Unmasking how Pre-service Engineering Graphics and Design Teachers read and interpret Assembly Drawing at a University of Technology: A case study in Umgungundlovu, KwaZulu-Natal

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ABSTRACT

The study sought to find out how engineering graphics and design (EGD) pre-service teachers (PSTs) read and interpret assembly drawing (AD). This study was undertaken because newly qualified teachers of EGD need the relevant skills to teach EGD so that it activates learners' spatial visual reasoning, and ensure good pass rates in the subject. Also pre-service teachers at a University of Technology in South Africa, find assembly drawings difficult to read, to interpret and to learn.

The study was guided by four research questions:

1. What are first year EGD PSTs' levels of spatial visualization ability?
2. How do first year EGD PSTs read and interpret AD?
3. Why do first year EGD PSTs read and interpret AD the way they do?
4. Does the reading and interpretation of AD, among first year EGD PSTs, change after mediation? If so how? If not why?

The qualitative case study design approach was adopted. Data were generated through the Purdue spatial visualization test (PSVT), which is a mental rotation test, through two think aloud tasks, by individual interviews, focus group interview and collage making for both tasks.

The findings reveal that as an object undergoes more rotations it becomes increasingly more difficult for first year EGD PSTs to mentally visualize and manipulate the object. Challenges experienced by the first year EGD PSTs include the inability to read and interpret information provided by exploded isometric drawing (3-D) and different views of each part in 2-D. The result is an inability to differentiate between orthographic and isometric projections, and to visualize the different views, inability to visualize or see spatial relationships between objects and rotate objects, inability to measure accurately and apply SANS code of practice as well as inability to assemble and recognize lines. Findings also confirm that spatial ability, the ability to mentally rotate or manipulate objects is not innate; instead it can be learned with training.

The findings from this study are used to propose a model for linking the teaching and learning of AD in EGD. The model is shown as a graphic, indicating the links between teaching and learning of AD in EGD for PSTs doing Engineering Drawing and Design as their specialization subject.

Key words: assembly drawing, engineering graphics and design, read, interpret, understanding, pre-service teachers.

DECLARATION

I hereby declare that “Unmasking how Pre-service Engineering Graphics and Design teachers read and interpret Assembly Drawing at a particular University of Technology: A case study in Umgungundlovu, KwaZulu-Natal” is my own work and that all the sources I have used or quoted, have been indicated and acknowledged by means of complete references.

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DEDICATION

This thesis is dedicated to my dear sister **Samukelisiwe P.P. Sotsaka,** my Mom **Sibongile G. (MaMtima) Sotsaka,** my children **Ovuyonke, Amkele and Ethaba,** and my nephews **Lulonke and Luzelwande.** You keep me grounded and are my everything. Thank you for your unconditional love, patience, tolerance, support, motivation and allowing me the space to pursue my academic endeavours. I love you dearly.

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LIST OF ACRONYMS

2-D- Two dimensional

3-D- Three dimensional

AD-Assembly Drawing

BOM-Bill of Material

CAD- Computer Aided Draughting

DBE- Department of Basic Education

EGD- Engineering Graphics and Design

FET- Further Education and Training

ICT-Information Communication Technology

ILS-Index of learning style

LSI-Learning style inventory

LSQ-Learning style questionnaire

MBTI-Myers –Briggs type indicator

MI-Multiple intelligence

NCS-National Curriculum Statement

NSC-National Senior Certificate

PCK- Pedagogical Content Knowledge

PST-Pre-Service Teacher

PSVT- Purdue Spatial Visualization Test

SANS-South African National Standards

TD-Technical Drawing

ZPD-Zone of Proximal Development

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CHAPTER ONE

INTRODUCTION

The purpose of this study is to explore how first year Engineering Graphics and Design (EGD) pre-service teachers (PSTs) read and interpret assembly drawings. This introductory chapter provides a synopsis of the background, rationale, objectives, critical questions and significance of the study. Additionally an outline of the research approach deployed to answer the research questions posed is presented.

1.1.Background

In South Africa, severe skills shortages have been identified in critical fields, such as engineering (Department of Labour, DoL, 2006; Joint Initiative on Priority Skills Acquisition, JIPSA, 2006; National Planning Commission, 2011). The skills shortages identified in the engineering field has been linked directly to the schooling system, despite the National Education Department's increased budget for schools (Kraak, 2008). In this regard, studies by Sotsaka (2015); Konadu-Yiadom (2016) and Cheng (2006) illuminate the failure of schools to develop through subjects like EGD the fundamental skills required in engineering courses, such as the ability to communicate graphically, apply spatial visual reasoning (also referred to visual spatiality) as well as the ability to read and interpret graphical text. Additionally, it has been noted that much of school teaching, learning and assessment emphasizes verbal and written skills rather than spatial visual skills (Shea, Lubinski, & Benbow, 2001; Gohm, Humphreys, & Yao, 1998).

Spatial visual reasoning has been well documented as the fundamental skills needed to function effectively in engineering courses (Seery, Lynch, & Dunbar; 2010; Branoff & Dobelis, 2012; Uttal, Meadow, Tipton, Hand, Warren & Newcombe, 2013; Contero, Naya, Company & Saorín, 2006; Sorby & Baartmans, 2000; Deno, 1995; Miller & Bertoline, 1991). Strong spatial visual skills are important when creating and interpreting engineering drawings, which infers the importance of critical thinking, modelling, mental manipulations and problem solving process skills (Igbinomwanhia & Aliu, 2013; Konadu-Yiadom, 2016; Makgata & Khoza, 2016; Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson 2001; Baynes, 2010). Many scholars such as Seery et al. (2010), Branoff and Dobelis (2012), Uttal et al. (2013) and Contero , Naya, Company and Saorín (2006) put forward the idea that in EGD, learners learn to communicate graphically and are expected to be able to read and interpret graphical text. That being said, it is of concern that studies by Sotsaka (2015) and Singh-Pillay and Sotsaka (2017) indicate that many practicing teachers of EGD lack the pedagogical content knowledge (PCK) needed to develop the spatial visual skills required by learners to cope with engineering drawings such as assembly drawings. Consequently, many EGD learners emerging from the school system (in this case including first year EGD PSTs) have poorly developed or activated spatial visual skills (Branoff & Dobelis, 2012). Resonating with the aforementioned points the annual reports from National Senior Certificate (NSC) EGD examiners and moderators consistently highlight matric learners' (in)ability to read and interpret engineering drawings, for example assembly drawing (AD) (Department of Basic Education, DBE, 2011-2018). Even though these NSC examiners' and moderators' reports are sent to schools, the identified area of weakness pertaining to reading and interpreting AD persists. Put simply, this means that practicing teachers of EGD are repeatedly failing to action the suggestions contained each year in the NSC EGD examiners' and moderators' report in order to activate EGD learners' spatial visual skills. Taking into consideration the problem identified in the literature with regard to EGD learners (in)ability to read and interpret AD, as well as practicing EGD teachers' lack of pedagogical content knowledge needed to develop spatial visual skills, this study pays attention to first year engineering, graphics and design (EGD) pre-service teachers (PSTs). The first year students are training to teach EGD and are learning how to teach AD. Gaining deeper insights into first year EGD PSTs' spatial visual skills and how they read and interpret AD will assist in scaffolding how they read and interpret AD, with a view to developing such skills, so that when they qualify they will be equipped with the fundamental abilities needed to activate their learner's spatial visual skills.

1.2. Rationale for the study

This study is underpinned by two reasons. The first reason is linked to the consequences of having teachers of EGD who are qualified but who do not have the relevant skills to teach EGD in a way that activates learners' spatial visual reasoning (Sotsaka, 2015; Singh-Pillay & Sotsaka, 2017; Tholo, Monobe, & Lumadi, 2011). This subsequently leads to few learners passing the subject at matric level at a high enough level and with sufficient skills for further study in EGD related courses at tertiary institutions. As a result, few learners study EGD related fields at tertiary level, which compounds the scarce skills shortage in the country.

The second reason arises from my experience as a lecturer of EGD at the DS University of Technology (pseudonym) in South Africa. As a lecturer of EGD I have observed that pre-service teachers in the technology teacher education programs at the aforementioned university who are enrolled for the Bachelor of Education (Technical Education) course find assembly drawings difficult to read, interpret and learn. Consequently, they have trouble passing EGD. As a result, they opt to change their stream or study option in the middle of the year. This invariably means that learners of EGD are disadvantaged compared to learners taking other subjects, as they are not only expected to read and interpret question posed in the written exam text, but also be able to work with the visual text in the form of drawings. In other words, learners are expected to have developed visual literacy, with well activated spatial visual skills. This observation prompted me to explore how first year EGD PSTs read and interpret AD. I focus here on first year EGD PSTs' approach to AD firstly because Shulman (2005) maintains "learning begins with how students approach a topic" (p. 38). First year EGD PSTs are learning about AD and how to teach AD and will eventually teach learners perusing EGD at schools. Furthermore, many studies agree that first year university students in engineering courses have trouble with spatial visualization abilities in drawing sections (Makgato & Khoza, 2016; Garmendia et al. 2007; Nagy-Kondor, 2007; Upadhye et al., 2011 Akasah & Alias, 2010). Whilst these studies confirm that engineering students have poorly developed spatial visual ability, there is, however, a paucity of literature on: how students in EGD education read and interpret AD specifically, or, perhaps of greater importance, what can be done to assist students to enhance their spatial visual abilities. Furthermore, these studies have focused on engineering education in general rather than specifically with engineering graphics and design education or EGD pre-service teachers. This study responds to these two gaps identified in the literature: the implications of teachers with poorly developed PCK for EGD, and the paucity of literature on pre-service teachers and AD.

The study aims to address the above problem by gaining deep insight into how first year EGD pre-service teachers read and interpret AD, which is an uncharted terrain. Knowing how first year EGD PSTs read and interpret AD will enable me to note the challenges they encounter and hence scaffold their learning by making them aware of their areas of weakness. Wilson and Devereux (2014) assert that scaffolding is a teaching strategy that allows the lecturer to guide PSTs with the expectation of PSTs being able to complete the activity on their own. Vygotsky's theory concerning the zone of proximal development suggests that all PST do have the ability to develop cognitively, even if there are gaps in their prior knowledge, provided their learning is scaffolded. Consequently, I will be able to propose an instructional model that could be used in an initial teacher training programme to assist first year EGD PSTs to activate their spatial visual reasoning ability.

1.3.Purpose of this study

The purpose of this study is to explore how first year EGD pre-service EDG teachers read and interpret assembly drawing.

The objectives guiding this study are:

1. Establish first year EGD PSTs' level of spatial visualization ability.
2. Ascertain how first year EGD PSTs read and interpret AD.
3. Determine why first year EGD PSTs read and interpret AD the way in which they do.
4. Establish whether first year EGD PSTs' reading and interpreting of AD changed after mediation.

The research questions that guide this study are:

1. What are first year EGD PSTs' levels of spatial visualization ability?
2. How do first year EGD PSTs read and interpret AD?
3. Why do first year EGD PSTs teachers encounter challenges when they read and interpret AD?
4. Does the reading and interpreting of AD, among first year EGD PSTs, change after mediation? If so how? If not, why?

1.4.Significance of the study

Insight from this study should contribute to addressing the current status quo with regard to the reading and interpretation skills needed in AD and so lead to transforming of the initial teaching program. Such changes should equip and support PSTs of EGD by activating their visual skills and teaching the necessary pedagogical content knowledge related to AD, so that all learners would subsequently be better equipped to respond to AD examination questions. Furthermore, the university lecturing personnel, particularly for the EGD course, should also become acquainted with the situation and challenges faced by the first year EGD PSTs, so they can reflect on their methodology and approach in teaching AD.

The curriculum policy makers or developers should also benefit from the findings of the study. In other words, the study could present other dynamics or ideas for teaching the AD section.

1.5.Methodology

An interpretative qualitative approach was adopted in the study in order to put into effect the methods considered to be appropriate for data generation by Creswell (2013). A case study design was used to answer the research questions. Data was generated through the Purdue spatial visualization test, think-aloud task based activities, individual interviews, focus group interviews, collage making and post collage making focus group interview. The 41 participants were selected purposively; they were all first year EGD PSTs enrolled for the Bachelor of Education degree specializing in technology education at DS University of Technology.

1.6.Limitations

Limitations, as suggested by Du Plooy-Cillers, Davis and Bezuidenhout (2016), are constraints in your research that are beyond the researchers' control. The limitations of a study are those characteristics of design or methodology that impacted on or influenced the interpretation of the findings from your research. They are the constraints on generalizability that arise from the design the study and/or the method used to establish internal and external validity.

Since the study adopted a case study design, the findings generated cannot be generalized. Furthermore, the relatively small sample size may be a concern. Statistical tests normally require a larger sample size to ensure a representative distribution of the population. This was addressed by ensuring that rich thick descriptions were provided when qualitative data was analysed. First year EGD PSTs absenteeism was also another limitation that could have impacted data generation. To overcome this particular challenge I set up appointments with students who were absent to allow them to complete the tasks. A further limitation was time available for data generation. There is always the threat of looming student protest as the DS University of Technology. Data needed to be generated between February and June 2018. To overcome this challenge I reduced my sample size for phases 2-4 from 16 to 8 participants, based on the advice I received from staff in the Science and Technology Education Cluster, University of KwaZulu-Natal.

1.7.Clarification of terms

To minimize confusion and misunderstanding, some key terms used in the study are clarified below.

First year EGD pre-service teacher: Students in a teacher training qualification course with specialization in technology education studying Engineering Graphics and Design as one of their major subjects or modules to be taught at school level

PSTs' interpretation is the process of mental translation of the subject knowledge content to clarify the meaning of AD for better understanding.

1.8.Overview of chapters to follow

The study is arranged in eleven chapters. The current chapter covers the research problem, research background, kind of participants and its setting or study site. It gives an outline of research objectives and research questions that guide the development of remaining chapters.

Chapter 2 focuses on the context of the study. It highlights the shift from the old technical drawing curriculum to EGD, with regard to content and weighting of sections. Additionally the content of the first year EGD module and how it relates to first year PSTs EDG examinations is also foregrounded in chapter two. A deeper insight in assembly drawing is provided.

Then Chapter 3 pays attention to a review of literature concerning key skills associated with the reading and interpreting of engineering drawings, student difficulties with engineering drawings, how to improve spatial ability, traits of spatial learners, learning styles, gender differences and spatial ability, teaching EGD and assembly drawing, and competencies required by EGD teachers to teach AD.

The theoretical framework underpinning this study is elaborated in Chapter 4. Vygotsky's zone of proximal development and Gardner's multiple intelligence and learning style theory framed this study.

The data generation strategy used to generate data is expanded upon in Chapter 5. This qualitative study adopted a case study design. Data was generated via the Purdue spatial visualization test (PSVT), two think aloud tasks, individual interviews, collages and post collage making focus group interviews. Data from using the PSVT is presented and analyzed in Chapter 6, while Chapter 7 elaborates the factors impinging on how first year EGD PSTs read and interpret AD. Chapter 8 responds to research question three and details the challenges first year EGD PSTs encounter when they read and interpret AD. Chapter 9 explains the teaching intervention programme I used to scaffold first year EGDS PSTs reading and interpreting of AD. Chapter 10 responds to research question four and expands on how first year EGD PSTs' reading and interpreting of AD changed. Finally, in Chapter 11, I present the final interpretation, summary, conclusions and recommendations.

1.9.Conclusion

This chapter covers the background of the whole thesis. In the engineering field, EGD is a key school subject, which has a mechanical drawing component encompassing AD. This aspect is a challenge for most of first year EGD PSTs enrolled in the B.Ed. qualification program. The study focuses how first year EGD PSTs read and interpret AD. The findings will be used to provide support to first year EGD PSTs to improve their performance in the AD section and EGD. Four research questions will be addressed in the study.

CHAPTER TWO

CONTEXT OF THE STUDY

2.1. Introduction

This study is located within the context of engineering graphic and design (EGD), which comprises engineering drawing. In this chapter, I provide the context of the study; namely, assembly drawing (AD). As mentioned earlier in Chapter 1, assembly drawing is an integral part of engineering graphics and design. I elaborate in this chapter on the similarities and differences between EGD and the school subject Technical Drawing (TD), from previous school curricula. I here further highlight the content, skills and competencies first year EGD PSTs are expected to acquire when they engage with AD.

2.2. Shift from Technical Drawing (TD) to EGD

Engineering Graphics and Design subject has superseded the school subject of Technical Drawing (TD). TD was a subject offered mainly at technical high schools and a few non-technical high schools. Prior to the restructuring of the apartheid education landscape in South Africa, TD was offered from Standards 6 to 10 (Grades 8 to 12 or Forms 1 to 5). The purpose of this subject was to prepare learners to work in the engineering field or industry as tradesmen, artisans, technicians and engineers. TD was normally taken with one or more of the following technical subjects: bricklaying and plastering, woodworking, welding, or metalwork in a school course. In the transition of TD to EGD, there has been a shift in emphasis in the context, assessment and methodology as reflected in Table 2.1 below. The NATED report 550, refers to the National Education curriculum for technical subjects (which was in use prior to democracy) while the NCS refers to the National Curriculum Statements (which is in use post democracy).

