b) **Give two reasons** for your answer.
2 Of the following: Left iliac bone is broad/right iliac bone is thin/right obturator foramen is open/right pubic bone is elongated/left pubic bone is foreshortened/left obturator foramen is closed/right s.i. joint is slightly open… (2)

FILM 2
Postero-anterior projection of the sterno-clavicular joints

(a) **Give** the **full name** of this projection.
Left anterior oblique of the s-c joints ...………………………………………. (1)

(b) **Give one reason** for your answer.
Vertebrae has rotated towards the left side/right side of chest or ribs is broad/ sternum has rotated towards the right side/left side of chest or ribs is narrow/ left s-c joint is open ………………………………………………………. (1)

(c) Which sterno-clavicular joint is demonstrated open? …..Left………………… (1)

FILM 3
Lateral projection of the left femoral neck
- done with horizontal central ray

(a) **Describe two ways** whereby this **critical positioning fault can be rectified** (letter excluded).
(i) More flexion of the right hip and knee /pull right leg more cranially/ /raise right femur higher...………………………………………………… (1)
(ii) Angle more cranially ……….…………………………………………… (1)

FILM 4
Sitting infero-superior ("skyline") projection of the knees

(a) **Identify** the **critical positioning fault** that you observe at the patellae (letter excluded).
The joints posterior of the patellae are not demonstrated or the patellae are not demonstrated "end on" ……………………………………………………... (1)

(b) **Name one way** to rectify this mistake.
Adjust the angulation of the tube to direct it parallel with the long axis of the patellae/centre higher, more through the joints …….…………………………… (1)

[10]

STATION 2: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………

FILM 1

Supero-inferior projection of the right shoulder

(a) **Identify** the **direction** in which the arrow is pointing on this projection.

……………………………………………………………………………………. (1)

FILM 2

Reversed Occipito-mental 0º projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter and scratch mark excluded).

(i) ……………………………..…………………………………………… (1)

(ii) ……………………..…………………………………………………….. (1)

FILM 3

Infero-superior projection of the right clavicle

(a) **Identify** the **most critical positioning fault/appearance** that you observe on this projection (letter and name excluded).

…………………………………………………………………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance at (a).

…………………………………………………………………………………… (1)

…………………………………………………………………………………… (1)

FILM 4

Antero-posterior projection of the kidneys

(a) **Give** the **correct name** of this projection ……………………………………. (1)

(b) Is die patient **more** or **less** than **45º** rotated? Too Lat or too AP?

………………………………………………………………………………….. (1)

(c) **Motivate** your answer at (b).

……………………………..……………………………………………………… (1)

(d) **Name** the **most critical positioning fault** that you observe (letter excluded).

……………………………………………………………………………………. (1)

[10]

<u>STATION 2: MEMORANDUM</u>

<u>FILM 1</u>

<u>Supero-inferior projection of the right shoulder</u>

(a) **Identify** the **direction** in which the arrow is pointing on this projection.

Anteriorly ………………………………………………………………….. (1)

<u>FILM 2</u>

<u>**Reversed** Occipito-mental 0º projection of the facial bones</u>

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter and scratch mark excluded).

(i) Angle more cranially ………..……………………………………………. (1)

(ii) Raise the patient's chin more……………………………………………..(1)

(Rotate skull to the left = 1)

<u>FILM 3</u>

<u>Infero-superior projection of the right clavicle</u>

(a) **Identify** the **most critical positioning fault/appearance** that you observe on this projection (letter and name excluded).

The clavicles are not projected above the apices/ribs ………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance at (a).

Patient was not reclining enough.

Not angled cranially enough.

(2)

<u>FILM 4</u>

<u>Antero-posterior projection of the kidneys</u>

(a) **Give** the **correct name** of this projection.

Left posterior oblique projection of the kidneys………………………………..(1)

(b) Is die patient **more** or **less** than **45º** rotated? Too Lat or too AP?

More than 45º (too Lat)……………………………………………………(1)

(c) **Motivate** your answer at (b).

The left transverse processes ("muzzles" of "dogs") are foreshortened/do not touch the left sides of vertebral bodies ……………………………………….. (1)

(d) **Name** the **most critical positioning fault** that you observe (letter excluded).

Too little centred towards the raised side/right side…………………………… (1)

[10]

APPENDIX K: FILM-VIEWING ASSESSMENT 3 (2005)

FILM-VIEWING ASSESSMENT 3

CLINICAL RADIOGRAPHIC PRACTICE II

10 NOVEMBER 2005

FILM-VIEWING ASSESSMENT

SECOND YEAR RADIOGRAPHIC (DIAG.) STUDENTS

DATE:	**10 NOVEMBER 2005**
VENUE:	**ULTRASOUND LECTURE ROOM**
DURATION:	**6 MIN. PER STATION x 2 STATIONS = 12 MIN. 12 MIN. + 3 MIN. ROTATION TIME = ± 15 MIN. PER GROUP 15 MIN. x 8 GROUPS = TOTAL DURATION = 2 HOURS = ± 08H30 – 10H30**
FILMS:	**4 FILMS ON EACH VIEWING BOX**
VIEWING BOXES:	**2 VIEWING BOXES**
NUMBER OF STUDENTS:	**16 (8 GROUPS OF 2 STUDENTS)**

ROTATION LIST:

Grouping done by lecturer (previous rotation lists taken into account). No suitcases/bags or cell phones are allowed in lecture room (not before or during evaluation)! Students must already be seated at 08:20 in the Second years' lecture room.