Table 2.1: Shift in emphasis from TD to EGD

NATED Report 550		NCS
Technical Drawing		**Engineering Graphics and Design**
Context	Geometrical and mechanical	Civil, electrical and mechanical
	Instrument drawing with some freehand drawing	Freehand drawing, instrument drawing and computer aided draughting
Assessment	Examination orientated	School based assessment and examinations
	First angle projection	First and third angle projection
Methodology	Unrelated to industry and needs of country	Relates to industry and the needs of the country
	Limited links to other subjects	Encourages links with other subjects
	Environmental issues and human rights not addressed	Strong emphasis on environmental issues, HIV/Aids and human rights
	Little or no creative thinking	Emphasizes critical and creative thinking skills

Source: DBE (2011)

In the above table, it is interesting to note that the shift of focus in the context, assessment and methodology of TD and EGD has contributed to EGD placing greater emphasis on critical thinking and creative skills. The aim of EGD is to develop the learner's ability to address problems and exploit opportunities in a creative and innovative way. In EGD, learners are equipped to apply cognitive skills, such as critical and creative thinking, analysis, synthesis and logic to practical, real life design and engineering problems. The aims of this subject are to equip learners with the skills, knowledge and values needed to function in an engineering and design environment. It should also stimulate an innovative and entrepreneurial spirit and enhance learners' technological literacy. The learner would thus be equipped to appreciate the interaction between peoples' values, society, environment, human rights and technology. Therefore EGD should equip learners with the basic occupational competences required by engineering and technology disciplines.

2.3. Content of EGD according to CAPS policy

The Curriculum and Assessment Policy Statement (CAPS) for EGD in the Further Education and Training Phase (FET) Grade 10–12 is based on internationally acknowledged principles that have both academic and technical applications (DBE, 2011). The emphasis in EGD is on teaching specific basic background knowledge and various drawing techniques and skills that the EGD learners can then use to interpret and produce drawings within the contexts of three technology subjects taught in the manufacturing, engineering and technology field (Mechanical Technology, Civil Technology and Electrical Technology). The main topics covered in EGD are as follows: general drawing principles for all technological drawings, freehand drawing, first-and third-angle orthographic projects, descriptive and solid geometry, mechanical working drawing, civil working drawing, isometric drawing, perspective drawing, electrical diagrams, interpenetrations and developments, loci of helixes, cams and mechanisms, design process and computer-aided drawing or design (CAD). Through these concepts, EGD aims to teach graphical drawings as a means of communication in the world of technology, solution of technology problems graphically, use of drawing instruments, and application of content and concepts for the design process in the contexts of mechanical, civil and electrical technology. In the FET phase, the EGD examination comprises two three-hour papers in accordance with the weighting reflected in Table 2.2 below. Assembly drawing falls under the section mechanical assembly, which has the greatest weighting in Paper 2.

Table 2.2: Structure and percentage weighting of Grade 12 examination papers

Paper 1 (3 hours) in first-angle orthographic projection			Paper 2 (3 hours) in third-angle orthographic projection		
Question 1	Civil analytical	+/- 15%	Question 1		+/- 15
Question 2	Interpenetration and development and or development of a transition piece and/or solid geometry	+/- 20%	Question 2	Loci of a helix and/or loci of cam and/or loci of a point(s) of a mechanism	+/- 20
Question 3	2-point perspective drawing	+/-20%	Question 3	Isometric drawing	+/- 20
Question 4	Civil working drawing including electricity features	+/-45%	Question 4	Mechanical assembly	+/- 45

Source: DBE (2011) p. 40.

2.4. Content of first year EGD Module at DS University of Technology

Below in Table 2.3, are the sections of the curriculum content of the EGD module for first year PSTs in the B Ed programme qualification in the Technology focus specialization. SANS refers to South African National Standard. SANS is s a special code of standards that applies to all engineering drawings.

Table 2.3. First year EGD Module content at DS University of Technology

Topic	Content and Concept
Introduction to EGD / Free-hand drawing	Educational Career opportunities related to EGD, Inclusivity and HIV/AIDS issues Four basic hand movement and multi views
Drawing principles in SANS code, setting up drawing sheet / instruments and scale drawing	Practice lines as in SANS code of practice (0111, 0142 & 0143) Drawing sheet features, using drawing set squares
Visualization cognitive and perception	Analyze drawings on single multi-views and pictorial drawings in civil, electrical and mechanical perception exercises
Orthographic projection	1st and 3rd angle projections applied in simple castings
Mechanical drawing: Assembly Drawing Mechanical drawings: Principle of sectioning	Draw outside, sectional, simple assemblies and intro to complex drawings as per SANS and symbol of projections. Simple and complex castings with sectioning.
Solid Geometry	Construction of polygons: perpendicular, parallel and inclined to one principal plane Prisms and pyramids, tilted, auxiliary views, developments and true shapes
Descriptive Geometry	Points and line segments and laminas
Principles of pictorial drawing	Isometric and oblique: complex, non-isometric line and circles.

Source: Sotsaka (2017) EGD 101 Study guide, AD, Faculty of Art and Design: School of Education.

The above table depicts the topics and content covered by first year EGD PSTs in the first year of their study. The section on visualization cognitive and perception lays the foundation for students in spatial thinking. It also forms a link with orthographic projection in 1st and 3rd angle. This section is where students are expected to master the interpretation of two dimensional (2-D) drawing in three views, which are front, top and side together with the respective symbol of projection. Mechanical assembly drawing can then be tackled when this background has been laid. As indicated in the EGD CAPS document (DBE, 2011) learners are expected to have covered these drawing skills from Grade 10 to 12.

2.5. Structure of first year examination paper

Table 2.4 below shows the weighting of marks for a 3hour examination paper for first year EGD PSTs at DS University of Technology. The grand total of the paper is 150. The section with the highest weighting is AD (55 marks): it makes up approximately 30% of the paper.

Table 2.4. Structure of the first year EGD examination paper

	EGD 101 Examination Paper	
Question	Content	Marks
1	Analytical civil/ mechanical	20
2	Descriptive drawing	20
3	Pictorial Drawing	30
4	Geometrical Solids	25
5	Mechanical : Assembly Drawing	55

Source: EGD 101 study guide 2017

2.6. Engineering drawing

Engineering drawing is a means of graphical communication. It consists of some technical rules or drawing conventions and visual skills. Technical rules provide standardization. Sorby and Baartmans (1996) state "a standard drawing layout typically includes the top, front, and right-side views of the object (from the viewer's perspective, the right hand side is determined by looking at the front of the object), as well as an isometric or corner view of the object" (p. 348). Sectional views may also be needed to show the interior details of a complex object. The top, front, right-side views, and sections are two-dimensional representations of a three-dimensional (3-D) object, each taken from an angle perpendicular to the referent side. The isometric view, on the other hand, is a two-dimensional representation, taken from a certain angle so that a 3-D object can be represented with its three dimensions on a plane surface. In general, those views that show only two dimensions of an object such as top, front, and right-side views, are called orthographic views, while the views that represent three dimensions are called perspective. These aspects are illustrated below in Figure 2.1, which shows a sample engineering drawing. Assembly drawing is a type of engineering drawing.

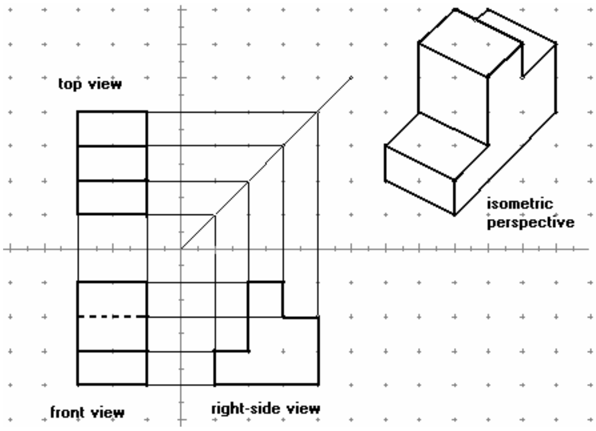


Figure 2.1 Simple engineering drawing showing the top, front and side views

As with other communication media, rules for making orthographic drawings are necessary for effective graphical communication (Sorby & Baartmans, 1996). Some of the basic rules are explained below (see Figure 2.1 as reference for each rule). Although there are many other rules for engineering drawings these rules are those that are relevant in this study.

1. The orthographic views of an object should be aligned as adjacent with one another. This rule gives a clue that the widths of the top view and of the front view are equal. Similarly, the heights in both the front and the side views are equal. These equalities are accomplished through alignment of the views. The equal lengths in the top and the side views are obtained through a 90-degrees rotation of the lengths.
2. When an orthographic drawing or sketch is created, lines are drawn to represent the edges of the object as line segments.
3. Hidden edges for the chosen view are drawn as dashed lines, whereas visible edges are drawn as solid line segments, or object lines. In standard drawing practice, if an object line coincides with a hidden line, only the object line is shown.
4. The number of orthographic views is determined according to the real object. That is, orthographic views must be able to represent all of the dimensions of the real object so that the real object can be visualized from the orthographic views including section views.

Apart from the drawing rules summarized above, there are some skills involved in engineering drawing. These skills are acquired through experience with simple to more complex visual patterns. Understanding drawings means visualizing the geometrical form and the spatial layout of the object portrayed (Roorda, 1994; Deno, 1995; Miller & Bertoline, 1991; Pleck, 1991; Sorby & Baartmans, 2000). Since there are mainly two kinds of drawing, orthographic and perspective, the understanding can occur in two different ways:

The first task is to understand the perspective drawing and create its corresponding orthographic drawings. The second is the other way around, by integrating a number of different views into a drawing showing a single spatial image. The second task seems a little more difficult than the first because integration of a number of different views into a single spatial image depends on the correct reading of the views (Roorda, 1994; Martín-Dorta, Saorín, & Contero, 2008; Sorby, 2001), and therefore requires more attention (Lord, 1985). Both drawings might involve many individual geometrical figures, such as circles, triangles, curves, lines. Therefore, the spatial ability needed in EGD should supposedly involve, but is not limited to, the manipulation of different lines, curves, plane shapes, and solid figures, and the transformations among them. Drawing perspectives, or imagining the real object from the orthographic views, also involves mental integration. Some technical rules like alignment of the views, and line weights make the visualization easier to understand. Therefore, teaching higher order visualization skills for engineering drawing should go hand in hand with technical rules.

The communication in drawing is done through reading and understanding various line types that are used in EGD. According to *South African National Standard Code of Practice for Engineering Drawing (SANS 0111-1)* of 1993 (South African Bureau of Standards, SABS, 1993) there are 10 type of lines that are used in engineering drawings. The very same lines are used in the school curriculum for EGD as a subject or module, in order to be aligned with in the requirements of industry. Assembly drawing activities could contain most of the line types depending to the level of complexity and the level of learners or students or participants. On the next page, Table 2.5 shows the 10 EGD lines types together with their use and description.

Table 2.5. EGD line types

LINE TYPE	DESCRIPTION	GENERAL APPLICATIONS
A	Continuous thick line	Used for visible outlines and visible edge
B	Continuous thin (straight or curved)	Imaginary lines of intersection, dimensions lines, projection lines leader lines, sectional lines, hatching line etc.
C D	Continuous thin freehand, continuous (straight) with zigzag	Used to indicate limits of partial or interrupted views and sections Break line
E _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ F _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	Dashed thick Dashed thin	Used to show hidden details
G___ _ ___ _ ___ _ ___ _ ___	Chain thick	Used for centre lines Lines of symmetry Trajectories
H	Chain thin, thick at ends and changes of direction	Used to show cutting planes in sectional drawing
J___ _ ___ _ ___ _ ___ _ ___	Chain thick	Used to indicate of lines or surfaces to which a special requirement applies
K______ _ _ _____ _ _ _____	Chain thin double-dashed	Used to indicate outlines of adjacent components Alternative and extreme positions of movable components Centroidal lines etc.

Source: SANS 0111 Code of practice for engineering drawing (SABS, 1993, p.5)

Line type has become fundamental knowledge that is needed to cope with the field of engineering and draughting. Table 2.5 above shows the main line types that are used in EGD, along with their descriptions and statements of their use. As can be seen, each line conveys different information to someone who understands the drawing language. According to the SANS 0111 code of practice, AD contains line types A, B, F and G as basic information for clear communication. Moolman and Brink, 2010, p. 12 also point out the standard thickness of line types in 0.3 mm. They describe the type G line as a chain-like line, which is used as a centre line and to show that a drawing is hollowed. For instance, it could show that a cylindrical part has been removed to create a hole in an object. Knowing the description and use of each line assists the learner or students to be able to interpret and understand each line in the drawing. As Moolman and Brink (2010, p. 16) emphasize, drawing is a graphic language used by engineers and draughtsman, which consist of different line types, symbols, dimensions and notes to communicate the correct meaning and ideas of the engineer as the designer of structures.

2.7. What is assembly drawing?

Assembly drawing (AD) is, according to Narayana, Kannaiah, Reddy and Venkata (2006), the presentation of various parts of a machine in their working positions. These drawings are classified as design assembly drawings, working assembly drawings, subassembly drawings, or an installation assembly. Van Leeuwenn and du Plooy (2011) are more specific. They define AD as the combination of any two or more individual components; the components being individually designed parts that when manufactured will fit together to form a functional unit or a multiple-component device. Along these lines, they contend that a drawing showing only a few parts of a larger assembly should be referred to as a subassembly.

Narayana et al. (2006) assert that AD requires spatial visualization ability, visualization skills and drawing skills, because it entails mental manipulation of objects and their parts in 2-D and 3-D space, which Kovac (1989) terms spatial ability. An assembly drawing consists of a numbers of different parts or components of a machine or system, along with a number of dimensions for clear interpretation. These different parts are given in 3-D as an exploded axonometric drawing and in 2-D, each as in two elevations. When these parts are interlocked, they form a complete functional machine. As has been briefly described above, an assembly drawing shows how different parts of a multi-component design fit together, and are generally represented as one or more orthographic projections. One or more full section views such from the front, top and left or right are often used in an assembly drawing to show the necessary internal features of the object.

According to Plantenberg (2007), AD may contain of the following components:

- One or more views, including sections or auxiliaries,
- Enlarged views to show small details,
- Overall or specific dimensions needed for assembly,
- Notes on manufacturing processes required for assembly,
- Balloons to indicate item numbers, and
- Parts list or bill of materials (BOM).

A balloon is a circle that contains a single number, which is connected to an assembly component with a leader line, usually leader lines are not horizontal or perpendicular. All parts of the object or machine are written in a parts list, which is a table that contains information about each of the parts contained in an assembly. The items are arranged such that all items numbers correspond with the balloon numbers. This is the information that is provided for the manufacturer of the machine or object.

Assembly drawings may fall into six categories (cecs.wright.edu/~dan.young/ME202); these are described in the next subsections.

2.7.1 Design assemblies

Design assembly drawings are used to show the relationships among a number of different components, usually by means of a freehand sketch. The design assembly shows the how a machine component will be assembled together for harmonious and smooth operation of the machine. For example a drawing could show the kinematic relationship that exists between the fly wheel's 360° rotation, and the extreme angular motion of the piston cylinder body. Design assemblies are often used at the planning or preliminary phases of a design process, where the sketches may be used to study the relationships that exist between the components before the design is modelled or exhibited. Figure 2.2 below shows a free hand sketch that indicates ideas in the planning phase.

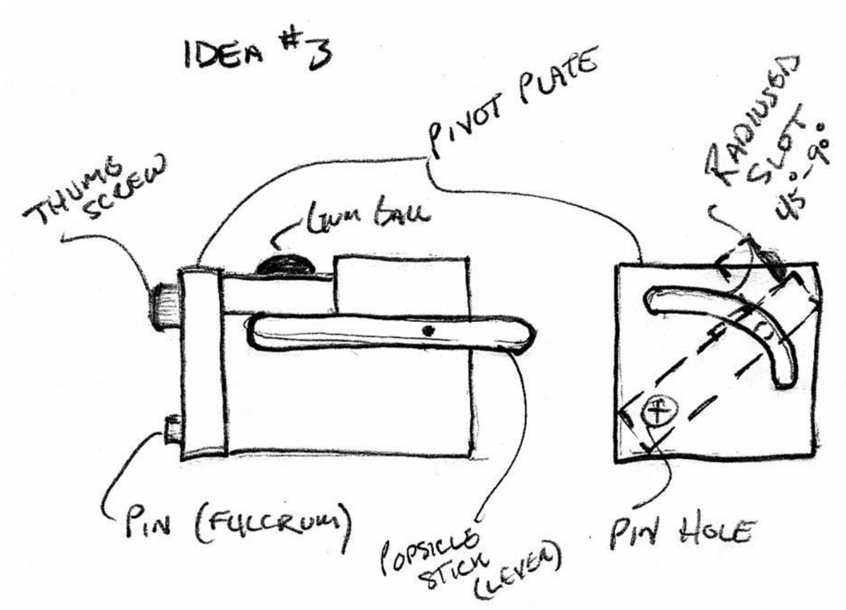


Figure 2.2. Free hand sketch – planning stage

Source: cecs.wright.edu/~dan.young/ME202//Assembly_Drawings_Balloons_Parts_Lists.ppt

2.7.2 General assembly

General assembly is the most common type of machine drawing. It is displayed as a multi-view drawing; it may contain a section view, but it does not contain dimensions. The purpose of this drawing is to give simple background knowledge or a holistic idea about the object. Sectional drawings, according to Brink et al. (2003, p.163), are the basic knowledge and skills of EGD, taught in Grade 9 of the NCS curriculum, where graphic communication is studied. Nevertheless, Khoza (2013) asserts that sectional drawing demands considerable insight because of its abstract nature, where the use of drawing models and a good insight into line work are needed to enhance visualization.