Group 1: (08:30-08:45)
M Cloete
J Roberts

Group 2: (08:45-09:00)
A Rabe
E Smith

Group 3: (09:00-09:15)
D van Wyk
M Booys

Group 4: (09:15-09:30)
I Appel
B Johnson

Group 5: (09:30-09:45)
U Horn
L Cloete

Group 6: (09:45-10:00)
D Cloete
V Francke

Group 7: (10:00-10:15)
D Kotze
M Molde

Group 8: (10:15-10:30)
E Deyzel
N Lerm

OBJECTIVES

The student is tested regarding the **IDENTIFICATION** of the following on radiographic images:

- Modified/special radiographic images (specific name of projection/position of patient)
- Technique faults (also correction thereof)
- Radiographic anatomy

NECESSARIES

Answer sheet (per station)	x 16 (+2)
Instructions to invigilator	x 1
Viewing box	x 2
Stopwatch	x 1
X-ray film	x 8
Pen	x 2
Adhesive tape roll	x 1
Memorandum (per station)	x 1
Extension cord	x 1
Double power socket	x 1

INSTRUCTIONS TO INVIGILATOR

1. Check that the films are placed in the correct sequence on the viewing boxes before each assessment.

2. Place the correct answer sheet at each viewing box before each assessment.

3. Check that the students fill in their names on the answer sheets.

4. Set the stopwatch for 6 min. and press “start”, when the students are standing ready next to the viewing boxes.

5. No assistance regarding the questions may be rendered to the students.

6. Put the completed answer sheets in the specific X-ray envelopes.

7. Check that there are 16 x 2 answer sheets in the envelopes at the end of the film-viewing assessment.

8. The invigilator has to complete an evaluation form at the end of the film-viewing assessment.

9. Let each student complete an evaluation form at the end of each round.

STATION 1: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………

FILM 1
Antero-posterior oblique projection of the left s.i. joint

(a) **Name** the aspect of the pelvis that was in contact with the film.

………………………………………………………………………………………(1)

(b) **Give one reason** for your answer.

………………………………………………………………………………………(1)

FILM 2
Postero-anterior oblique projection of the left ribs

(a) **Give** the **full name** of this projection.

……………………………………………………………………………………. (1)

(b) **Give three reasons** for your answer at (a).

……………………………………………………………………………………. (1)

……………………………………………………………………………………. (1)

……………………………………………………………………………………. (1)

FILM 3
Left lateral projection of the cervico-thoracic vertebrae ("Swimmer's") (done supine on perspex trolley)

(a) **Describe two ways** whereby this **critical positioning fault** can be rectified (letter excluded).

(i) ……………………………………………………………………...…………. (1)

(ii)………………………..……..……………………………………………… (1)

FILM 4
Sitting axial projection of the right calcaneus

(a) **Name two ways** whereby this **critical positioning fault** can be rectified (letter excluded).

(i) ………………………………………………………………………………. (1)

(ii) ……………………………………………………………………………… (1)

[10]

STATION 1: MEMORANDUM

FILM 1
Antero-posterior oblique projection of the left s.i. joint

(a) **Name** the aspect of the pelvis that was in contact with the film.
Right posterior aspect ……..………………………………………………… (1)

(b) **Give one reason** for your answer.
Left iliac bone is thin or "end on" ………………………………………………(1)

FILM 2
Postero-anterior oblique projection of the left ribs

(a) **Give** the **full name** of this projection.
Right anterior oblique projection of the ribs ………………………………….. (1)

(b) **Give three reasons** for your answer at (a).
Vertebrae have rotated towards the right side/left side of chest or ribs is broad/ sternum has rotated towards the left side/right s-c joint is open/left scapula is broad ……………………………………………………..……………… (3)

FILM 3
Left lateral projection of the cervico-thoracic vertebrae ("Swimmer's") (done supine on perspex trolley)

(a) **Describe two ways** whereby this **critical positioning fault** can be rectified (letter excluded).

(i) Pull the right arm/shoulder nearer to the tube more caudally …...…………. (1)
(ii) Angle caudally ……………….…….………………………………………… (1)

FILM 4
Sitting axial projection of the right calcaneus

(a) **Name two ways** whereby this **critical positioning fault** can be rectified (letter excluded).
(i) Modify the tube angulation so that the central ray will be more perpendicular to the long axis of the calcaneus/angle more cranially ….. (1)
(ii) More dorsiflexion of foot necessary/pull foot backwards (put ankle in dorsiflexion) ……………………………………………………………….. (1)

[10]

STATION 2: ANSWER SHEET

NAME OF STUDENT: ………………………………………………………………

FILM 1
Modified infero-superior ("Westpoint") projection of the left shoulder

(a) **Identifiy** the **anatomical structure** (i) on this projection.

…………….…………………………………………………………………… (1)

(b) **Identify** the **direction** in which the arrow is pointing on this projection.

……. ……………………………………………………………………. (1)

FILM 2
Sitting Occipito-mental 0º projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter excluded).

(i) …………………………… ……………………………………………… (1)

(ii) ……..…………………….………………………………………………. (1)

(b) **Name one** more **important positioning fault** that has been made.

………………………..……………………………………………………. (1)

FILM 3
Antero-posterior sitting apical projection of the lungs

(a) **Evaluate** the **technique** during this projection regarding faults/correctness. (letter excluded).

…………………………………………………………………………….. (1)

………..……………………………………………………………….. (1)

………..……………………………………………………………….… (1)

FILM 4
Postero-anterior projection of the lumbar spine

(a) **Give** the **correct name** of this projection.

……………………………………………………..…………………….. (1)

(b) **Identify** in which direction the arrow is pointing (side in contact with film or side raised).

……………..……………………………………………………………… (1)

[10]

STATION 2: MEMORANDUM

FILM 1

Modified infero-superior ("Westpoint") projection of the left shoulder

(a) **Identify** the **anatomical structure** (i) on this projection.

Acromion ………………………………………………………………………… (1)

(b) **Identify** the **direction** in which the arrow is pointing on this projection.

Posterior ……………………………………………………………………….. (1)

FILM 2

Sitting Occipito-mental 0° projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter excluded).

(i) The patient's chin should be raised more ..………………………………… (1)
(ii) Angle caudally …………..……………………………………………………. (1)

(b) **Name one** more **important positioning fault** that has been made.
Skull is rotated towards the left side ………………………………………… (1)

FILM 3

Antero-posterior sitting apical projection of the lungs

(a) **Evaluate** the **technique** during this projection regarding faults/correctness (letter excluded).
2 Of the following:
The clavicles are not totally projected above the upper ribs/less than 30° cranially angled/patient not reclining enough/the clavicles are projected above the apices/patient reclining enough (30°) or tube was angled enough cranially (30°) ………………………………………………………………. (2)
1 Of the following: Too little of the apices are included on the film/tube centred too high/patient was not positioned in the middle of the cassette .… (1)

FILM 4

Postero-anterior projection of the lumbar spine

(a) **Give** the **correct name** of this projection.
Left anterior oblique projection of the lumbar spine/vertebrae……………… (1)

(b) **Identify** in which direction the arrow is pointing (side in contact with film or side raised).
Side raised ………………………………………………………………………. (1)

[10]

APPENDIX L: RADIOGRAPHIC PROJECTIONS USED IN ASSESSMENTS (2006)