2.7. 3 Detail assembly

The detail assembly is made up of a combination of an assembly view with several of its parts depicted as dimensioned multi-views; names of each component and cutting plane being reflected on one drawing sheet. A student or learner would find it too complicated to interpret or assemble all components, but could encounter a written question statement of assembly drawing, with dimensions and part names. Dimensions are details of paramount importance to be provided with proper guidance to candidates. Figure 2.3 below is an example of detail assembly drawing for a jack lift.

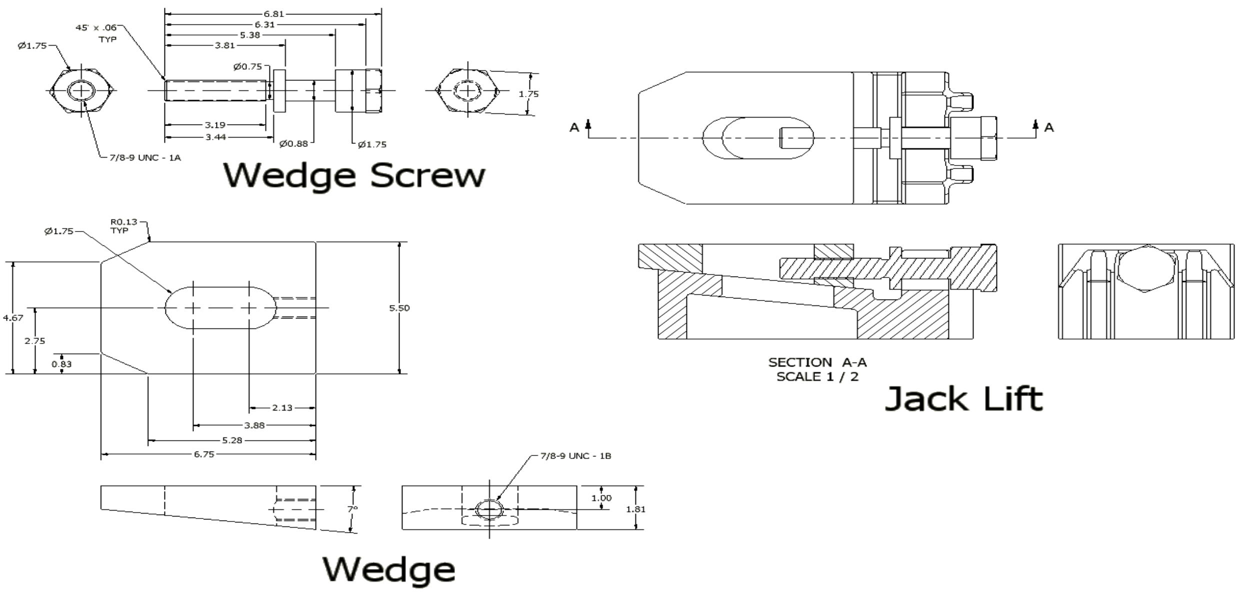


Figure 2.3. Detailed assembly drawing of Jack Lift

Source: cecs.wright.edu/~dan.young/ME202//Assembly_Drawings_Balloons_Parts_Lists.ppt

2.7. 4 Erection Assembly

Erection assembly is similar to general assemblies, except dimensions and fabrication specifications are commonly included. It is typically associated with cabinetry or products that are made from structural steel. These are used for both fabrication and assembly.

2.7. 5 Subassembly drawings

Subassembly drawings are sub-detail drawings of portions of the main drawing. The purpose of subassembly drawings is to provide fine details for a particular part from the main machine. Sub assembly drawings are useful practice exercises for students to have all details needed to be able to interpret, draw and assemble the object. Complex or large assemblies may also be communicated by subassembly drawings.

2.7.6 Pictorial Assembly

In simple terms a pictorial assembly is a 3-D drawing that shows at most three surfaces of each component. It depicts the interlinking between each component to complete the whole machine or object. These drawings are usually depicted as an isometric or perspective drawing, which can be single or double perspective. Pictorial assemblies are often used in catalogues, journal articles and advertisements. Figure 2.4 below is an example of a pictorial drawing, which has been sectioned to show interior details.

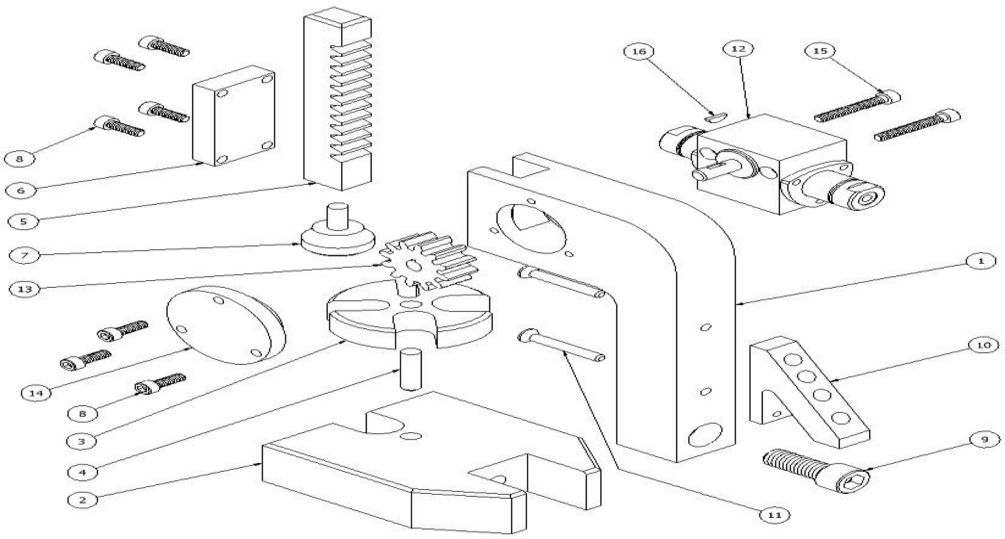


Figure 2.4 . Pictorial assembly
Source: cecs.wright.edu/~dan.young/ME202//Assembly_Drawings_Balloons_Parts_Lists.ppt

2.8 Conclusion

This chapter mapped the context of the study, which is assembly drawing. The shift from the school subject of technical drawing to Engineering Graphics and Design was shown. The SANS 0111 Code of practice for engineering drawing and the types of assembly drawings were made explicit. The next chapter presents to the literature review.

CHAPTER THREE

LITERATURE REVIEW

3.1. Introduction

Chapter 2 provided an in-depth review of the study context, namely assembly drawing (AD), which is one topic in Engineering Graphics and Design (EGD). This chapter focuses on past studies pertaining to the teaching and learning of EGD. The next section pays attention to key skills associated with reading and interpreting engineering drawings. The following subsections consider the literature as informed by the research questions; they focus on improving spatial ability; traits of a spatial learner; gender differences in spatial ability; learning styles; learning EGD; competencies required by EGD teachers to teach AD and teaching of EGD. The chapter ends with a conclusion.

3.2. Key Skills associated with Reading and Interpreting Engineering Drawings

3.2.1. Visualization skills

Visualization skills can be defined as the ability to mentally "see" or produce three dimensional images. According to Marunić and Glažar (2014), visualization skills refer to the ability to understand a 3-D object from 2-D images. Other than that, it is also refers to the ability to think in three dimensions (Stachel, 2016). Visualization skills play a vital role in engineering drawing courses and can determine the future success of engineers (Ali & Nordin, 2012; Rodriguez & Rodriguez, 2016). Developing visualization skills among learners requires careful selection of teaching strategies and tools (Salinas, Quintero and Gonzalez-Mendivil, 2015).

3.2.2. Spatial skills

Although the terms "spatial abilities" and "spatial skills" are often used interchangeably, Sorby (1999) discusses the difference between the two. According to Sorby (1999), *abilities* refers to innate characteristics, implying that someone is born with the ability or inability and cannot learn it, while *skills* suggests learned characteristics; implying that the skill can be improved with practice. A variation of the above idea is shared by many scholars (Hsi, Linn, & Bell, 1997; Martín-Dorta, Saorín & Contero, 2008; Delice, Ertekin, Yazici & Aydin, 2009; Revina, Zulkardi, Darmawijoyo & van Galen 2011; Yue, 2006; Walker, Winner, Hetland, Simmons & Goldsmith, 2011; Sorby, 2001), who assert that spatial and visual skills and abilities are not determined genetically but rather are a result of a long learning process. Put simply, this means that through relevant teaching everyone's spatial ability and skills can be activated, but appropriate learning opportunities must be offered and learning must be supported (Hartman & Bertoline, 2005). However, in the South African context there are few opportunities to develop spatial visualization skills, because our education system pays more attention to written text, so it tends to favour the development of verbal, written and numerical skills rather than spatial skills.

3.2.3. Spatial ability

There are many definitions of spatial ability in literature**.** In a recent study by Mulligan (2015) the definition of spatial ability has been advanced as “the ability to recognize and mentally manipulate the spatial properties of objects and the spatial relations among objects” (p.513). Mulligan further maintains that spatial ability comprises different skills. In a similar vein, Whiteley, Sinclair and Davis (2015) also listed the skills characterizing spatial ability as locating, orienting, decomposing /recomposing, balancing, diagramming, symmetry, navigating, comparing, scaling, and visualizing. Spatial ability is considered to be a form of mental activity that enables individuals to create spatial images and to manipulate them in solving various practical and theoretical problems (Hegarty and Waller, 2005; Kozhevnikov, Motes & Hegarty, 2007; Pittalis & Christou, 2010). Along similar lines, Olkun (2003) defined spatial ability as the skill of mentally manipulating objects and their parts in 2-D and 3-D space. Lohman (1993) defined spatial ability as the skill of generating, retaining, retrieving, and transforming well-structured visual images, while Lord and Holland (1997), maintain that spatial ability refers to visualizing words or figures in the mind and moving them by focusing on your thoughts.

According to Levine, Huttenlocher, Taylor, and Langrock (1999) individual differences in spatial ability emerge at a young age. These differences in spatial ability have been explored from a biological perspective (Hampson, 1995; Nelson, Lee, Gamboa & Roth, 2008), who are of the view that spatial ability is an innate quality. Other scholars believe that it may also be due to experiential factors, being shaped by one’s life experiences which may account for variations in spatial ability among individuals (Ebbeck, 1984; Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005; Newcombe & Sanderson, 1993). A review of the literature shows that one of the important issues in studies related to spatial ability is gender (Battista, 1990; Halpern, Beninger, & Straight, 2011; Kaufman, 2007; Lawton, 1994; Linn & Petersen, 1985; Mohler, 2008; Nemeth, 2007). Although there is no consensus in the literature about gender difference regarding spatial ability, most of the studies supported the idea that males have better spatial ability than females. For instance, Nemeth (2007) investigated spatial ability development among engineering students and concluded that the spatial ability performance among male students was better than among their female counterparts. Similarly, Battista (1990) reported in his cross-sectional study that, in high school, males outperformed females in most situations requiring spatial visualization. In the same way, Ben-Chaim, Lappan and Houang (1988) conducted a study among fifth through to eighth grade students to investigate differences in spatial visualization abilities and the differing effects of instruction on spatial visualization skills by grade, gender and site. They found a positive correlation between grade level and spatial visualization skills and reported male superiority in their study. Similarly, Linn and Petersen (1985) indicated gender differences occurring in two of three categories of spatial ability, with an especially large gender difference for a task that required mental rotation of two-dimensional or three-dimensional objects, which involved Gestalt-like analogue process. The reasons underlying gender differences in spatial ability are attributed to multiple factors, which include genetic factors (Coluccia & Louse, 2004; Linn & Petersen, 1985), educational experiences (Richardson, 1994; Sorby & Veurink, 2010), parental encouragements towards gender-typed activities (Lytton & Romney, 1991) and social experiences (Baenninger & Newcombe, 1989; Ramirez, Gunderson, Levine & Beilock, 2012)

From the aforementioned definitions, it is apparent that spatial ability is an important element of intellectual ability, which involves being able to not only mentally rotate, manipulate or transform an object depicted graphically, but also visualizing the appearance of the object after such changes. A closer examination of the above definitions of spatial ability reveals that spatial ability is related to higher order skills such as problem solving (Clements & Battista, 1992; Hegarty & Kozhevnikov, 1999; Kragten, Admiraal, & Rijlaarsdam, 2015), ability to visualize, creative thinking (Smith, 2009) and reasoning (Yurt, 2014). Spatial ability is closely intertwined with mathematical achievement; being integral to mathematical thinking (Clements, Battista, Sarama, Swaminathan & McMillen, 1997) and being associated with comprehension of symbols, shapes, and figures (Guzel & Sener, 2009). Furthermore, scholars such as Hegarty and Waller (2005) and Guzel and Sener (2009) indicate that spatial ability is closely intertwined with mathematical ability, because as. Guzel and Sener (2009) indicate, it helps students to make sense of figures, shapes, or graphs, to interpret the visual representations, to notice easily the links between different concepts, to make generalizations about complex concepts, and to think in a multidirectional way.

Spatial ability has been recognized as an important skill that students need to have, both for their educational or occupational success and for their everyday competence (Yurt, 2014, Delice et al., 2009; Revina et al., 2011; Walker, Winner, Hetland, Simmons & Goldsmith, 2011). Many researchers suggest that spatial ability can be categorized into spatial visualization and spatial relations (Lohman, 1979: 2000). It is also affected by spatial anxiety. These three aspects are defined and illustrated below.

- **Spatial visualization** is described by McGee (1979) as "the ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object" (p. 893). Delacour (2004) defines visualization as the ability to imagine rotating objects that are pictorially represented in two and three dimensional. Expanding this notion of spatial visualization, Martín-Dorta, Saorín, and Contero (2008) define spatial visualization as the ability to imagine rotations of objects or their parts in 3-D space by folding and unfolding (p. 506). For students to be able to engage in spatial visualization, Linn and Petersen (1985) assert that students are specifically required to locate the horizontal or vertical axis in a stationary display, while ignoring distracting information. According to Linn and Petersen (1985) this requires the students to have the necessary background knowledge of principal planes, in order to know where and how the views of an object are to be drawn. This means that if learners lack background knowledge of principle planes, they will be unable to rotate mentally or draw the object.

  From the forgoing views on spatial visualization it can be reasoned that, if individuals possess well-developed spatial visualization ability, they can move an object mentally and imagine the visual representation from different views (McGee, 1979). This means that pictures and shapes prompt the mental processes, such as representations of the intuitive understanding of complex operations or the concretization of the abstract relations and processes.

  Developing spatial visualization skills has two great benefits. They allow someone to translate a very abstract thing into a less abstract or a concrete thing. Another benefit is that spatial visualization skills develop an individual's ability to think dimensionally. The ability to capture concepts of shapes and dimensions affects a child's thought and cognitive development positively, so it develops the ability of the child's two or three dimensional thinking (Özdemir, Guneysu &Tekkaya, 2006). The mental formation of a geometrical shape in space in two or three dimensions and imagining it from different points of view are two of the most important part of geometrical thinking.

- **Spatial relations** is the visualization of shapes, rotations of objects, and knowing how pieces of a puzzle fit together, according to Sternberg (1990, p. 5). Additionally, McGee (1979) defined spatial relations as "the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude to remain unconfused by the changing orientations in which a spatial configuration may be presented" (p. 897). Likewise, Martín-Dorta et al. (2008) define spatial relations as the ability to imagine rotations of 2-D and 3-D objects as a whole body, which includes mental rotation and spatial perception (p. 506). This means that if individuals possess a high level of spatial relation ability, they will be able to comprehend the arrangement of elements within a visual pattern and not be affected when their own orientation is changed around the visual object. In addition, they can easily imagine how the elements of an object are arranged or could be re- arranged.

- **Spatial anxiety**, which has been defined as "anxiety about environmental navigation" (Lawton, 1994, p. 767), is an important factor affecting an individual's spatial visual behaviours and performance. Spatial anxiety refers to a student's anxiety about performing spatial tasks (Ramirez, Gunderson, Levine, & Beilock, 2012). As mentioned earlier, some scholars believe that spatial ability may be influenced by life experiences. Understanding the relationship between spatial anxiety and spatial ability may provide new ways of thinking about individual differences in spatial ability, and reducing spatial anxiety may improve spatial ability. However, little work has examined how spatial ability is influenced by affective or emotional factors.

  Research confirms that fear of math related to performance failure can lead to performance decrements (Ashcraft & Kirk, 2001; Engle, 2002; Steele, Spencer & Aronson, 2002). Furthermore, spatial anxiety brought about by situational stress, or pressure to perform well, may be a critical factor in the differences observed in spatial ability between the two sexes (Beilock & Carr, 2005). Existing negative sexual stereotypes may impair students' performance on difficult math problems (Beilock, 2008).