M TECH D VENTER

FILM-VIEWING ASSESSMENTS 2006

SKILLS TESTED	FILM-VIEWING ASSESMENT 1 (BASELINE)	FILM-VIEWING ASSESSMENT 2	FILM-VIEWING ASSESSMENT 3
The student should be able to:	**Projection**	**Projection**	**Projection**
Suggest tilting of the X-ray tube or adjusting the position of the skull to project structures of the skull (e.g. petrous bones) in the correct position (from an AP or PA aspect). Suggest ways to rectify rotation or other positioning mistakes.	Occipito-frontal 20°↓ skull.	Reversed occipito-mental 0° facial bones.	Sitting occipito-mental 0° facial bones.
Suggest tilting of the X-ray tube or adjusting the patient's body to separate overlying (remove unwanted) structures (from a lateral aspect).	Lateral-oblique projection of the mandible (two projections demonstrating different technique errors).	Lateral projection of the femoral neck.	Lateral projection of the cervical-thoracic region ("Swimmer's").
Recognise the position of structures with a 30°↑ tilt of the X-ray tube/patient leaning 30° backwards during a chest projection. Suggest ways to rectify mistakes.	Lordotic projection of the chest.	Antero-posterior 30°↑ projection of the apices.	Infero-superior projection of the clavicle.
Recognise the position and shape of structures when rotating the chest through 45°. Identify the name of the projection (which aspect is in contact with the film).	Rotated postero-anterior projection of the lungs.	Postero-anterior oblique projection of the sterno-clavicular joints.	Postero-anterior oblique projection of the left ribs.
Recognise the position and shape of structures when rotating the pelvis through 15 - 45°. Identify the name of the projection (which aspect is in contact with the film).	Rotated antero-posterior projection of the pelvis.	Posterior oblique projection of the left s.i. joint.	Left posterior oblique projection of the bladder.
Recognise the position and shape of structures with supero-inferior/ infero-superior projections. Identify direction e.g. anterior or posterior.	Pelvic inlet projection.	Supero-inferior projection of the shoulder.	Modified infero-superior projection of the shoulder ("Westpoint").
Recognise the position and shape of structures when rotating the lumbar spine/abdomen through 45°. Identify the name of the projection (which aspect is in contact with the film).	Posterior oblique projection of the lumbo-sacral junction.	Anterior oblique projection of the lumbar spine.	Posterior oblique projection of the kidneys.
Suggest modifications in angulation of the tube to project a structure "end on" or foreshortened (tube parallel to axis of structure) or to project a structure to demonstrate it's full width or length (tube perpendicular to axis of structure).	Flexed antero-posterior projection of the elbow (forearm seen "end on").	Axial projection of the calcaneus.	Infero-superior ("Skyline") projection of both patella.

- The above-mentioned projections of the different film-viewing assessments test similar skills.

Examiner: ..[signature]......................(Mrs. D. Venter) Date: 20/11/2006

Moderator: ..VDaries................................. (Mrs. V. Daries) Date: 20/11/2006

APPENDIX M: FILM-VIEWING ASSESSMENT 1 (2006)

FILM-VIEWING ASSESSMENT 1

CLINICAL RADIOGRAPHIC PRACTICE II

29 AUGUST 2006

(ONLY THE TWO STATIONS APPLICABLE TO RESEARCH INCLUDED)

FILM-VIEWING ASSESSMENT

SECOND YEAR RADIOGRAPHIC (DIAG.) STUDENTS

DATE:	**29 AUGUST 2006**
VENUE:	**RADIOTHERAPY LECTURE ROOM**
DURATION:	**6 MIN. PER STATION x 4 STATIONS = 24 MIN. 24 MIN. + 11 MIN. ROTATION TIME = ± 35 MIN. PER GROUP x 6 GROUPS TOTAL DURATION = ± 12:30 – ± 16:06**
FILMS:	**1 - 5 FILMS ON EACH VIEWING BOX**
VIEWING BOXES:	**4 VIEWING BOXES**
NUMBER OF STUDENTS:	**25 (5 GROUPS OF 4 STUDENTS, 1 GROUP OF 5 STUDENTS)**

ROTATION LIST:

Grouping done by lecturer from middle of alphabetical class list.
No suitcases/bags or cell phones are allowed in lecture room (not before or during evaluation)!
Students must already be seated at 12:15 in the Second years' lecture room.

Group 1: (12:30-13:05) A Kennedy C Koch C Kapopwe S Koortzen Group 2: (13:05-13:40) L Kannemeyer F Kuhn A Jansen J Mkile Group 3: (13:40-14:15) E Jacobs J Phillips A Havenga M Roux Group 4: (14:15-14:50) L du Plessis G Schwartz P Dreyer S Syster	Group 5: (14:50-15:25) S de Reuck C Valentine J Coetzee A van Hooi Group 6: (15:25-16:06) A Brussel S van Tonder T Abrahams C van Vuuren L Wilhelm

<u>OBJECTIVES</u>

The student is tested regarding the **IDENTIFICATION** of the following on radiographic images:

- Abnormal appearances
- Possible pathology
- Modified/special radiographic images (specific name of projection/position of patient)
- Technique/exposure faults (also correction thereof)
- Film artefacts
- Radiographic anatomy

NECESSARIES

Answer sheet (per station)	x 25 (+2)
Instructions to invigilator	x 1
Viewing box	x 4
Stopwatch	x 1
X-ray film	x 14
Pen	x 2
Adhesive tape roll	x 1
Memorandum (per station)	x 1
Extension cord	x 2
Double power socket	x 1

<u>INSTRUCTIONS TO INVIGILATOR</u>

1. Check that the films are placed in the correct sequence on the viewing boxes before each assessment.

2. Place the correct answer sheet at each viewing box before each assessment.

3. Check that the students fill in their names on the answer sheets.

4. Set the stopwatch for 6 min. and press “start”, when the students are standing ready next to the viewing boxes.

5. No assistance regarding the questions may be rendered to the students.

6. Put the completed answer sheets in the specific X-ray envelopes.

7. Check that there are 25 x 4 answer sheets in the envelopes at the end of the film-viewing assessment.

8. The invigilator has to complete an evaluation form at the end of the film-viewing assessment.

9. Let each student complete an evaluation form at the end of each round.

STATION 1: ANSWER SHEET

NAME OF STUDENT: ………………………………………………………………

FILM 1

Rotated Antero-posterior projection of the pelvis

(a) Which **side** of the pelvis is **raised** from the film? …………………………. (1)

(b) **Give three reasons** for your answer.

……………………………………………………………………………….

………………………………………………………………………………. (3)

FILM 2

Rotated Postero-anterior projection of the lungs

(a) Which **aspect** of the chest is **closer** to the film? …………………………… (1)

(b) **Give one reason** for your answer.

………………………………………………………………………………… (1)

FILM 3 + 4

Lateral-oblique projections of the right mandible

- done sitting

(a) **Describe two ways** whereby this **critical positioning mistake** at **FILM 3** can be **rectified.**

…..……………………………………..………. ……………………………… (½)

…..……………………………..……………………………………………….. (½)

(b) **Describe two ways** whereby this **critical positioning mistake** at **FILM 4** can be **rectified** (not letter).

…..…………………………………………..……. ……………………………… (½)

…..……………………………..……………………………………………… (½)

FILM 5

Antero-posterior projection of the elbow

(a) **Identify** the **critical positioning mistake** that you observe at the elbow.

……………………………………………………………………………….... (1)

(b) Name **one way** to rectify this mistake.

………………………………………………………………………… (1)

[10]

STATION 1: MEMORANDUM

FILM 1

Rotated Antero-posterior projection of the pelvis

(a) Which **side** of the pelvis is **raised** from the film?

Right side …………………………………………………………………. (1)

(b) **Give three reasons** for your answer.

3 Of: Left iliac bone is broad/right iliac bone is thin/right obturator foramen is more open/right pubic bone is elongated/left pubic bone is foreshortened/ left obturator foramen is more closed/right s.i. joint is open/"scottish dogs" look towards side in contact with film……………………………………………(3)

FILM 2

Rotated Postero-anterior projection of the lungs

(a) Which **aspect** of the chest is **closer** to the film?

Right anterior aspect……………………………………………………….. (1)

(b) **Give one reason** for your answer.

Spine has rotated towards the right side/left side of chest or rib cage is broad/ left clavicle further away from spinous process/heart rotated towards the left side……………………………………………………………………………… (1)

(Difference in lung densities = ½)

FILM 3 + 4

Lateral-oblique projections of the right mandible

- done sitting

(a) **Describe two ways** whereby this **critical positioning mistake** at **FILM 3** can be **rectified.**

Tilt the skull more towards the cassette………………...……………………… (½)

Angle more cranially ……………………………….……………………….. (½)

(b) **Describe two ways** whereby this **critical positioning mistake** at **FILM 4** can be **rectified** (not letter).

Tilt the skull less towards the cassette …………………………………………… (½)

Angle less cranially ……………………………………………………………… (½)

FILM 5

Antero-posterior projection of the elbow

(a) **Identify** the **critical positioning mistake** that you observe at the elbow.

The forearm is perpendicular to the film (not parallel to the film)/……………..
or the central beam is parallel to the long axis of the forearm – "end on"…….. (1)
(foreshortening of forearm = ½)

(b) Name **one way** to rectify this mistake.

Adjust the angulation of the tube so that the beam runs midway between the humerus and forearm (angle caudally)/or try to get forearm parallel to the cassette/or angle central beam to get it more perpendicular to forearm…….. (1)

[10]

STATION 2: ANSWER SHEET

NAME OF STUDENT: …………………………………………………………………

FILM 1

Pelvic-inlet projection

(a) **Identify** the **direction of displacement** of the fracture at the **left pubic bone.**

……………………………………………………………………………………… (1)

FILM 2

Occipito-frontal 20º↓ projection of the skull

(a) **Identify two critical positioning mistakes** that were made when executing this projection.

……………………………………………………………………………………… (1)

……………………………………………………………………………………… (1)

FILM 3

Antero-posterior sitting projection of the lungs

(a) **Identify** the **most critical positioning mistake/appearance** that you observe on this projection **(not collimation)**.

……………………………………………………………………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance (a).

……………………………………………………………………………………… (1)

……………………………………………………………………………………… (1)

FILM 4

Antero-posterior oblique projection of the lumbo-sacral spine area

(a) **Identify** the **direction** of the arrow: side of patient closest to film or raised side?

……………………………………………………………………………………… (1)

(b) **Give one reason** for your answer at (a).

……………………………………………………………………………………… (1)

(c) Is the patient **less** than or **more** than 45º or **45º** rotated? (too AP or too Lat or correct?)

……………………………………………………………………………………… (1)

(d) **Motivate** your answer at (c).

……………………………………………………………………………………… (1)

[10]

STATION 2: MEMORANDUM

FILM 1
Pelvic-inlet projection

(a) **Identify** the **direction of displacement** of the fracture at the **left pubic bone.**
Anterior……………………………………………………………………….. (1)

FILM 2
Occipito-frontal 20°↓ projection of the skull

(a) **Identify two critical positioning mistakes** that were made when executing this projection.

Skull was rotated towards the right side..…………………………………….. (1)
Not angled 20° caudally (or angled less than 20°) …..…………...………….. (1)
(Skull in skew position on film = ½)

FILM 3
Antero-posterior sitting projection of the lungs

(a) **Identify** the **most critical positioning mistake/appearance** that you observe on this projection **(not collimation)**.
The chest appears lordotic…..………………………………………………… (1)
(Rotation towards the left side = ½)
(b) **Give two** possible **reasons/causes** for this appearance (a).
Patient reclining ……………………………………………………………… (1)
Not angled caudally ………………………………………………………….. (1)

FILM 4
Antero-posterior oblique projection of the lumbo-sacral spine area

(a) **Identify** the **direction** of the arrow: side of patient closest to film or raised side?