  Gender differences regarding anxiety and spatial ability have been investigated. On the one hand, among adults, between the ages of 19 and 47, Hund and Minarik (2006), found no significant gender differences in way-finding strategies, navigation time and navigation errors, related to anxiety levels. On the other hand, gender differences in spatial tasks and spatial anxiety have been frequently reported in the literature. (Lawton, 1994; Lawton & Kallai, 2002; O'Laughlin, & Brubaker, 1998; Ramirez et al., 2012; Schmitz, 1997). The relationship between spatial ability (as expressed by spatial perception and mental rotation) and spatial anxiety has been studied. Lawton (1994) found a significant relationship between spatial anxiety and the use of strategies, of route and orientation. A route strategy was defined as "attending to instructions on how to get from place to place" (Lawton, 1994, p.765) while an orientation strategy is defined as "maintaining a sense of their own position in relation to environmental reference points" (p.765). It is believed that spatial anxiety prevents people from focusing on the clues provided in the environment in order to find their way. The study indicated a positive relationship between orientation strategy and spatial perception, but a negative relationship between orientation strategy and spatial anxiety. Thus, Lawton (1994) concluded that if individuals have greater spatial anxiety, they are more liable to get lost. In another study, Ramirez et al. (2012) investigated the relationship between spatial anxiety and the mental rotation component of spatial ability of young children by considering their working memory and gender. They concluded that young children experienced spatial anxiety, which negatively impacted their mental rotation ability. As for gender, their findings indicated that females had greater spatial anxiety than males. In addition, it was found that females preferred to employ verbal problem solving strategies, while males preferred to use the spatial approach. Ramirez et al. (2012) attributes the negative impact of stressors, such as spatial anxiety, on spatial performance to the worries caused by these stressors interfering with the individual's working memory. In a study by O'Laughlin and Brubaker (1998), females demonstrated a higher level of anxiety in drawing the plan of a floor and were not as successful as males in way-finding tasks in a building. Moreover, males preferred global reference points, such as cardinal directions, North, South, East and West, to explain their strategies, whereas females preferred landmarks. Consequently, although the evidence is not conclusive, spatial anxiety has the potential to affect negatively students' performance in tasks requiring spatial visualization ability, especially among females.

The aforementioned definitions concerning spatial ability illuminate its significance; it enables one to imagine figures, to think how objects can move and rotate, and to understand how pieces come together to form a whole. Spatial ability can be improved with spatial thinking activities. Therefore teachers of courses such as mathematics, physics, and engineering graphics and design must be knowledgeable about spatial ability, identify students who have (or do not have) the ability, and know how it could be improved (Lord & Holland, 1997; Mulligan, 2015). Teachers who lack spatial visualization abilities or who have spatial anxieties may have difficulties in providing their students with effective learning opportunities through visual materials.

3.3. Improving Spatial Ability

There is widespread evidence that spatial reasoning can be developed at any age from early childhood to adulthood (Hawes, Tepylo & Moss, 2015). Studies have shown that training can enhance visualization skills in a relatively short time. In particular, many research studies have found that the spatial ability of an individual can be improved by means of effective instruction employing concrete materials (Battista, Clements, Arnoff, Battista, & Borrow, 1998; Robichaux & Guarino, 2000), manipulatives (Bishop, 1973), digital manipulatives (Olkun, 2003), various toys (Roorda, 1994; Tracy, 1987) or computer programming (Francis, Khan, & Davis, 2016; Onyancha, Derov, & Kinsey, 2009). For instance, Robichaux and Guarino (2000) concluded that spatial visualization abilities among undergraduates majoring in architecture, mathematics education, mathematics and mechanical engineering were significantly related to their childhood experiences. In a recent study, Francis, Khan and Davis (2016) examined how the spatial reasoning of the children aged 9 to 10 years developed when they were learning how to program LOGO, Mindstorms and EV3 robots. During the coding process, children were imagining the robot movements in three dimensions, while they were coding in two dimensions. The researchers asserted that this coding application included fluency in shifting between 2-D and 3-D and developed the children's spatial reasoning (Francis, Khan, & Davis, 2016). Similarly, Sundberg (1994) organized a summer school with 36 voluntary students, who were distributed to four groups randomly. Two groups were spatial groups in which concrete materials such as geoboards, tangram pieces, cubes, spatial puzzles and pentominoes were used to develop their spatial visualization ability while the other two groups were traditional geometry instruction groups in which an eighth grade textbook was used. A mathematics achievement test and spatial visualization test developed in the Middle Grades Mathematics Project (MGMP, 1983) were administered as pre- and post-instruction tests. The results indicated an increase in the spatial visualization ability levels of 6th, 7th and 8th grade students in the spatial groups subsequent to receiving instruction based on concrete materials. Pitta-Pantazi and Christou (2010) investigated the relationship between students' visualization (spatial and object) and their creative and practical abilities in 3-

dimensional geometry. The findings from the research indicated that an improvement of students' spatial abilities results in an improvement of their 3-D geometry thinking. However, there was no difference in spatial visualization ability levels of the students in traditional instruction groups. In addition to these middle grade students, there are also research studies among young children regarding their spatial visualization ability. Roorda (1994) and Tracy (1987), for instance, found that playing with various toys significantly improved the spatial ability of children. Thus, it can be claimed that an individual's experiences have a significant role in the development of their spatial visualization abilities.

From the above discussion, it can be seen that spatial ability needs to be recognized as an important part of intellectual functioning. It can no longer be dismissed as a narrow aspect of intelligence that is only important for certain manual or practical occupations. In this regard, teachers should be aware of multiple intelligence theory, and they should teach according to the types of intelligence of their students. As Gardner (1993) has pointed out, "spatial intelligence" is one type of intelligence. Furthermore, there is concurrence among mathematics educators and researchers that this ability helps an individual to understand their surrounding and some fields of mathematics (Usiskin, 1987). People with powerful visual or spatial intelligence learn best by visualizing entities, events or facts or by studying with images, drawings and colours (Saban, 2002). It has been seen in the studies that using mathematical modelling, appropriate teaching materials and computer applications throughout the teaching process have a positive effect on improving spatial skills (Keskin, 2008; Toptaş, 2008; Yolcu, 2008; Guzman, 2002, Sinoplu & Olkun, 2004).

3.4. Traits of Spatial Learners

According to Felder and Silverman (1988), spatial or visual learners are holistic learners who display specific traits. They perceive relationships between the parts and the whole but they do not understand if learning is carried out in small chunks. They have difficulty attending to details, and cannot grasp isolated facts until the big picture is in view. They detest routine or repetitive tasks and do not learn by rote memorization. They have, amazing imaginations, often have imaginary playmates, and may make up rich stories, which they cannot always write down. They are reflective. They need extra thinking time and so may appear to be lazy or to be daydreaming, but they can arrive at surprising conclusions. They may never be good oral readers, and frequently prefer reading heavily illustrated material.

3.5. Learning Styles

A learning style is not in itself an ability, but rather a preferred way of using one's abilities (Hatami, 2012). The term ‘‘learning styles’’ therefore refers to the concept that individuals differ in regard to which mode of instruction or study is most effective for them. They differ in their "natural, habitual, and preferred way(s) of absorbing, processing, and retaining new information and skills" (Reid 1995, p.8). With ample evidence that individuals differ in how they prefer to take in, process, and acquire new information, nevertheless, the educational implications of such preferences have been a source of great controversy among researchers and educators (Pashler, McDaniel, Rohrer & Bjork, 2009). Proponents of learning styles assessment believe that learning styles can be measured and used as a valuable teaching tool inside the classroom (for example, Sternberg, Grigorenko & Zhang, 2008). According to these scholars, by diagnosing students' preferred learning styles and matching them to teaching methods (for example for a ‘visual learner', presenting information through pictorial illustrations), enhances students' achievement, increases their interest in and enjoyment of subject matter, and increases their desire to study other subjects (Felder & Silverman, 1988).

Learning styles are based on the idea that knowledge is acquired by means of the senses. Kolb (1976), Honey and Mumford (2000),Myers-Briggs (1957) and Felder and Silverman (1988) have came up with patterns of learning styles that were preferred by students in order for them to understand content knowledge more meaningful.

Table 3.1. Learning style inventory of characteristics

Kolb's experiential learning model: Learning Style Inventory (LSI)	Honey and Mumford's Learning Styles Questionnaire (LSQ)	Myers-Briggs Type Indicator (MBTI)	Felder-Silverman Index of Learning Styles (ILS)
Diverger Assimilator Converger Accommodator	Active Reflector Theorist Pragmatist	Extravert Sensor Thinker Judger	Sensory/Intuitive Visual/Verbal Active/Reflective Sequential/Global

In 1976 Kolb developed his learning style inventory (LSI), which was later revised in 1985. In Kolb' experiential learning model students are classified or categorized in two ways. Firstly into concrete experience or abstract conceptualization (how they take information in) and secondly into active experimentation or reflective observation (how they process information) (Cornwell & Manfredo, 1994; Kolb, 1983; Stice, 1987). Kolb pointed out that four types of learners respond in the following manner in this classification.

- Diverger: learners respond well to explanation of how course material relates to their experiences, interests and future careers. “Why?” as their key question.
- Assimilator: learners respond to information presented in an organized, logical fashion and benefit if they are given time for reflection. “What?” as their key question.
- Converger: learners respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to fail safely. “How?” as their key question.
- Accommodator: learners like to apply course materials in new situations to solve real problems. “What if?” as their key question.

Honey and Mumford (2000) came up with another set of learning styles through their learning styles questionnaire (LSQ), the aim of which it is to identify strengths and weakness while learners are engaged with the process. They describe their set of learning styles as “a description of the attitudes and the behaviours that determines an individual’s preferred way of learning” (Honey & Mumford, 2000 p. 6). The styles are:

- Activist: learners learn best when they are actively involved (Strengths: sociable, open- minded, highly involved etc. Weaknesses: bored by implementation details and the longer term etc.).
- Reflector: learners learn best through review and reflect (Strengths: good listener, tolerant, sees different perspectives etc. Weaknesses: takes a back seat in meetings, low profile, inactive etc.).
- Theorist: learners learn best when they can relate new information to concept and theory (Strengths: integrates observations with theory, objective, rational etc. Weaknesses: perfectionist, detached etc.).
- Pragmatist: learners learn best when they see relevance of real life issues (Strengths: experimenter, practical, quick to adopt and try out new ideas etc. Weaknesses: impatient with theory, impatient with open-ended discussion).

Both the Kolb and the Honey and Mumford sets of learning styles overlap or talk to each other; or maybe one could say they intertwine. Honey and Mumford suggested a model almost similar to Kolb’s, in that both have four learning styles. Both Kolb’s learning styles inventory (LSI) and Honey and Mumford’s learning styles questionnaire (LSQ) are diagnostic tests. Both are designed to assist individuals identify their strengths, weaknesses and developmental needs. Through the use of LSQ instrument, teachers or instructors can gain a better understanding of individual learners' attitudes, behaviours and learning processes (Armstrong et al., 2005; Jackson & Trochim 2002). This will be of great assistant to the teacher or instructor to prepare an effective and productive teaching and learning environment for both learners and him or herself as teacher.

Myers-Briggs came up with another four scale set of dichotomous preferences, derived from Jung's theory of psychological types (McCaulley, 2000; Pettenger, 2005). People, that is learners in this thesis, are classified on the Myers-Briggs Type Indicator (MBTI). Felder and Brent (2005) discuss that most engineering instruction is oriented toward introverts, intuitors, thinkers and judgers.

- Extraverts: try things out, focus on the outer world of people. Introverts: think things through, focus on the inner world of ideas.
- Sensors: practical, detailed-oriented, focus on facts and procedures. Intuitors: imaginative, concept-oriented, focus on meanings and possibilities.
- Thinkers: skeptical, tend to make decisions based on logic and rules. Feelers: appreciative, tend to make decisions based on personal and humanistic considerations.
- Judgers: set and follow agendas, seek closure even with incomplete data. Perceivers: adapt to changing circumstances, postpone reaching closure to obtain more data.

Felder and Silverman (1988) developed a model known as Index of Learning Style Model (ILS). It classifies students along four dimensions: sensing/intuitive, visual/verbal, active/reflective and sequential/global.

- Sensing/Intuitive: Sensors prefer facts. data experimentation, sights and sound, physical sensations are careful and patient with details, but may be slow. Intuitives prefer concepts, principles and theories, memories, thoughts, insights and may be quick but careless.
- Visual/Verbal: Visual learners prefer pictures, diagrams, charts, movies demonstrations and exhibition. Verbal learners prefer words, discussions, explorations, written and spoken explanations, formulas and equations.
- Active/Reflective: Active learners learn by doing and participating through engagement in physical activity or discussion. Reflective learners learn by thinking or pondering through introspection.

- Sequential/Global: Sequential learners take things logically step by step and will be partially effective with understanding. Global learners must see whole picture for any of it make sense and are completely ineffective until they suddenly understand the entire subject.

Fleming and Mills (1992) identified another four categories of learning styles; namely, visual, auditory, read/write, and kinesthetic. These learning styles can be summarized as the visual (V) learner learning best by visualizing the information, e.g. use of charts, diagrams, and mind maps, while the auditory (A) learner learns best by hearing the information. The read/write (R) learner, on the one hand, learns best when the information is displayed in words; and on the other hand, the kinesthetic (K) learner learns best with practice or simulation. Considering that learning styles vary from one person to another, and that individuals are likely to have more than one learning style (Şeker & Yılmaz, 2011), it would be ineffective to teach classes using one single method. Students can learn faster and more easily when they know about and study in accordance with their own learning styles. To design instruction that incorporates students' learning styles, the teacher must employ three steps: (1) examine students' learning styles; (2) classify the students' learning styles according to several large categories; and, finally, (3) incorporate students' learning styles into the instructional process.

However, in designing lessons it is worth noting that the learning styles of the students are only one of several factors of the learning process interwoven in the classroom (Khoza, 2003). The instructor is believed to be a key player affecting the learning process in the classroom as his or her preferred learning style itself plays a significant role in teaching, since an instructor tends to teach in the style in which he or she learns best (Khoza, 2003).

Efforts to improve teaching and learning in engineering have been noted by Lee and Sidhu (2015), where there has been increased attention given by engineering educators to learning style theories. This has resulted in educators being alert to students' learning preferences, and choosing their teaching strategies accordingly, so as to unleash the learning potential of the students. Making use of diverse didactic methods in teaching and learning is thus recommended to enhance students' learning capabilities in engineering or technology education. Accordingly, awareness of diverse learning preferences shows in educators creating learning environments that are conducive for every student to reach his or her potential.

Findings from the study conducted by Lee and Sidhu (2015) reflected that engineering students share a common preferred learning style; specifically, they prefer to learn in a sequential, logical way with various hand-on practical activities. I tend to concur with them, since my experience with engineering drawing learners is that they learn best by doing or being actively involved in activities. The research further highlighted that learners in such an environment are more open-minded and willing to try out new forms of learning activities. Therefore, a serious challenge faced by instructors or teachers is to strike a balance among learning approaches so as to best accommodate the learning preferences of students. Based on their findings, Lee and Sidhu (2015) recommended the provision of well-structured computer software tools that match the learning styles of engineering students in order to strengthen their problem solving skills.

3.6. Gender differences and spatial ability

As alluded to earlier in Section 3.2, the literature highlights the important issue of whether there is a relationship between spatial ability and gender (Battista, 1990; Halpern, Beninger, & Straight, 2011; Kaufman, 2007; Lawton, 1994; Linn & Petersen, 1985; Mohler, 2008; Nemeth, 2007). There is no consensus in the literature about gender difference regarding spatial ability but most of the studies support the idea that males have better spatial ability than females. For instance, Nemeth (2007) investigated the development of engineering students' spatial ability and concluded that male and female students' spatial ability performances differ, in favour of males. Similarly, Battista (1990) reported in his cross-sectional study, that, in high school, males outperformed females in most situations requiring spatial visualization (Battista, 1990). In the same way, Ben-Chaim, Lappan and Houang (1988) conducted a study among 5^{th} to 8^{th} Grade students to investigate differences in spatial visualization abilities and the effects of instruction on spatial visualization skills by grade, gender and site. They found a positive correlation between grade level and spatial visualization skills and reported male superiority in their study. Similarly, the findings from Linn and Petersen (1985) indicated gender differences in two of the three categories of spatial ability investigated. There was an especially large gender difference for mental rotation, which requires two-dimensional or three-dimensional objects to be rotated in the mind and involves a Gestalt-like analogue process.

3.7. Students' difficulties with engineering drawings

According to Perez Carrion and Serrano (2012), the high failure rate among students in their exit examinations in EGD is due to the difficulty presented by representations of 3-D objects in 2-D, making understanding of the mechanisms problematic. This means that learners have not sufficiently developed their spatial ability before the exit point. Chinonso (2014) found that this high failure rate is associated with traditional teaching methods, which do not develop learners' spatial ability; in particular not emphasizing connections between the drawing and the design of the product itself. For students to be able to master this spatial skill, the teachers should create a learning environment where students can engage practically in drawing activities. This above view is fully supported by Branoff, Hartman and Wiebe (2003), who contend that EDG teachers must expose students to hands-on experience of drafting techniques, drafting standards and conventions. These competencies can only develop by engaging students in activities using a variety of media that target problem-solving skills and the ability to think, see, create and model 3-D visual images in space or on paper from 2-D blueprints. Rote learning or memorizing cannot be the solution to the above mentioned problem of poor success rates. Moreover, Kabouridis (2010) as well as Branoff and Dobelis (2012) recommended that EGD students should be specifically trained to develop their spatially-related problem-solving abilities. When the spatial skill is developed it should remain active and continuously improved to meet the needs of industry.

Despite spatial ability being an essential engineering skill, Abdullah, Burvill and Field (2011) and Garmendia, Guisasola and Sierra (2007) argue that many engineering curricula do not allocate sufficient time to advancement of spatial ability. Typically, engineering students are given little or no formal instruction that develops their spatial abilities. This means that educators do not teach visual-spatial thinking. Furthermore, the above scholars argue that engineering texts present static, orthogonal views of concepts, theories and ideas, with little or no explanation of how to interpret the spatial information. Hence, students struggle to develop their spatial ability.

3.8. Teaching of EGD/AD

Teaching and learning are two inseparable processes. For both processes to be effective, the teaching approach should match the learning style or vice versa. Felder and Silverman (1988) assert that learning styles of engineering students and teaching styles of engineering professors are incompatible in several respects. However, the selected teaching style may have considerable impact on the learners' learning style and so their understanding of content. The view that learning occurs in a structured education setting and is a merely a two-step process that involves the reception and processing of information is problematic. Felder and Silverman (1988) described these two steps as follows: processing as memorizing or reasoning, inductively or deductively, reflecting as action, and introspection or interaction with others. They based this description on the finding that many engineering students' preferred learning styles are visual, sensing, inductive, and active, whereas most engineering education is auditory, abstract (intuitive), deductive, passive and sequential. So, in order to avoid professorial frustration, and poor student performance, with the consequent loss of potentially excellent engineers to society, they recommend that teaching styles should be appropriate for engineering students.

It is clear that this is not a 'one size fit all' stance. It is recommended that for effective teaching and learning, the teaching method or didactic approach should be selected carefully, in view of the best approach for a particular field of study. For the best teaching of EGD, in particular for assembly drawing, the teacher should have clear subject content knowledge and pedagogical knowledge (Shulman, 1986). According to Shulman, PCK includes "an understanding of what makes the learning of specific topics easy or difficult" (1986, p. 9) and is "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (1987, p. 15). Central to Shulman's conceptualization of PCK is that PCK is learner-targeted or learner-oriented. This learner-oriented perspective runs through later research on PCK or PCK models (Ball, Thames & Phelps, 2008; Banks, Leach, & Moon, 2005; Grossman, 1990; Koballa, Gräber, Coleman & Kemp, 1999; Magnusson, Krajcik & Borko, 1999; Russell & Martin, 2007; Van Driel, de Jong & Verloop, 2002). Knowledge of contexts is closely related to PCK (Cochran, DeRuiter &, King, 1993; Fernández-Balboa & Stiehl, 1995; Shulman, 1987). In this regard, Grossman (1990) listed knowledge of context together with subject matter knowledge and general pedagogical knowledge as three domains influencing PCK. Teachers' beliefs and perceptions of teaching and learning are strongly influenced by such contextual parameters as the school culture and the educational system in general (Jimoyiannis, 2010; Siorenta & Jimoyiannis, 2008). What is explicit among the aforementioned publications is the belief the PCK should be approached and understood in specific contexts. Hence, I argue that an essential part of PCK is a set of instructional methods and strategies used in teaching practice to transform subject matter knowledge (SMK) and to make it comprehensible and teachable in specific teaching situations. In the next section, I elaborate on scholars' views on teaching practice that promotes learning in EGD in general, and AD in particular.

Like any language, engineering drawing is a means of communication, which consists of technical rules or drawing conventions (Olkun, 2003). In engineering, lines and symbols are the more effective means of communicating thoughts than are verbal descriptions. Thus to be capable of reading or interpreting a drawing accurately there is a non-negotiable need to learn how to read and write a drawing. Therefore, like language, one needs to know and use the conventions and rules (Olkun, 2003). In order to apply the rules, certain skills are needed; especially spatial perception and visualization (as discussed above) as well as spatial ability. Olkun (2003) argues that spatial thinking is essential for scientific thought as it is used to represent and manipulate information in learning and problem solving.

Branoff, Hartman and Wiebe (2003) contend that EDG teachers must expose learners to hands-on experience of drafting techniques, drafting standards and conventions. In order to do this, the curriculum should expose students to practical engineering graphics skills and knowledge about how various design components and systems are related and so work together on any given project. These competencies develop only by engaging students in activities that target hands on problem-solving skills. By implication, these skills cannot be developed by teaching that promotes rote learning or memorization. In addition, students should be exposed to emerging trends in technical graphics, developments in industrial technologies and advances in computer technology. Simply put, this means that EGD students have to be trained in developing spatially-related problem-solving abilities (Sotsaka, 2015; Kabouridis, 2010). A major limit in traditional instruction is the problem of presenting three dimensional spatial information (3-D) in a two dimensional format (2-D). Felder and Silverman (1988) assert that learning styles of engineering students and teaching styles of engineering professors are incompatible in several respects. For many reasons, some teachers apply, or prefer, a certain method for a particular topic. Nevertheless, tuition or teaching style should match the learning style of students. They point out that students learn in many different ways: by seeing and hearing; by reflecting and acting; by reasoning logically and intuitively; by memorizing; by visualizing; by drawing analogies and by building mathematical models.

Information communication technology (ICT) may provide a solution for teaching fundamental visual skills to mechanical engineering students. According to Zuo, Feng and Chen (2003), Chinese teaching content and methods have remained static for many years in China, so the effective teaching of Engineering Drawing had been challenged. For instance, most universities in China mixed descriptive geometry and engineering drawing in one course. Traditionally, twice as many notional hours were allowed for teaching (40-80 hours) as for practice exercises (20-40 hours). Zuo, Feng and Chen (2003) implemented engineering graphics education reform for a period of more than six years in Chinese schools. Their objective was to capacitate and improve the teaching ability of teachers in Engineering Graphics Drawing and improve students' imagination and ability in design. In their study, they changed the course system and combined the two teaching methods into three aspects; namely, drawing combination, manual drawing combined with computer drawing, and class teaching combined with interactive studying in network. They found that with these changes large numbers of students could be taught by one teacher in a shorter period of time, and with better results. Integrating teaching and practice thus resulted in more effective use of staff and better student achievement. Zuo et al. (2003) thus recommend the use of multimedia computer aided drawing and web-based education software. They point out that multimedia software is one means of modernizing technical education. They also emphasized that with modern education techniques, engineering drawing was no longer dull and dry. The subject became more attractive and accessible than before. In other words, the use of computers in drawing made it more user-friendly for students.

Poor performance of mechanical engineering students has also been noted by Kabouridis (2010), who then designed a learning environment based on ICT. The aim of this new environment was to tackle the problem by modification of course design, with teaching methods being made more compatible with students' learning styles; thus saving class time and making the subject more accessible to a large number of students. The author pointed out that each textbook so developed had a multimedia CD attached. Whilst this is an excellent ideal it should be noted that not all users might have computers.

Over the last 30 years, engineering graphics content in engineering programmes has changed to meet the needs of industry and also to meet changes in accreditation requirements, which has been reported by Branoff and Dobelis (2012). These scholars conducted a study in North Carolina State University, to measure students' ability to model objects from assembly drawing. Engineering graphic courses had been strengthened and curricula modified. Solid modelling and other CAD tools have replaced descriptive geometry and other engineering graphics topics. Livshits and Sandler (1999) had earlier emphasized that computerisation within engineering programmes was necessary to provide students with up to date skills, but again it comes at the cost of deficiencies in other areas. Their small scale study among high school students in assembly drawing indicates that after class tuition less than half the students were able to successfully model seven parts in an assembly during a 110-minute class. In the study, there was a wide range of student scores indicating difficulties with reading the engineering drawing (Livshits & Sandler, 1999). Although it was possible that the students had not taken the task seriously, it did indicate that they had not been able to visualize the individual parts within the context of an assembly; thus posing a question as to whether or not the teaching and learning mode had been appropriate. Uçan, Ercan, and Ercan (2012) maintained that design is the common denominator of engineering; it is the repeated or iterative process through which an engineer is able to optimally covert available resources into devices or systems that satisfy the consumer needs to which the design is addressed. From their research, the findings indicated that drawing forms the core of all engineering courses. Technical drawing and design must be taught in all engineering departments, not only the engineering drawing department. All students must be introduced to computer usage to develop their visualization skills and so be capacitated to fit in the world of industry. From the above studies and discussion it can be inferred that EGD teachers need certain specific knowledge

The biggest problem engineering students face in the classroom is visualization (Strong & Smith, 2001; Turner & Neto, 2002). The important questions is therefore: what kind of teaching and learning environment is need to facilitate the development of spatial visual reasoning among students? Among the ways of teaching 2-D modelling, there is no substitute for physical models, which are the best way for students to learn how to transfer a real object into a 2-D drawing. When models are used in EGD an interactive teaching technique is applied, which increases students' interest and effectiveness in learning EGD (Meneghetti, Borella & Pazzaglia, 2016). A new and innovative teaching strategy has been developed based on using models, which includes the following aspects.

- Third angle orthographic projection model, which helps students to understand the concept of orthographic presentation and the layout of the standard orthographic views.
- Type of hole and slot model which shows the views of different holes and SANS symbols used to identify the parameters of the holes.
- Types of sections models, in which visualization, as a problem, is most evident in students' incapability of clearly seeing the interior features of parts. This set of models reveals to students the interior features of parts and helps students understand the concept of creating full, half, offset, broken out, revolved, removed, aligned, assembly and auxiliary section views (Sotsaka, 2015).

Project-based active learning is another teaching strategy used in teaching engineering. A project based active learning environment provides students with an opportunity to learn solid modelling as a tool for the design process and product realization in addition to developing skills and competencies that traditional introductory graphics classes promote. The project-based component is composed of three learning stages. Each stage begins with introduction to a concept, followed by physicals exercises (observation) with objects or parts in which the concept is most relevant to promote experiential learning, followed by tasks to further promote the concept and culminating in a group project where a few of the concepts covered are utilized. The first one emphasizes sketching and visualization skills. This stage is finished by a project involving design documentation of solids with simple geometry. The second stage emphasizes geometrical construction and multi-view projections. This cycle ends with projects involving multi-view projection and geometrical construction. The last stage incorporates all concepts covered in the class. The projects are designed to illustrate the relationships among the conceptualization of the part, its functionality and its realization.

3.9. Competencies required by EGD Teachers to teach AD

According to Abdulwahab and Usman (2014), teachers of EGD are expected to have certain competencies that ought to promote learning amongst their learners. Their survey highlights the competencies expected of EGD teachers in order to engage meaningfully with specific sections of the curriculum. Thus, for teaching AD, the teacher should be competent enough to, at least:

- Know how to dismantle, prepare parts list and make pictorial and orthographic sketches of the parts of a simple mechanical device.
- Draw orthographic views–full and sectional– of simple assemblies, solving problems in link mechanism, true lengths, angles and surfaces.
- Understand the principal and application of loci.
- Draw and give examples of ellipse, parabola and hyperbola.
- Use wood or paper to construct a simple link machine.
- Recognize true and foreshortened lines and surfaces in projected views.
- Determine the angle of an inclined line to the principal planes.
- Demonstrate and sketch the concept of auxiliary planes.
- Use auxiliary and cutting plane methods to determine the line of intersection of two meeting surfaces e.g. intersection ducts, prisms and cones.
- Use wood and paper to model different objects from the understanding of development.
- Explain graphically cam and gear motion.
- Explain harmonic motion graphically.
- Identify types of gears.
- Draw meshing gear profiles from given data.
- Draw and interpret simple electric and electronic circuits.

3. 10. Conclusion

In this chapter, the key skills required to read and interpret engineering drawings in general were discussed. The traits of a spatial visual learner and the ways in which these could be improved were illuminated. The importance of recognizing the learning styles of students and the challenges they encounter with engineering drawings was made explicit in this chapter. The teaching strategies that could be used to address students' challenges with engineering drawings were elaborated. The next chapter presents the theoretical framework of the study.

CHAPTER FOUR

THEORETICAL FRAMEWORK

4.1.Introduction

In this chapter, I present the theoretical frameworks that undergird this study. According to Cohen, Manion and Morrison (2018), the theoretical framework affects every aspect of the study, from the research questions, to the methodology, through to how we make sense of the data that is generated. In a similar vein, McMillan and Schumacher (2001) give the purpose of a theoretical framework being to provide a simple explanation of the observed relation relevant to a phenomenon. As mentioned previously in Chapter 1, this study, explores how first year EGD PSTs read and interpret AD. In particular it should be noted that each first year EGD pre-service teacher (PST) is a unique individual with his or her own learning style (Bhagat et al, 2015) and so also a unique way of making sense of AD. Furthermore, all first year EGD PSTs would have studied EGD to matric level, hence they enter their teacher training course with prior knowledge or preconceptions (or even misconceptions) of how to read and interpret AD. First year EGD PSTs are learning how to teach AD, so they are positioned as learners who via social interactions with the lecturer and their peers ought to improve their ability to read and interpret AD. In order to explore how and why first year EGD PSTs read and interpret AD in the way that they do I drew on Vygotsky's theory of the zone of proximal development and Gardner's theory of multiple intelligences and learning styles. These frameworks when fused together illuminate a renewed approach to the teaching and learning of AD, as indicated in Figure 4.1.

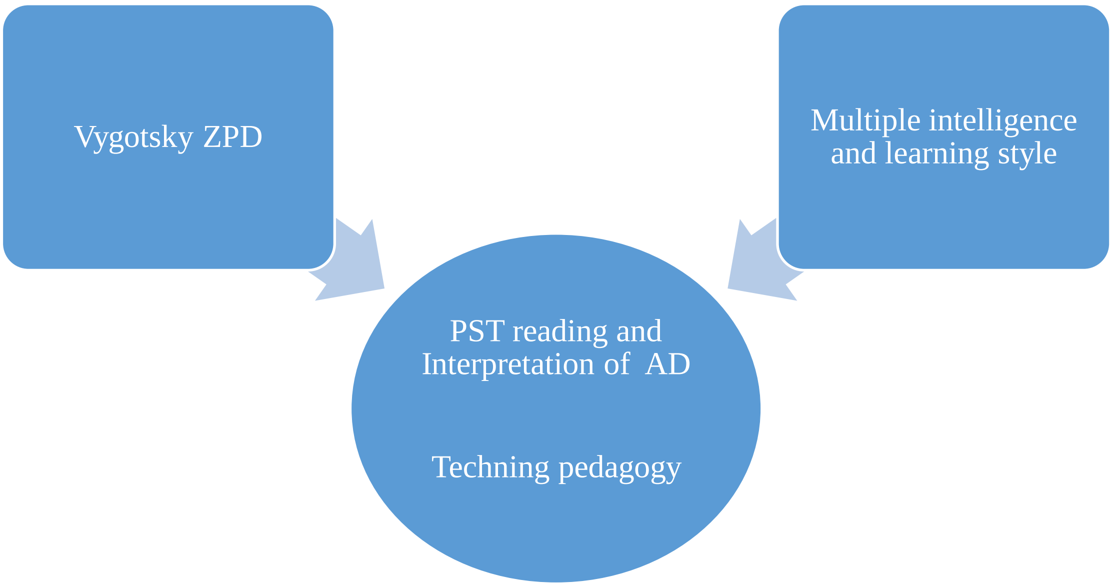


Figure 4.1. Theoretical framework and the phenomenon being explored.

4.2. Vygotsky's zone of proximal development theory

Vygotsky's zone of proximal development (ZPD) focuses on the impact of social interactions during learning (McLeod, 2018). Vygotsky's theory focuses on the influence of external stimuli on development. He defined the lack of external stimulation as cultural deprivation. In terms of cultural and environmental influences on intelligence, Vygotsky (1978, p. 13), refers to children who do not develop the necessary cognitive skills (in this case, spatial visualization ability), as 'culturally deprived' (Vygotsky, 1978, p. 13).

Vygotsky developed the zone of proximal development theory to provide an alternative view to that of Swiss psychologist Piaget, who asserted that the biological development stages that a child undergoes are even and universal and that children are solitary learners (Zebroski, 1994). Vygotsky disagreed with Piagets' idea that development is a cognitive process that occurs inside a person's head and is separate from the external world in which people live (Sarker, 2019). In other words, for Vygotsky the development of a child is not cognitive and biological, as Piaget proffered, but more importantly it is social. This means that the objects and people surrounding the child influence the cognitive development of the child. Thus, to Vygotsky, teaching and learning are an integrated process in human development. In describing Vygotsky's concept of the teaching and learning process, Campbell (2008) states that learning is viewed as a social process; with the students bringing to the process their own lived experiences as grounded in their own socio-cultural contexts. During the teaching and learning process, students are expected to actively participate in their own learning through the use of language and interactions with their colleagues and instructors.