Side against film..……………………………………………………………. (1)
(b) **Give one reason** for your answer at (a).
One of:
"Scottish dog" looks towards side closest to film/left iliac bone appears thin .. (1)
(c) Is the patient **less** than or **more** than 45° or **45°** rotated? (too AP or too Lat or correct?)
Correct/45°…………………………..……..…………………………………. (1)
(d) **Motivate** your answer at (c).
The transverse processes ("muzzles" of "dogs" touch the sides of the vertebral bodies ……………………………………………………………………….. (1)

[10]

APPENDIX N: FILM-VIEWING ASSESSMENT 2 (2006)

FILM-VIEWING ASSESSMENT 2

(Not part of year mark)

CLINICAL RADIOGRAPHIC PRACTICE II

9 OCTOBER 2006

FILM-VIEWING ASSESSMENT

SECOND YEAR RADIOGRAPHIC (DIAG.) STUDENTS

DATE:	**9 OCTOBER 2006**
VENUE:	**ULTRASOUND LECTURE ROOM**
DURATION:	**6 MIN. PER STATION x 2 STATIONS = 12 MIN.** **12 MIN. + 3 MIN. ROTATION TIME** **= ± 15 MIN. PER GROUP (2)** **15 MIN. x 6 GROUPS** **= TOTAL DURATION = 1 HOUR 30 MIN.** **= ± 08:00 – 09:30** **x 2 (DUPLICATE FILMS ON TWO MORE VIEWING BOXES)** **= 12 GROUPS (OF 2) + 1 STUDENT = 25** **= ± 08:00 – 09:30 (+ 15 MIN.)**
FILMS:	**4 FILMS ON EACH VIEWING BOX**
VIEWING BOXES:	**4 VIEWING BOXES (2 BOXES = DUPLICATE FILMS)**
NUMBER OF STUDENTS:	**25 (12 GROUPS OF 2 STUDENTS + 1 STUDENT)**

ROTATION LIST:

Grouping done by students (number of group drawn by each student). No suitcases/bags or cell phones are allowed in lecture room (not before or during evaluation)! Students must already be seated at 07:50 in the Second years' lecture room.

Group 1+ 2: (08:00-08:15)	First station
A Jansen + L du Plessis	(station 1)
A Brussel + S de Reuck	(station 2)
Group 3 + 4: (08:15-08:30)	
F Kuhn + G Schwartz	(station 1)
C Koch + M Roux	(station 2)
Group 5 + 6: (08:30-08:45)	
A Kennedy + J Phillips	(station 1)
C van Vuuren + L Wilhelm	(station 2)
Group 7 + 8: (08:45-09:00)	
S Koortzen + A van Hooi	(station 1)
A Havenga + E Jacobs	(station 2)
Group 9 + 10: (09:00-09:15)	
T Abrahams + P Dreyer	(station 1)
C Kapopwe + S van Tonder	(station 2)
Group 11 + 12: (09:15-09:30)	
S Syster + J Coetzee	(station 1)
J Mkile + L Kannemeyer	(station 2)
Student: (09:30-09:45)	
C Valentine	(station 1)

OBJECTIVES

The student is tested regarding the **IDENTIFICATION** of the following on radiographic images:

- Modified/special radiographic images (specific name of projection/position of patient)
- Technique faults (also correction thereof)
- Radiographic anatomy

NECESSARIES

Answer sheet (per station)	x 25 (+2)
Instructions to invigilator	x 1
Viewing box	x 2 (+ 2)
Stopwatch	x 1
X-ray film	x 8 (+8 duplicates)
Pen	x 4
Adhesive tape roll	x 1
Memorandum (per station)	x 1
Extension cord	x 2
Double power socket	x 1

INSTRUCTIONS TO INVIGILATOR

1. Check that the films are placed in the correct sequence on the viewing boxes before each assessment.

2. Place the correct answer sheet at each viewing box before each assessment.

3. Check that the students fill in their names on the answer sheets.

4. Set the stopwatch for 6 min. and press “start”, when the students are standing ready next to the viewing boxes.

5. No assistance regarding the questions may be rendered to the students.

6. Put the completed answer sheets in the specific X-ray envelopes.

7. Check that there are 25 x 2 answer sheets in the envelopes at the end of the film-viewing assessment.

8. The invigilator has to complete an evaluation form at the end of the film-viewing assessment.

9. Let each student complete an evaluation form at the end of each round.

STATION 1: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………………

FILM 1
Antero-posterior oblique projection of the left s.i. joint

(a) **Name** the aspect of the pelvis that was in contact with the film.

…………………………………………………………………………………………(1)

(b) **Give one reason** for your answer.

…………………………………………………………………………………………(1)

FILM 2
Postero-anterior projection of the sterno-clavicular joints

(a) **Give** the **full name** of this projection.

………………………………………………………………………………………. (1)

(b) **Give two reasons** for your answer.

…………..……………………………………………………………………….. (1)

…………..……………………………………………………………………….. (1)

(c) Which sterno-clavicular joint is demonstrated open? …………..……………… (1)

FILM 3
Lateral projection of the left femoral neck
- done with horizontal central ray

(a) **Describe two ways** whereby this **critical positioning fault can be rectified** (letter excluded).

(i) ……………………………………...………………………………… (1)

(ii) ...……………………………………………………………………… (1)

FILM 4
Sitting axial projection of the right calcaneus

(a) **Name two ways** whereby this **critical positioning fault** can be rectified (letter excluded).

(i) …………………………………………………………………………. (1)

(ii) ………………………………………………………………………… (1)

[10]

STATION 1: MEMORANDUM

FILM 1
Antero-posterior oblique projection of the left s.i. joint

(a) **Name** the aspect of the pelvis that was in contact with the film.
Right posterior aspect ……..……………………………………………………. (1)

(b) **Give one reason** for your answer.
Left iliac bone is thin or "end on" ………………………………………………(1)

FILM 2
Postero-anterior projection of the sterno-clavicular joints

(a) **Give** the **full name** of this projection.
Left anterior oblique of the s-c joints ...………………………………………. (1)

(b) **Give two reasons** for your answer.
Vertebrae has rotated towards the left side/right side of chest or ribs is broad/
sternum has rotated towards the right side/left side of chest or ribs is narrow/
left s-c joint is open …………………………………………………………. (2)

(c) Which sterno-clavicular joint is demonstrated open? …..Left………………… (1)

FILM 3
Lateral projection of the left femoral neck
- done with horizontal central ray

(a) **Describe two ways** whereby this **critical positioning fault can be rectified** (letter excluded).
(i) More flexion of the right hip and knee /pull right leg more cranially/
/raise right femur higher...………………………………………………… (1)
(ii) Angle more cranially ………..………………………………………… (1)

FILM 4
Sitting axial projection of the right calcaneus

(a) **Name two ways** whereby this **critical positioning fault** can be rectified (letter excluded).
(i) Modify the tube angulation so that the central ray will be more
perpendicular to the long axis of the calcaneus/angle more cranially ….. (1)
(ii) More dorsiflexion of foot necessary/pull foot backwards (put ankle in
dorsiflexion) ……………………………………………………………….. (1)

[10]

STATION 2: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………

FILM 1

Supero-inferior projection of the right shoulder

(a) **Identify** the **direction** in which the arrow is pointing on this projection.