According to Roosevelt (2008), Vygotsky conceptualized the zone of proximal development as a way of viewing what children are coming to know. This means that children are able to solve problems beyond their actual developmental level if they are given guidance in the form of prompts or leading questions from someone who is more advanced. This person could be another student, a parent, a mentor, a coach, a guide or a teacher. Vygotsky (1978) defined the ZPD as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peer" (p. 86). Put simply, this means when students receive instructional support from a peer who happens to be more capable in that particular context, they internalize the new information and will be more able to perform tasks independently in the next similar problem-solving situation. This is illustrated in Figure 4.2. Vygotsky's notion of ZPD takes into account individual differences among students, and focuses on the communicative nature of learning in which the students come to an understanding of the operations they are performing (Sarker, 2019). Chaiklin (2003) further observes that the common conception of the ZPD presupposes an interaction on a task between a more competent person and one who is less competent, such that the less competent person becomes independently proficient at what was, initially, a jointly accomplished task. The term ZPD has become synonymous in the literature with scaffolding, a term coined by Wood, Bruner, and Ross (1976).

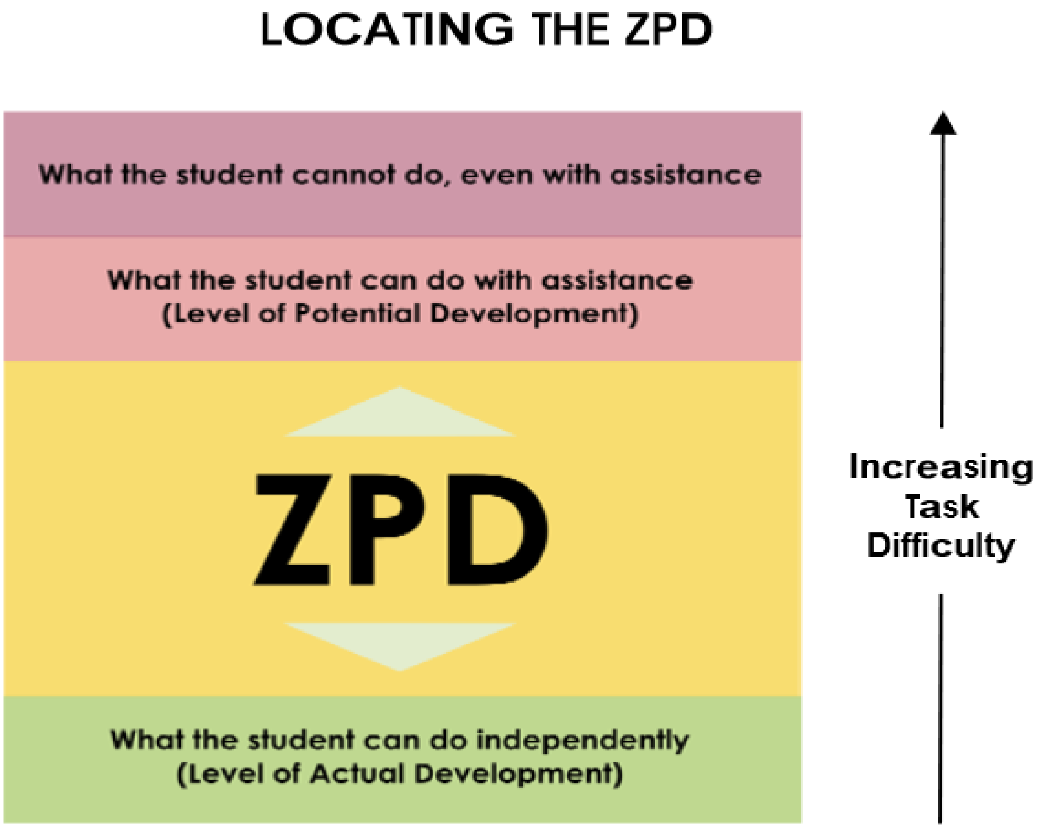


Figure 4.2. The ZPD

In the general conception of ZPD, three main aspects or assumptions are made: the generality assumption (applicable to learning all kinds of subject matter), assistance assumption (learning is dependent on interventions by a more competent other) and potential assumption (properties of the learner that enable best and easiest learning) (Chaiklin, 2003). The first assumption focuses on the idea that a person is able to perform a certain number of tasks alone, but a greater number in collaboration. The range of tasks performed in collaboration is sometimes presented as the definition of ZPD (Berk, 2017), but this is surely mistaken for even the classic definition refers to levels of development, not tasks. Therefore, it is significant to note that it is not simply the range of tasks performed, but the levels of development that are needed for their performance, which represent the ZPD. At best, the number or kinds of tasks may be taken as indicators to be interpreted in relation to a level of development. A related issue has to do with what kinds of tasks involve a ZPD. It is often assumed that the ZPD is meant to be applied to any kind of learning task (Tharp & Gallimore, 2010). Alternatively, in an expanded conception formulated by Wells (2015), ZPD applies to any situation in which, while participating in an activity, individuals are in the process of developing mastery of a practice or understanding a topic.

The second assumption for ZPD, assistance assumption, emphasizes how an adult, teacher, or more competent person or peer should interact with a child. Sometimes this aspect is presented as the defining characteristic. Arguably, the notion of the ZPD is little more meaningful than that of a learning situation presented to a child, where adults or more advanced children directly or indirectly have a positive influence on the child (Gillen, 2010).

The third aspect, potential assumption, focuses on properties of the learner, including notions of the learner's potential and or readiness to learn. This aspect often seems to inspire the expectation that it is possible to accelerate or facilitate a child's learning greatly if the zone could be identified properly. For Fabes and Martin (2011), "It is within this zone that a person's potential for new learning is strongest" (p. 42). For LeFrancois (2010), this is Vygotsky's phrase for the individual's current potential for further intellectual development, a capacity not ordinarily measured by conventional intelligence tests. Sometimes this aspect is interpreted to mean that teaching within the ZPD should result in the easiest or most effortless form of learning for the child. As Rieber (2015) puts it, “A student's zone of proximal development is the range of book readability levels that will challenge a student without causing frustration or loss of development [and] is meant to be applied to any kind of learning task” (p. 37).

Hodson and Hodson (1998) posit that Vygotsky believed that it is through social interaction that children learn the cognitive and communicative tools and skills of their culture. This makes learning a lifelong process, within which learners are constantly constructing, deconstructing, and reconstructing their knowledge base and skills required to function in the world.

The concept of mediation is central to the Vygotsky's ZPD. It implies that developmental teaching and learning situations need to be facilitated or mediated in one way or another (John-Steiner & Mahn, 2008). For Vygotsky (1987), there are different forms of mediators: material; psychological; semiotic; and other human beings. The role of mediation in learning is therefore to transform the learners' skills from lower to higher cognitive functions as the learner progresses from prior to new knowledge forms (Kozulin, 2012). Although, Vygotsky never used the term in his writings, the idea of scaffolding was introduced by Wood et al. (1976). It implies that once the learner masters the task with the benefit of scaffolding, the scaffolding can then be removed, and the learner will be able to complete the task on his or her own. Mediated learning experiences thus describe scaffolded learning activities during which learners are taken through the paces (de Valenzuela, 2009; Wertsch, 2008). The objective of all forms of mediation is to therefore to ensure that every function in the learner's cultural development appears thrice; firstly, on the social level, and later on the individual level or between people (inter-psychological), and then inside the learner (intra-psychological; de Valenzuela, 2009; Vygotsky, 1978). For the purposes of this research in the context of assembly drawing, these three appearances translate into three stages of learning: specifically lecturer and PSTs, then the PSTs working together to read and interpret AD, and finally the individual PST applying the knowledge gained on his or her own to read and interpret AD.

Vygotsky's theory is applicable to this study when first year EGD PSTs are given tasks and left to discuss them amongst themselves; the lecturer would in this case, come in when students experience difficulties. This subsequently brings an understanding of each PST being a participant within the community (along with fellow PSTs enrolled for the EGD module) which connects him or her with all community activities (all activities pertaining to the EGD module). Hence, the PST becomes an active participant in a *community of practice*. Wenger (1998, p 34) viewed community of practice as a broad characterization encompassing all social relations contained within a community of workers who share similar activities and identities and who get things done when they come together around mutual engagement in an endeavour. The notion of community of practice talks to Vygotsky's ZPD concept, wherein they translate to group work or members interacting as the key drivers of this theory. Vygotsky believes that teachers focusing on teaching students within the students' ZPD would be the best learning to enable each student to develop within his or her range of thinking (Hodson & Hodson, 1998).

Application of ZPD to this study

The way in which Vygotsky's ZPD was applied to this study is illustrated in Figure 4.3 and described as follows:

- First year EGD PSTs' level of spatial visualization was ascertained via the Purdue spatial visualization test (PSVT)
- EGD PSTs' prior knowledge on reading and interpreting AD was ascertained by means of think-aloud task 1 (see Chapter 5 for more details)
- EGD PSTs' strengths and weakness in terms of reading and interpreting AD were identified by interviews and collages. Support was then provided to them as mediation (different teaching strategies) to scaffold their reading and interpretation of AD.
- EGD PSTs had the opportunity to adjust or correct the way in which they read and interpret AD. Think-aloud task 2, focus group interviews and collages were used to track the ZPD of PSTs.

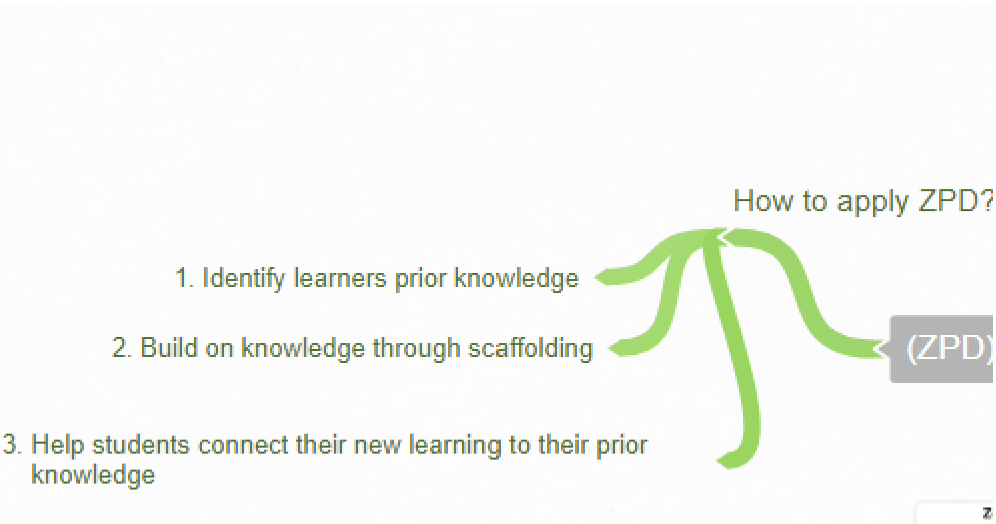


Figure 4.3. How ZPD applies to this study

4.3. Multiple intelligences and learning style

The concept of multiple intelligences (MI) was introduced by Gardner (2004). He argues that high scores in mathematics and language tests cannot alone serve as a proof of human intelligence. Instead, Gardner (1999) defines an intelligence as "biopsychological potential to process information that can be activated in a cultural setting to solve problems or create products that are of value in a culture" (pp. 33–34). Intelligence is something beyond the scores made in standard paper-and-pencil tests used to estimate success at schools (Chitty, 2011). In other words, traditional intelligence tests cannot measure the abilities of a chess player, an athlete or a violinist (Morgan, 2014). Gardner (2004) maintains that intelligence incorporates too many abilities to be explained by a single factor. He describes intelligence as the capacity of an individual to create products that are valued in one or more cultural setting, the individual's skill in producing effective and efficient solutions to problems in daily life and also his or her ability to discover new and complex problems demanding solutions (Saban, 2004; Hanafin, 2014). Humans have different types of dominant intelligences, and each individual's intelligence consists of different combinations of intelligences at certain levels (Gardner, 2004; Morgan, 2014). The MI theory indicates that individual differences result from differences in capacity to use ones intelligences. So it is assumed that individuals do not possess a single type of intelligence, but instead, different people have different levels of dominant types of intelligence, which brings us to the multiple intelligence domains. In the theory of multiple intelligences, these dominant intelligence domains may vary among all individuals in terms of their types, levels and capacity of use. To put it differently, along with his or her dominant intelligence, an individual also possesses non-dominant intelligence domains. Different intelligences could be independent and an individual may well lack any ability in a specific domain, while possessing a very high level of ability in another.

Gardner (year) defined seven different types of intelligence, as follows.

1. Visual-Spatial– In this area the mind processes things in terms of physical space, as do architects and sailors. They enjoy drawing, doing jigsaw puzzles, reading maps, and daydreaming. They can be taught best through sketches and drawings, and verbal and physical imagery. Tools include models, graphics, charts, photographs, drawings, 3-D modelling, video, videoconferencing, television, multimedia, texts with pictures, charts or graphs.

2. Bodily-kinesthetic– In this area the body is most effective, like with a dancer or a surgeon. There is a keen sense of bodily awareness. These people like movement, making things and touching. They communicate well through body language and they prefer to be taught through physical activity, hands-on learning, acting out, or role playing. Tools include equipment and real objects (touching or doing is the key).

3. Musical– The sense of hearing is dominant in this area; these individuals show sensitivity to rhythm and sound. They love music, but they are also sensitive to other sounds in their environment. They may study better with music in the background. They prefer to be taught by turning lessons into lyrics, speaking rhythmically and tapping out time. Tools include musical instruments, music, radio, stereo, CD-ROM and multimedia.

4. Interpersonal– This is an area that is dominated by mixing with other people, understanding, and interacting with others. These students learn through interaction. They have many friends, empathy for others, and street smarts. They prefer to be taught through group activities, seminars or dialogues. Tools include the telephone, audio conferencing, time and attention from the instructor, video conferencing, writing, computer conferencing and e-mail.

5. Intrapersonal- Individualism is dominant in this area; that is, understanding one's own interests and goals. These learners tend to shy away from others. They are in tune with their inner feelings; they have wisdom, intuition and motivation, as well as a strong will, confidence and opinions. They are most comfortable being taught through independent study and introspection. Tools include books, creative materials, diaries, privacy and time. They are the most independent of the learners.

6. Linguistic– Text is the most dominant or key in this area, which involves using words effectively. These learners have highly developed auditory skills and often think in words. They like reading, playing word games, and making up poetry or stories. They prefer to be taught by saying and seeing words, or reading books together. Tools include computers, games, multimedia, books, audio recorders, and lectures.

7. Logical -Mathematical– Numbers and patterns dominate this area of reasoning and calculating. Such students think conceptually and abstractly, and are able to see and explore patterns and relationships. They like to experiment, solve puzzles, and ask cosmic or intergalactic questions. They prefer to be taught through logic games, investigations, mysteries. They need to learn and form concepts before they can deal with details.

Adopting Gardner's theory of multiple intelligences has numerous implications for teachers in terms of classroom teaching or on their daily lesson presentation. According to Brualdi (1996), the theory states that all seven intelligences are needed to function productively in society. This clearly means that whatever is achieved within the classroom by learners will ultimately benefit society. Brualdi (1996) also points out that traditional education systems emphasize development of only one or two intelligences, which are typically verbal and mathematical intelligences. Thus, the Theory of Multiple Intelligences suggests that educators should prepare the lessons such that they cover a wide range of learns' talents and skills. Gardner (1999) believes that many individuals exhibit intelligences that are not measured by standard tests. This invites teachers, when preparing their lesson presentations, to be creative and consider all intelligences as being equally important.

Gardner (2004) maintains that one should consider the effects of both dominant and non-dominant intelligence domains upon individuals' learning processes or learning style. Learning styles may be defined in multiple ways, depending upon one's perspective. For example, Brown (2000) defines learning styles as the manner in which individuals perceive and process information in learning situations. Celce-Murcia (2001) defines learning styles as "the general approaches that students use in acquiring a new language or learning any other subject; that is, the manner in which a learner perceives, interacts with, and responds to the learning environment. Learning style is sometimes defined as the characteristic cognitive, affective, social, and physiological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (MacKeracher, 2004, p. 71).

One way to characterize learning styles is to define the learners' preferred modes of learning in terms of the sensory approaches through which they prefer receiving information (Lujan & Di Carlo, 2006). Four sensory styles of learning were introduced by Fleming and Bonwell (2006) that is visual (V), auditory or aural (A), read-write (R), and kinesthetic (K).

Students with a visual preference learn best by seeing or observing (drawings, pictures, diagrams, demonstrations, etc). Learners that prefer aural learning are best suited to learn by listening to or recording lectures, discussing materials, and talking through materials with themselves or among others. Read and write type of learners learn through interactions with textual materials. Kinesthetic learners perform best by using physical experiences such as moving, touching or performing an activity. They prefer lessons that emphasize doing, and manipulation of objects.