……………………………………………………………………………………. (1)

FILM 2

Reversed Occipito-mental 0º projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter and scratch mark excluded).

(i) …………………………….………………………………………………… (1)

(ii) ………………………..…………………………………………………….. (1)

FILM 3

Antero-posterior sitting apical projection of the lungs

(a) **Evaluate** the **technique** during this projection regarding faults/correctness. (letter excluded).

……………………………………………………………………………….. (1)

…………..…………………………………………………………………….. (1)

………….……………………………………………………………………… (1)

FILM 4

Postero-anterior projection of the lumbar spine

(a) **Give** the **correct name** of this projection.

……………………………………………………………..…………………….. (1)

(b) **Identify** in which direction the arrow is pointing (side in contact with film or side raised).

………………..………………………………………………………………… (1)

(c) **Give two reasons** for your answer.

………………………………………………………………………………… (1)

………………………………………………………………………………… (1)

[10]

STATION 2: MEMORANDUM

FILM 1

Supero-inferior projection of the right shoulder

(a) **Identify** the **direction** in which the arrow is pointing on this projection.

Anteriorly ………………………………………………………………….. (1)

FILM 2

Reversed Occipito-mental 0º projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter and scratch mark excluded).

(i) Angle more cranially ………..……………………………………………. (1)

(ii) Raise the patient's chin more……………………………………………..(1)

FILM 3

Antero-posterior sitting apical projection of the lungs

(a) **Evaluate** the **technique** during this projection regarding faults/correctness (letter excluded).

2 Of the following:

The clavicles are not totally projected above the upper ribs/less than 30º cranially angled/patient not reclining enough/the clavicles are projected above the apices/patient reclining enough (30°) or tube was angled enough cranially (30°) ……………………………………………………………. (2)

1 Of the following: Too little of the apices are included on the film/tube centred too high/patient was not positioned in the middle of the cassette …. (1)

FILM 4

Postero-anterior projection of the lumbar spine

(a) **Give** the **correct name** of this projection.

Left anterior oblique projection of the lumbar spine/vertebrae……………… (1)

(b) **Identify** in which direction the arrow is pointing (side in contact with film or side raised).

Side raised ……………………………………………………………. (1)

(c) **Give two reasons** for your answer.

"Scottish dogs" look towards side away from film/raised iliac bone more broad or central ray perpendicular to axis of right iliac bone. (2)

[10]

APPENDIX O: FILM-VIEWING ASSESSMENT 3 (2006)

FILM-VIEWING ASSESSMENT 3

CLINICAL RADIOGRAPHIC PRACTICE II

6 NOVEMBER 2006

FILM-VIEWING ASSESSMENT

SECOND YEAR RADIOGRAPHIC (DIAG.) STUDENTS

DATE:	**6 NOVEMBER 2006**
VENUE:	**ULTRASOUND LECTURE ROOM**
DURATION:	**6 MIN. PER STATION x 2 STATIONS = 12 MIN.** **12 MIN. + 3 MIN. ROTATION TIME** **= ± 15 MIN. PER GROUP (2)** **15 MIN. x 6 GROUPS** **= TOTAL DURATION = 1 HOUR 30 MIN.** **= ± 08:00 – 09:30** **x 2 (DUPLICATE FILMS ON TWO MORE VIEWING BOXES)** **= 12 GROUPS (OF 2) + 1 STUDENT = 25** **= ± 08:00 – 09:30 (+ 15 MIN.)**
FILMS:	**4 FILMS ON EACH VIEWING BOX**
VIEWING BOXES:	**4 VIEWING BOXES (2 BOXES = DUPLICATE FILMS)**
NUMBER OF STUDENTS:	**25 (12 GROUPS OF 2 STUDENTS + 1 STUDENT)**

ROTATION LIST:

Grouping done by lecturer (previous rotation list taken into account)). No suitcases/bags or cell phones are allowed in lecture room (not before or during evaluation)! Students must already be seated at 07:50 in the Second years' lecture room.

Student: (08:00-08:15)	First station
C Valentine	(station 1)
Group 1+ 2: (08:15-08:30)	
S Syster + J Coetzee	(station 1)
J Mkile + L Kannemeyer	(station 2)
Group 3 + 4: (08:30-08:45)	
T Abrahams + P Dreyer	(station 1)
C Kapopwe + S van Tonder	(station 2)
Group 5 + 6: (08:45-09:00)	
S Koortzen + A van Hooi	(station 1)
A Havenga + E Jacobs	(station 2)
Group 7 + 8: (09:00-09:15)	
A Kennedy + J Phillips	(station 1)
C van Vuuren + L Wilhelm	(station 2)
Group 9 + 10: (09:15-09:30)	
F Kuhn + G Schwartz	(station 1)
C Koch + M Roux	(station 2)
Group 11 + 12: (09:30-09:45)	
A Jansen + L du Plessis	(station 1)
A Brussel + S de Reuck	(station 2)

OBJECTIVES

The student is tested regarding the **IDENTIFICATION** of the following on radiographic images:

- Modified/special radiographic images (specific name of projection/position of patient)
- Technique faults (also correction thereof)
- Radiographic anatomy

NECESSARIES

Answer sheet (per station)	x 25 (+2)
Instructions to invigilator	x 1
Viewing box	x 2 (+ 2)
Stopwatch	x 1
X-ray film	x 8 (+8 duplicates)
Pen	x 4
Adhesive tape roll	x 1
Memorandum (per station)	x 1
Extension cord	x 2
Double power socket	x 1

INSTRUCTIONS TO INVIGILATOR

1. Check that the films are placed in the correct sequence on the viewing boxes before each assessment.

2. Place the correct answer sheet at each viewing box before each assessment.

3. Check that the students fill in their names on the answer sheets.

4. Set the stopwatch for 6 min. and press “start”, when the students are standing ready next to the viewing boxes.

5. No assistance regarding the questions may be rendered to the students.

6. Put the completed answer sheets in the specific X-ray envelopes.

7. Check that there are 25 x 2 answer sheets in the envelopes at the end of the film-viewing assessment.

8. The invigilator has to complete an evaluation form at the end of the film-viewing assessment.

9. Let each student complete an evaluation form at the end of each round.

STATION 1: ANSWER SHEET

NAME OF STUDENT: …………………………………………………………………

FILM 1
Antero-posterior projection of the kidneys

(a) **Give** the **correct name** of this projection.