Student learners are capable of using all of these sensory modes of learning; however, each individual has a unique preference, or set of preferences, in which one mode is often dominant. Learners with a single learning style preference are referred to as uni-modal, whereas others preferring a variety of styles are known as multimodal. Among the multimodal learners, there are sub classifications for bi-, tri- and quad-modal learners, who prefer to use two, three, or all four styles, respectively.

Use of teaching media, according to Brualdi (1996), is another way in which teachers could structure the presentation of material in a style that would engage most, if not all, of the intelligences. Through engagement of all intelligences one could foresee increased learner participation within the classroom as their preferred learning styles are accommodated. Taking an example, the teaching of assembly drawing (AD), a teacher could bring an old portable mechanical machine to class, which learners could see and handle as they dismantle and assemble the components, and then draw it. Colourful pictures based on assembly drawings (AD) could be used to formulate a collage, on which learners could work in groups and make presentations. This kind of approach can arouse learners' interest and also create opportunities for the teacher to emphasize the content knowledge to learners using the same material in a variety of techniques. By awakening a wider range of intelligences, teaching, leaning and assessment in this style can streamline a better understanding of the subject content knowledge.

Everyone is born possessing the seven intelligences, according to Brualdi (1996), Endorsing this view, I believe it devolves to the individual teacher how he or she can craft a teaching approach so as to facilitate learners using a set of intelligence to better understand the subject matter presented. I see this theory of multiple intelligences as a most effective tool for the teachers, so they may be better prepared to accommodate strengths and weakness of the different intelligences that learners bring in the classroom. This means accommodating many learning styles within one classroom (Brualdi, 1996). While it would be extremely difficult, perhaps even impossible, for an individual teacher to accommodate all learning styles in every lesson, nevertheless the teacher can show students how to use their more developed intelligences to assist in understanding a subject, instead of having to rely on their weaker intelligences (Lazear, 1992). For instance, when the class leans about the assembly drawing or geometrical solids, the teacher could encourage a linguistically intelligent learner to create a poem that could be presented in class. Such activities would create a well conducive environment for learners to master the required content knowledge in subjects other than languages.

Human beings are differentially gifted and they have special different sets of intelligences. As Gardner (1993) stated, "If we can mobilize the full range of human intelligences and ally them to an ethical sense, we can help to increase the likelihood of our survival on this planet, and perhaps even contribute to our thriving" (p. 12). So according all intelligences the same

importance will benefit mankind. If connections between the intelligences and teaching styles are established, certainly Howard Gardner's vision might be fulfilled at some stage.
Table 4.1. below is a summary of the key features of the theoretical framework embraced in this study.

Table 4.1. Features of Theoretical Framework

Vygotsky: *Social Interactions To see the incredible influence of Vygotsky's (1978) designs, one need only to look at the myriad studies focused on classroom interaction patterns. Vygotsky's theory suggests that one learns first through a social setting of person to person interactions and then personally through internalization process that leads to deep understanding. This belief in the socialization process of idea-making permeates the interactive classroom. Student-to-student engagements range from small groups of children bent over the map of the Antarctica, deep in discussion of human survival to pairs of students going head to head as they debate the most efficient method to solve the "tower problem."*	**Gardner**: *Multiple Intelligences is Gardner's (1983) gift to the new architects in his conceptualization of intelligence as multifaceted and multidimensional. He defines human potential in terms of the ability to solve problems in a culturally valued setting. With this broad perspective, Gardner has identified seven realms of intelligence: verbal, logical, visual, musical, bodily, interpersonal, intrapersonal, and naturalist. As seen in innumerable classrooms, these multiple intelligences are at work in various combinations as they converse and connect in the execution of complex tasks.*

Source: Robin (1999, p. 7-8). *Architect of the intellect*.

4.4. Link between theoretical constructs and this study

This study focuses on how first year PSTs of EGD read and interpret AD. Each PST is a unique individual with his or her own learning style and way of rationalising how they read and interpret AD. Further, because all PSTs of EGD would have studied EGD at matric level they enter their teacher training course with prior knowledge of how to read and interpret AD. While PSTs of EGD are to be teachers of AD, they are also positioned as learners who via social interactions with the lecturer and their peers improve their ability to read and interpret AD. When Vygotsky's ZPD and Gardner's multiple intelligences and other learning style theories are fused they illuminate the way towards a renewed approach to the teaching and learning of AD.

4.5. Conclusion

In this chapter, I have discussed the theories that frame this study; namely, Vygotsky's ZPD and Gardner's MI theory. These theories will help make sense of how PSTs of EGD read and interpret AD. The processes by which PSTs read and interpret AD will be linked to theories, which also talk to their leaning styles. The following chapter, Chapter 5, presents the methodology adopted in this study.

CHAPTER FIVE

METHODOLOGY

5.1. Introduction

As mentioned previously in Chapter 1, this study explored how first year EGD PSTs read and interpret assembly drawing. The research questions guiding the study were:

1. What are first year EGD PSTs' levels of spatial visualization ability?
2. What challenges do first year EGD PSTs encounter when they read and interpret AD?
3. Why do first year EGD PSTs encounter challenges when the read and interpret AD?
4. Does the reading and interpreting of AD, by first year EGD PSTs, change after mediation? If so how? If not, why?

A brief synopsis of the methodology was presented in Chapter 1. In this chapter, I elaborate on the philosophical assumption of the interpretative paradigm that underpins this study. I further provide the layout of the research method used and subsequently explain the reasons for a case study design. According to Maxwell (2016) and Merriam and Tisdell (2016), research design entails a well thought out system of plan, processes and procedures employed in the carrying out of a research study, in order to achieve the research objectives.

The link between the paradigm, research question, approach, design and instruments is illustrated in Figure 5.1. below:

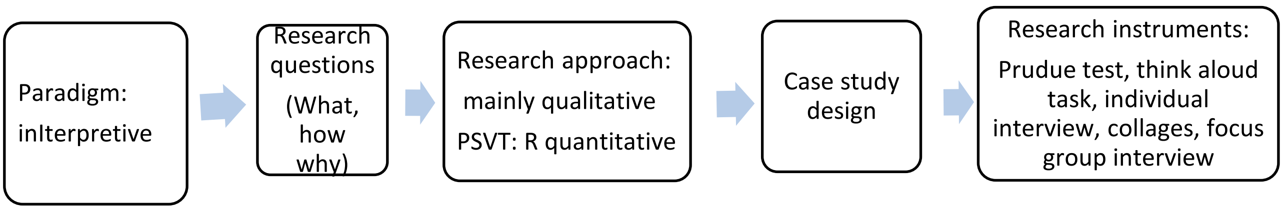


Fig 5.1.: The research design map

This chapter also gives a description of the location or site of the study. The approach used to gain access to different gatekeepers at each stage of the research is also clearly explained as well as the challenges the researcher encountered in the process of data generation. These aspects cover considerations of ethical clearance from the respective and relevant authorities.

The core of this chapter outlines the data generation instruments and sampling procedure. These are then followed by a detailed description of data generation and the method of data analysis. The chapter ends by justifying the validity of the instruments and analysis procedures. It is the strategy to promote the credibility of the research outcomes and to meet the objectives of the study.

5.2. Research paradigm

The key to having a clear direction for the method of inquiry is choosing a particular paradigm. The paradigm then flags and directs the thought patterns and actions in the study. A paradigm is regarded as one of the frames of references we use to organize our observations and reasoning (Maxwell, 2016) and it serves as a lens through which to view a phenomena (Cohen, Manion & Morrison, 2018). A paradigm is regarded as one of the frames of reference we use to organize our observations and reasoning (Babbie, 2011). Paradigms can help frame one’s approach to a research problem and guide decisions on how to address it, according to certain beliefs about the world. Thus, I see paradigms as a guide that the researcher can use to ground their research. Accordingly, because I seek to understand the challenges first year EGD PSTs encounter when they read and interpret AD, both initially and after subsequently scaffolding their reading and interpretation of AD using a qualitative approach, this study embraces the interpretative paradigm. Any paradigm has four philosophical assumptions, which are ontology, epistemology, axiology and methodology (Creswell, 2013; Mertens, 2010). According to Cohen, et al. (2018), the main concern of the interpretive paradigm is to understand the subjective world of human experience, in order to derive meaning from shared experience. The interpretative paradigm aims to develop a better understanding of how people make sense of the contexts in which they live, work and learn. Hence, researchers employing an interpretive paradigm aim to describe and make sense of social phenomena, such as people’s opinion and experiences. The interpretivist paradigm has the following characteristics, as given by Cohen et al. (2018). It focuses on the individual, it is small-scale research, it acknowledges subjectivity, it is qualitative in nature, it has multiple directions of causality, and it seeks understanding of actions or reasons rather than cause and effect. Researchers using this paradigm thus focus on the specific context in which people live and work (Creswell, 2013). This study is concerned with understanding how first year EGD PSTs read and interpret AD, as well as understanding the challenges first year EGD PSTs encounter when they read and interpret assembly drawing at DS University of Technology, and attempts to address the challenges identified through an intervention teaching programme.

The ontological assumptions of the interpretative paradigm required me to consider the existence of multiple realities. I understood the reality of the challenges first year EGD PSTs encounter when they read and interpret AD would be multifaceted and that I could only understand this reality from the perspective of the first year EGD PSTs. In this regard, Cohen, et al. (2018) state that the role of the researcher in the interpretive paradigm is to understand, explain, and demystify social reality through the eyes of the participants (p.16). For that reason, as the data for this study, I used the descriptions given by the participants themselves of their experiences, challenges and opinions of reading and interpreting AD.

In its epistemological stance, interpretivism values the subjective meaning of a social phenomenon (Cohen et al., 2011). According to Cohen et al. (2011) epistemology deals with ways of researching and enquiry into the nature of reality. In this study credible knowledge was generated from observable phenomenon (performance in the Purdue test, think-aloud tasks) and subjective meaning (understanding of way first year EGD PSTs read and interpret AD). Thus, different methods were employed to answer the research questions posed.

Axiology is concerned with values during data generation. In this study, I espoused both etic and emic approaches during data generation. The etic approach was embraced during the generation of data from the Purdue test, which was used as a baseline to gain insights into first year EGD PSTs' spatial ability. I had no influence on the data generated. The emic approach was used to generate data during the second, third and fourth stages of data generation where I was immersed in the data generation process, allowing for subjectivity in the interpretation (Wahyuni, 2012). The interpretative paradigm is best suited for this study rather than the pragmatic paradigm, as the bulk of the data generated is qualitative data and I seek to understand how first year EGD PSTs read and interpret AD.

5.3. Research Approach

Research approach is the term given to the technique or strategy followed in studying a phenomenon to acquire an in-depth insight. According to Creswell (2013) there are three essential research methodologies: the qualitative, the quantitative and the mixed method research approaches. The paradigmatic stance and purpose of study gives guidance to the selection of the most suitable research methodology (Maxwell, 2016).

The study embraces a qualitative approach. In this choice, I was guided by the ontological position of the interpretative paradigm, which embraces the notion of constructing multiple social realities (Creswell, 2013). Qualitative research is research that attempts to collect rich descriptive data in respect of a particular real life phenomenon (How first year EGD PSTs read and interpret AD) or context with the intention of developing an understanding of what is being observed or studied (Yin, 2014).

Qualitative research focuses on techniques associated with the collection of in-depth data that relies heavily on narrative, non-numeric analysis, interpretation and presentation (Mertens, 1998; Mertler & Charles, 2008; Tashakkori & Teddlie, 2010). I wanted to obtain thick, detailed descriptions about the challenges and experiences of EGD PSTs when they read and interpret AD. Qualitative research is an advantage when exploring a completely unknown or unpredictable situation (Creswell, 2013). It allows participants to express their opinions without bias, thereby providing uncut data for the researcher. Furthermore, qualitative research involving human subjects makes use of audio, visual or textual data, which enable the research to deduce meaning from active social context (Henning, Van Rensburg, & Smit, 2004). Accordingly, qualitative data analysis involves the researcher being able to develop a pattern or theme that best describes the phenomenon observed (Creswell, 2013). In this study, I explored how first year EGD PSTs read and interpret AD with a view of gaining in-depth knowledge of the challenges they encounter when they attempt to read and interpret AD.

5.4. Research Design

A research design is a summary of the various procedures that a researcher employs to collect, analyse, interpret and present his or her research data (Durrheim, 2004). In other words the research design is the plan of how the researcher will systematically collect and analyse the data that is required to give valid solutions to research problems.

This study embraced a case study design. Yin (2014) describes case study research as an empirical inquiry that investigates a contemporary phenomenon within its real life context using a variety of ways to generate data. This ensures that the issue is not explored through only one lens, but rather through a variety of lenses, which allows for multiple facets of the phenomenon to be revealed and understood (Baxter & Jack, 2008). A case study is therefore an in-depth study of one particular case, where the case may be a person or group of people, such as here, EGD PSTs at DS University of Technology.

5.5. Sampling and sampling method

According to Tashakkori and Teddlie (2010, p. 356) sampling is seen as "a process of selecting a sample unit from a larger group or population of interest" in order to answer the research questions. Cohen et al. (2018) describe sampling as the strategy that enables the researcher to select a sub-group from a larger group and subsequently use the sub-group as a basis for making judgements about the larger group. According to Cohan et al. (2018) sampling is a process of decision-making about the population, settings, events or deeds that have been chosen for observation.

The selection of participants for the study was guided by my research approach. Both purposive sampling and convenience sampling were used for the study. The criteria of the case study design require that participants be purposively selected. Purposive sampling is described by Rule and John (2011) as the "sampling where the people selected, as research participants, are deliberately chosen because of their suitability in advancing the purpose of the research" (p. 64). The criterion for the selection of participants in this study is they were PSTs enrolled for the first year of B.Ed. EGD module at a university of technology. Convenience sampling was also adopted. According to Maree (2013) convenience sampling refers to "situations when population elements are selected based on the fact that they are conveniently available" (p. 177). The geographical context of the particular university of technology was selected because of convenience: I am a lecturer of EGD at this institution.

There were 41 PSTs enrolled in 2018 at DS University of Technology to train as teachers of EGD (25 females and 16 males). Initially all 41 were requested to participate in phase one of this study (PSVT). Thereafter 50% (21) of the first year EGD PSTs were requested to participate in phases 2 to 4 of the study; all consented to this. However, during phase 4 of data generation, students embarked in protest action (# fees must fall,# better accommodation for students, # meal allowances for students), consequently only 10 of the 21 first year EGD PSTs participated in the making of collages and post collage focus group interview.

5.6. Location of the study

The study is located at DS University of Technology campus situated in the Imbali Township, which lies on the outskirts of Pietermaritzburg in the uMgungundlovu District of KwaZulu-Natal Province of South Africa. Figures 5.2 and 5.3 Show the location.

Figure 5.2 Map of South Africa (Google Maps)

Figure 5.3 Map of KwaZulu-Natal (Google Maps)

In close proximity to this particular Universality of Technology campus are secondary schools and a technical and vocational education training (TVET) College. Middle class dwellings, reconstruction and development programme (RDP) houses and some informal settlements surround the campus. In the Imbali township a few people are skilled workers, and a large number are semi-skilled. Unskilled people who are unemployed also reside in Imbali. Most of the working population in Imbali enjoy seasonal, temporary jobs like RDP construction projects or road construction projects (uMgungundlovu Municipality, 2018).

This Imbali campus of DS University of Technology serves students from a lower income background. The students come from different provinces within South Africa and few are from other countries like Botswana, Swaziland and Zimbabwe. The majority of students are African South Africans from KwaZulu-Natal. It well established that the majority of the students come from previously disadvantaged rural schools, which are under-resourced. Most of the high schools in the Imbali area offer commercial streams, science streams and general streams, but only a few schools offer technology streams, in particular the subject Engineering Graphics and Design.

Three qualifications are offered at this campus; specifically, a diploma in Civil Engineering, degrees of Bachelor of Technology (Nursing Science) and Bachelor of Education (Further Education and Training). This study focused on the B Ed (FET) degree, offered in the School of Education. The B Ed (FET) degree is a four-year teachers’ qualification. It prepares teachers to teach at the Further Education and Training band (Grades 10 to 12) in high schools. There are three specialisations, or streams, within the B Ed programme that students can pursue, namely sciences, commerce and technology. This study focuses on the technology stream, specifically on the Engineering Graphics and Design module offered in year one of study.

The School of Education consists of 22 lecturing staff including the Head of Department, two secretaries and one computer laboratory technician. In the year of this study, 2018, the total number of students per level (year) are as follows, level 1 = 430, level 2 = 200, level 3 = 237 and level 4 = 216. Only 41 students were enrolled in EGD module. As stated above, all these 41 first year EGD PSTs were purposively selected to participate in this study.

5.7. Research instruments

In order to answer the four research questions several instruments were used to generate data. These instruments include the Purdue spatial visualization test, two think-aloud tasks, collage making, individual interview and after the collage, a focus group interview and concept maps. The aforementioned instruments allow for the generation of rich in-depth qualitative data.