………………………………………………………………………………… (1)

(b) Is die patient **more** or **less** than **45º** rotated? Too Lat or too AP?

……………………………………………………………………………….. (1)

(c) **Motivate** your answer at (b).

…………………………….…………………………………………………… (1)

(d) **Name** the **most critical positioning fault** that you observe (letter excluded).

…………………………………………………………………………………. (1)

FILM 2
Sitting infero-superior ("skyline") projection of the knees

(a) **Identify** the **critical positioning fault** that you observe at the patellae (letter excluded).
………………………………………………………………………………… (1)

(b) **Name one way** to rectify this mistake.

…………………………………………………………………………………. (1)

FILM 3
Modified infero-superior ("Westpoint") projection of the left shoulder

(a) **Identifiy** the **anatomical structure** (i) on this projection……………………. (1)
(b) **Identify** the **direction** in which the arrow is pointing on this projection.

……..………………………………………………………………………. (1)

FILM 4
Left lateral projection of the cervico-thoracic vertebrae ("Swimmer's") (done supine on perspex trolley)

(a) **Describe two ways** whereby this **critical positioning fault** can be rectified (letter excluded).
(i) ……………………………………………………………………...…………. (1)

(ii)…………………………..…….……………………………………………… (1)
[10]

STATION 1: MEMORANDUM

FILM 1
Antero-posterior projection of the kidneys

(a) **Give** the **correct name** of this projection.
Left posterior oblique projection of the kidneys……………………………….(1)

(b) Is die patient **more** or **less** than **45º** rotated? Too Lat or too AP?
More than 45º (too Lat)………………………………………………………(1)

(c) **Motivate** your answer at (b).
The left transverse processes (“muzzles” of “dogs”) are foreshortened/do not touch the left sides of vertebral bodies …………………………………….. (1)

(d) **Name** the **most critical positioning fault** that you observe (letter excluded).
Too little centred towards the raised side/right side…………………………… (1)

FILM 2
Sitting infero-superior (“skyline”) projection of the knees

(a) **Identify** the **critical positioning fault** that you observe at the patellae (letter excluded).
The joints posterior of the patellae are not demonstrated or the patellae are not demonstrated “end on” …………………………………………………... (1)

(b) **Name one way** to rectify this mistake.
Adjust the angulation of the tube to direct it parallel with the long axis of the patellae/centre higher, more through the joints …….………………………… (1)

FILM 3
Modified infero-superior (“Westpoint”) projection of the left shoulder

(a) **Identify** the **anatomical structure** (i) on this projection.

Acromion ……………………………………………………………… (1)

(b) **Identify** the **direction** in which the arrow is pointing on this projection.

Posterior …………………………………………………………….. (1)

FILM 4
Left lateral projection of the cervico-thoracic vertebrae (“Swimmer’s”) (done supine on perspex trolley)

(a) **Describe two ways** whereby this **critical positioning fault** can be rectified (letter excluded).

(i) Pull the right arm/shoulder nearer to the tube more caudally …...…………. (1)
(ii) Angle caudally ……………….…….……………………………………… (1)

[10]

STATION 2: ANSWER SHEET

NAME OF STUDENT: ……………………………………………………………

FILM 1
Infero-superior projection of the left clavicle **(top projection)**

(a) **Identify** the **most critical positioning fault/appearance** that you observe on this projection (collimation excluded).

………………………………………………………………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance at (a).

………………………………………………………………………………… (½)

………………………………………………………………………………… (½)

FILM 2
Antero-posterior projection of the bladder

(a) **Give** the **full name** of this projection.

………………………………………………………………………………… (1)

(b) **Give two reasons** for your answer.

………………………………………………………………………………… (1)

………………………………………………………………………………… (1)

FILM 3
Postero-anterior oblique projection of the left ribs

(a) **Give** the **full name** of this projection.

………………………………………………………………………………… (1)

(b) **Give two reasons** for your answer at (a).

………………………………………………………………………………… (1)

………………………………………………………………………………… (1)

FILM 4
Sitting Occipito-mental 0º projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter and rotation excluded).

(i) ………………………… ……………………………………………… (1)

(ii) ……..…………………….………………………………………………. (1)

[10]

STATION 2: MEMORANDUM

FILM 1

Infero-superior projection of the left clavicle **(top projection)**

(a) **Identify** the **most critical positioning fault/appearance** that you observe on this projection (collimation excluded).
The clavicles are not projected above the apices/ribs ………………………… (1)

(b) **Give two** possible **reasons/causes** for this appearance at (a).
Patient was not reclining enough. (½)
Not angled cranially enough. (½)

FILM 2

Antero-posterior projection of the bladder

(a) **Give** the **full name** of this projection.
Left posterior oblique bladder ………………………………………………… (1)

(b) **Give two reasons** for your answer.
2 Of the following: Left iliac bone is broad/right iliac bone is thin/right obturator foramen is open/right pubic bone is elongated/left pubic bone is foreshortened/left obturator foramen is closed/right s.i. joint is slightly open… (2)

FILM 3

Postero-anterior oblique projection of the left ribs

(a) **Give** the **full name** of this projection.
Right anterior oblique projection of the ribs ………………………………….. (1)

(b) **Give two reasons** for your answer at (a).
Vertebrae have rotated towards the right side/left side of chest or ribs is broad/ sternum has rotated towards the left side/right s-c joint is open/left scapula is broad …………………………………………………………..……………… (2)

FILM 4

Sitting Occipito-mental 0° projection of the facial bones

(a) **Name two ways** whereby the **most critical positioning fault can be rectified** (letter and rotation excluded).

(i) The patient's chin should be raised more ..………………………………… (1)
(ii) Angle caudally …………..…………………………………………………. (1)

[10]

APPENDIX P: EXAMPLE OF FORM: FEEDBACK FROM STUDENTS ON FILM-VIEWING ASSESSMENTS

RADIOGRAPHY TRAINING
CAPE PENINSULA UNIVERSITY OF TECHNOLOGY
TYGERBERG HOSPITAL SATELLITE CAMPUS

OBJECTIVE STRUCTURED CLINICAL EVALUATION (O.S.C.E.)

STUDENT'S OPINION OF THE O.S.C.E

	YES	NO	COMMENTS
1. WERE THE ASSIGNMENTS CLEAR?			
2. WERE THE ASSIGNMENTS TOO DIFFICULT FOR YOU?			
3. WERE THE STATIONS REALISTIC? (Not applicable to film evaluation)			
4. WAS THE TIME ENOUGH TO COMPLETE THE ASSIGNMENTS?			
5. WERE THE PATIENTS CO-OPERATIVE? (Not applicable to film evaluation)			
6. DID THE INVIGILATORS: - **MAKE YOU FEEL AT EASE?** - **DISPLAY HELPFULNESS?** - **CREATE A CALM ATMOSPHERE?**			
7. WERE YOU ABNORMALLY TENSE/ANXIOUS DURING THE EXAMINATION?			
8. DID YOU PREPARE YOURSELF ENOUGH FOR THE EXAMINATION?			
9. ARE YOU HAPPY WITH THE EXAMINATION DAY'S PROGRAM?			

ANY SUGGESTIONS FOR THE FOLLOWING PRACTICAL EXAMINATION?

……….

……….

……….

……….

APPENDIX Q: EXAMPLE OF FORM: INFORMAL FEEDBACK FROM STUDENTS ON RESEARCH ACTIVITIES (2006)

M TECH D VENTER

FEEDBACK FROM STUDENTS ON PRACTICAL DEMONSTRATIONS 2006

NAME OF STUDENT: …………………………………………………………..

PLEASE TICK √ THE APPROPRIATE ANSWER **DID THE PRACTICAL SESSIONS GIVE YOU INSIGHT ON THE FOLLOWING:**	**SLIGHTLY**	**YES**	**NO**
To suggest tilting of the X-ray tube or adjusting the position of the skull to project structures of the skull (e.g. petrous bones) in the correct position (from an AP or PA aspect) e.g. OM 0° projection.			
To suggest tilting of the X-ray tube or adjusting the patient's body to separate overlying structures (from a lateral aspect) e.g. femoral neck projection.			
To recognise the position of structures with a 30°↑ tilt of the X-ray tube/patient leaning 30° backwards during a chest projection and to suggest ways to rectify mistakes.			
To recognise the position and shape of structures when rotating the chest through 45° and to identify the name of the projection (which aspect is in contact with the film).			
To recognise the position and shape of structures when rotating the pelvis through 15 - 45° and to identify the name of the projection (which aspect is in contact with the film).			
To recognise the position and shape of structures with supero-inferior/ infero-superior projections and to identify direction e.g. anterior or posterior.			
To recognise the position and shape of structures when rotating the lumbar spine/abdomen through 45° and to identify the name of the projection (which aspect is in contact with the film).			
To suggest modifications in angulation of the tube to project a structure "end on" or foreshortened (tube parallel to axis of structure) or to project a structure to demonstrate it's full width or length (tube perpendicular to axis of structure).			

COMMENTS: ……………………………………………………………………………………….

…………………………………………………………………………………………………...

APPENDIX R: EXAMPLE PAGE: SPATIAL APTITUDE TEST

TOETS 9

RUIMTELIKE WAARNEMING
(3 - D)

In elke vraag is daar ses blokkies. Een van die laaste vyf blokkies lyk net soos die eerste een.

SOEK DIE EEN BLOKKIE WAT NET SOOS DIE EERSTE EEN LYK. DIE BLOKKIE MAG, IN JOU GEDAGTE, IN ENIGE RIGTING GEDRAAI OF OMGEKEER WORD. MAAK DAN DIE SPASIE OP JOU ANTWOORDBLAD SWART WAT DIESELFDE LETTER HET AS DIE BLOKKIE WAT JY GEKIES HET.

(Aanvaar dat die sye van die eerste blokkie wat nie sigbaar is nie geen figure op het nie.)

Kyk na vraag 1.

TEST 9

SPATIAL PERCEPTION
(3 - D)

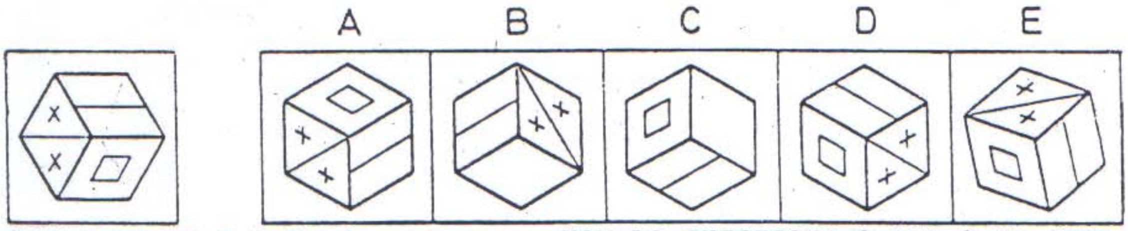
Each question consists of six blocks. One of the last five blocks is similar to the first one

FIND THE ONE BLOCK THAT LOOKS EXACTLY LIKE THE FIRST ONE. IN YOUR MIND THE BLOCKS MAY BE TURNED ROUND OR OVER IN ANY DIRECTION. ON YOUR ANSWER SHEET BLACKEN THE SPACE WHICH HAS THE SAME LETTER AS THE BLOCK WHICH YOU HAVE CHOSEN.

(Assume that the sides of the first block which are not visible have no designs on them.)

Look at question 1.

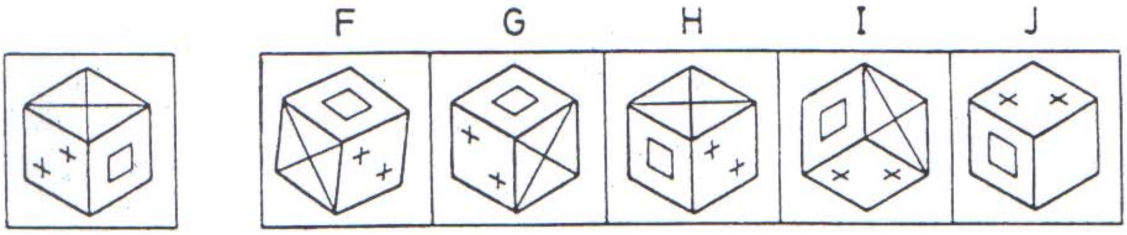
1



DOEN NOU SELF VRAE 2 EN 3.

NOW DO QUESTIONS 2 AND 3 ON YOUR OWN.

2



3