5.7.1. Purdue Spatial Visualization test

The PSVT test has been used by many engineering and technology educators to evaluate the spatial visualization ability of students at a number of colleges and universities (Ardebili, 2006; Branoff, 2011; Branoff & Connolly, 1999; Hamlin, Boersma & Sorby, 2006; Sorby, 1999; 2001; Sorby & Baartmans, 2000; Towle et al., 2005; Yue, 2006). The PSVT has 30 items consisting of 13 symmetrical and 17 non symmetrical figures of 3-D objects, which are drawn in a two-dimensional (2-D) isometric format. A sample item of the PSVT is shown in Figure. 5.4.

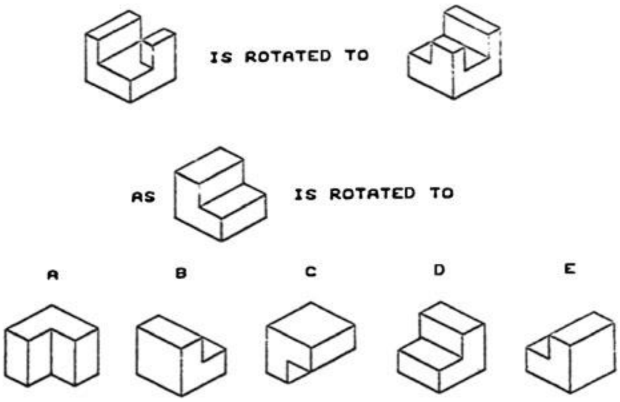


Figure 5.4: A sample item from the PSVT (Guay, 1976)

All figures contain cubes or cylinders with varied truncated slots. For each item, the respondents' task is to mentally rotate a figure in the same direction as is visually indicated in the instructions and identify the most appropriate choice among the five options. The PSVT test comprises three sections: in the first section (questions 1-6) the three dimensional object is rotated once, in the second section (questions 7-22) the object is rotated twice and in the third section (questions 23-30) the object is rotated thrice.

The Purdue spatial visualization test (see appendix C6 for test) was the first instrument used in this study as the diagnostic tool to determine the spatial visualization level of PSTs. The Purdue Spatial Visualization Test (PSVT) was developed by Guay (1976) to test spatial abilities. It consists of 36 multiple choice questions related to spatial visualization. The test originally consisted of three sections (developments, rotations, and views), each containing twelve problems (Guay, 1976, P.11). The first section is developments (folding 2-D flat patterns along fold lines into 3-D objects (surface models). The second section is orthogonal rotations of 3-D objects about the axes of the Cartesian coordinate system. Rotations are designed to "help visualize the rotation of a three-dimensional (3-D) object" (Guay, 1976, p. 6).The third section is the isometric views of 3-D objects. Each section of the test starts with an example that shows how an object has been rotated. This serves as a clue for participants to understand the rotation of each item or object. The PSVT was used with the aim of generating data needed to respond to Research Question 1.

5.7.2 Think aloud task based activities

Think aloud protocols involve participants thinking aloud as they are performing a set of specified tasks. Participants are asked to say whatever comes into their mind as they complete the task. This might include what they are looking at, thinking, doing, or feeling whilst completing the task. This allowed me to gain insight into the first year EGD PSTs' cognitive processes as they attempted to read and interpret the AD contained in the think aloud task (rather than only their final product) and helped to make sense of these processes, which became explicit during the task performance. A think aloud task allows for the voice of the participant to be heard. For the think aloud task to be effective, I had to constantly remind first year EGD PSTs to "keep talking" if they were silent. The think aloud task were video recorded (as it allows the researcher to go back and refer to what participants did and how they reacted during the think-aloud task). All recording were transcribed verbatim and were used for retrospective probing where questions are asked after completion of the given activity (Ericsson & Simon, 1993). Hence, the think aloud tasks are useful in uncovering new or emerging phenomena, rather than testing or confirming what is already known

I opted to use think aloud tasks to generate data for Research Questions 2, 3 and 4 as the tasks set (see appendix C1 and C2 for think-aloud tasks one and two respectively) involved cognitive processes that take more than a few seconds to complete (Payne, 1994). As Branch (2000) asserts, when using a think aloud task it is important to be familiar with the participants' current level of performance. Thus the PSVT was used before think aloud task one to ascertain EGD PSTs' level of spatial visualization (for Research Question 1) and to ensure that the activity set in the think aloud tasks were neither excessively difficult, nor could they be performed with such automaticity that PSTs would be unable to break down the task into its component and sequential cognitive steps.

The advantage of using think aloud tasks is that PSTs were engaged with a real activity, which required a sequence of cognitive processes in which they became immersed. This gave more realistic data than would be obtained by merely asking an individual how he or she would complete an activity, without actually engaging in the activity.

Think aloud tasks are also an excellent instrument to capture the facial expression, gestures and verbal expressions precipitated by the engagement of the participant with AD. In the space of four weeks participants did two think aloud tasks, and their expressed thoughts and feelings were captured by video recordings.

5.7.3. Semi-structured Individual interview

Cohen, Manion and Morrison (2007) define an interview as a two-person conversation initiated by the interviewer for the specific purpose of obtaining research-relevant information. Cohen, Manion and Morrison (2018) redefine an interview as an interchange of views between two or more people on a topic of mutual interest.

Numerous advantages to using interviews are apparent (Cohen et al, 2018), as follows.

- The researcher is present during the interview with the respondent, and thus can make the questions clear.
- A researcher can ask more questions to probe for more detailed information if the respondent has not initially given sufficient detail.
- It is usually easier for respondents to talk to an interviewer than to write long questionnaire responses, allowing for more detailed and descriptive data to be collected.
- Interviewing is a good method to use for gaining in–depth data from a small number of people.

Nevertheless, there are disadvantages to using interviews, as follows.

- Interviewing is not simple a data collection exercise, but is also a social, interpersonal encounter.
- Interviews generate large amounts of textual data. When transcribed, a 45 minutes interview can become 15 pages of text. This can be overwhelming unless the research has a very clear idea of how that data will be analyzed.
- Interviews result in self-reported data. This means that interviewees are reflecting on their own behaviour or beliefs and reporting these to the interviewer.

Interviews range from structured interviews through semi-structured to informal, unstructured interviews. Structured interviews conform to a set range of questions with the responses falling into parameters that are predefined by the interviewer. Unstructured interviews involve questions that are developed from immediate context, with the interview taking on a more conversational tone.

The semi-structured interview approach is highly favoured in educational research as they allow for a set of pre-determined questions to be asked and the flexibility to pursue interesting tangents in the conversation. According to Hesse-Biber and Leavy (2011), a semi-structured interview provides valuable information from the context of the participants' experience because it does not limit the respondent, it allows for the probing of responses, and encourages elaborate responses. Resonating with this view, Longhurst (2010, p. 35) expresses the idea that "interviewing is about talking, but it is also about listening. It is about paying attention. It is about being open to hear what people have to say. It is about being non-judgmental. It is about creating a comfortable environment for people to share."

Semi-structured interviews (see Appendix C3 and C4 for the interview questions) were conducted with first year EGD PSTs after each think aloud task activity (this means that an interview was conducted after the completion of think aloud task one and a second interview was conducted after the completion of think aloud task 2). The semi-structured interview allowed the researcher to further probe the participants' responses and reactions that had been recorded during the think aloud task activities. The interview was semi-structured in that all of the participants were asked questions in the same order. In this way, it served the purpose of sampling the participants' responses, thereby increasing the comparability of the responses (Cohen et al., 2018). In accordance with the suggestions advocated by Longhurst (2010), the following issues were taken into account during the interviews:

- Establishing rapport and trust with the interviewees;
- Empathy and neutrality;
- Using non-verbal nods and verbal “um-hms” to show interest;
- The researcher monitoring himself;
- Sensitivity towards gender and cultural differences;
- Providing sufficient time for the interviewees to respond; and
- Maintaining control of the interview and keeping the interview focused.

All interviews conducted were video recorded, as with the think-aloud tasks. Again video recording could capture nonverbal communication such as facial expressions and body gestures that could not be captured in an audio recording. According to Cohen et al. (2011) the advantage of using video recordings is that it is a mirror image of what occurs, and it allows for repeated viewing and checking. The video recording was transcribed and the transcripts sent to participants for member checking.

5.7.4. Collage making

Guided by the multiple intelligence theoretical framework (Section 4.3) and the importance of spatial visualization skills in this study, I decided to incorporate an art based method of data generation, namely making a collage. Making a collage is a piece of art, made by sticking various photographs and other materials on a poster or similar backing; as such it can represent feelings and experiences about the situation depicted (Threadgold, 2003): in this instance, first year EGD PSTs engagement with AD. The use of art as a data generation method is becoming more used in qualitative research (Mayaba & Wood, 2015; Theron, Mitchell, Smith & Stuart, 2011). Using art as a research method provides researchers with a window into the lived experiences of the participants and a means of understanding how they make meaning of these experiences pertaining to AD; meaning their enculturation, stereotypes, etc. Collages also provide a powerful intervention to engage participants in the construction of alternative realities (Mayaba & Wood, 2015).

Collages allow for access to different levels of consciousness, and many conversations with the self and others, thereby communicating a holistic picture of “what is” or the reality of an experience (Prosser and Loxley, 2008). I provided the first year EGD PST with a wide variety of magazines from which to source picture for their collages. The brief provided to PSTs was that they had to position themselves, their encounters, experiences with regard to their reading and interpretations of AD in the collage. The chosen picture(s) or word(s) would tell a story about their experiences or challenges pertaining to their reading and interpretation of AD.

To create the collages first year EGD PSTs sat in groups. For Research Question 2, there were four groups, each with five individuals. Participants self-selected their groups, based on convenience. Each group collectively looked through magazines, newspapers and catalogues for pictures and words that captured their engagement when they read and interpreted AD (Khanare, 2009). The intention of this exercise was to choose pictures or images that best captured their experiences of how they read and interpret AD the way they did, as well as the factors that impeded or promoted their reading and interpretation of AD. They also cut out words and sentences that added to what they aimed to articulate through their collages. When PSTs could not find suitable images to represent their engagement with AD they were allowed to draw images to represent their encounters and experiences for their collage. As a group they had to look at images collated by each member of the group and collectively make choices based on which ones best spoke to what they wished to express concerning their experiences and engagement with AD. PSTs then collectively created the collage as they negotiated and debated over the construction of the collage. Four collages were made. The rationale for making collages collectively rather than as individuals was to allow joint participation, reflection and discussion on PSTs reading and interpretation of AD. It also served as an empowering experience for them as they had an opportunity to express themselves freely with the support of their peers. Further, it ties in with my conceptual framework of ZPD, where learning occurs with and from peers Here there was a shared understanding of how first year EGD PSTs read and interpret AD.

First year EGD PSTs were also involved collages making after my mediation/teaching intervention. Two collages were made. In other words first year EGD PSTs made collages twice, first after think aloud task one and after my planned mediation (teaching) intervention.

5.7.5 Concept maps

After making the collages, the PSTs were exposed to the task of constructing a concept map based on their collages. Concept mapping is a form of art-based research. Concept maps are described as graphical tools for organizing and representing knowledge (Novak & Cañas, 2008). Wheeldon and Faubert (2009) describe concept mapping as a technique that can demonstrate how people visualize relationships between various concepts, and it therefore provides a visual representation of dynamic schemes of understanding within the human mind. Concept maps allow for a synergy to exist between more mainstream data generation methods, which are word based, and thematic data generation methods such as collages (Jackson & Trochim, 2002). This integrated approach allows abstract concepts to be more concretely visualized while retaining the freedom and expressive insight one hopes to gain from qualitative research. Jackson and Trochim (2002) go on to describe concept mapping as an informal process whereby an individual draws a picture of all the ideas related to some general theme or question, and shows how these are related. The resulting map usually has each idea in a separate box and the boxes are then connected by connective terms to show how they are related. For the purpose of this study, concept maps were useful as the manner in which the participants constructed the maps demonstrated their belief in the importance and commonality among different concepts and the nature of perceived relationships in reading and interpreting AD (Wheeldon & Faubert, 2009).

The first year EGD PSTs transcribed meanings from their collages into the concept maps. The main images from the collages were numbered consecutively, and thereafter the sets of related concepts were grouped. This allowed the PSTs to represent their understanding of the relationships between important sets of concepts concerning their engagement with AD.

5.7.6 Post collage focus group interview

The post collage focus group was another approach used to get in-depth information from participants. According to Patton (2002, p. 2) a focus group interview is an interview with a small group of people on a particular topic. Focus groups are a method of generating qualitative data through unstructured discussion between researcher and participants (Cohen et al., 2018). They usually involve between four and twelve people "exploring a specific set of issues" (Tong, Sainsbury & Craig, 2007, p. 351). Yin (2014) also emphasizes that "the groups are 'focused' because you have gathered individuals who previously have had some common experience or presumably share some common views" (p. 141). According to Kvale and Brinkmann (2009) the intention of a focus group interview is not to arrive at a unanimous decision, but rather to articulate different points of views. In comparison with individual interviews, there are several merits attached in using focus group interviews, as posited by Fahad (as cited in Ngure, 2013, p 108), which are shown in Table 5.1. on the next page.

Table 5.1: Merits of Focus group interviews

S/N	Merit	Merits explained.
1	Synergism	Combined effect of the group produces a wide range of information, and ideas.
2	Snowballing	When a member of the group raises a comment, the comment often triggers a chain of responses from other participants in the group.
3	Motivation	Participants tend to respond quicker after the first course and are more likely to express their attitudes and feelings as the overall level of enthusiasm increases.
4	Security	Most participants find comfort in a group that shares their feelings and beliefs
5	Spontaneity	Since a participant is not meant to answer specific questions, their responses are likely to be more spontaneous and less conventional.
6	Serendipity	The ethos of the group is likely to produce wider ideas and often when least expected.
7	Specialisation	The content allows a more trained interviewer to be used and minimize the possibility of subjectivity.
8	Scientific scrutiny	The nature of the research gives room for scrutiny in the technique by allowing the observers to play back and by analysing recording sessions.
9	Structure	Discussions afford more flexibility in the topics that can be covered and in the depth in which these are treated.
10	Speed	Given that several participants are being interviewed at the same time, this speeds up the process of collecting and analysing data.

A focus group interview was, accordingly, introduced as a data collection method among the first year EGD PSTs as another means of generating quality information and thereby strengthening the findings from the study. The purpose of the focus group interview was, therefore, to get the respondents’ responses by asking them questions about their feelings while developing the collage, as well as allowing the researcher to further probe and gain insight into the participants’ collage activity concerning their reading and interpretation of AD. In this way the focus group interview These responses would allow increased comparability of responses (Cohen et al., 2007). Furthermore, a focus group interview could generate debates amongst the participants when they present their ideas regarding reading and interpretation of AD, and this in turn provided the researcher with a deeper insight into participants’ understanding of AD.

Check and Schutt (2012, p. 205) affirm that “focus groups generate qualitative data using open-ended questions posed by the researcher or group leader”. Krueger and Casey (2009, p. 7) agree that “the data in the focus group are solicited through open-ended questions”. Accordingly, the interview protocol was semi-structured and open-ended so as to allow the participants to provide details of their experiences in order to reveal the way they perceived their reality. The protocol involved a schedule of questions designed to provide answers to my research questions, while still allowing the participants to engage freely and give their insights as they related to the phenomenon of how they read and interpret AD. The interview questions thus related to the experiences of PSTs of their engagement with AD as depicted in the collages and concept maps. The focus group interview schedule is given in Appendix C5.

Participants, who participated in collage making (during phase three and four of data generation, see section 5.8) were invited to participate in a focus group interview. During phase three of data generation two focus group interviews were conducted, each group had 10 participants, participants self-selected their groups.

During phase four of date generation two focus group interviews were conducted, each group had 5 participants, participants self-selected their groups.

During the interview, some of the participants were prompted to speak while listening to their peers’ contributions. This corroborates the views of Patton (2002) and Cohen et al. (2018) that in focus group interviews, it is the interaction among peers that results in useful data. The focus group interviews was video recorded to capture both verbal and non-verbal information. Responses were than analyzed and described. Data from the focus group interview was then also used to identify any gaps so as to make recommendation for future study.

5.8. Data generation plan

In qualitative research, the term data generation is preferred to data collection, as the process entails intellectual, analytical and interpretative activities, rather than measurements. It is necessary to have a data generation plan in order to ensure that all research questions would be answered. Table 5.2, (on the next page), reflects the steps that were undertaken to generate data, which took place in four phases.

Table 5.2. Data generation plan.

Research question	Phase	Data source	Instrument	Analysis
1. What are first year EGD PSTs' levels of spatial visualization ability?	1	First year EGD PSTs (41)	Purdue Spatial Visualization test: mental rotation test and views	Mean, mode, simple frequencies to compare results of male and female students in the different sections of the test
2. What challenges do first year EGD PSTs encounter when they read and interpret AD?	2	First year EGD PSTs (21)	Written think-aloud task 1 Semi-structured interviews	Tasks marked with areas of strengths and weakness will be noted. After task 1 PSTs will be made aware of their areas of weakness and will be exposed to an intervention to improve their results.
3. Why do first year EGD PSTs encounter challenges when the read and interpret AD?	3	First year EGD PSTs (21)	Collage, Concept maps, Post collage making focus group interviews, semi structured individual interviews (from phase 2)	Content analysis bearing the research question in mind
4. Does the reading and interpreting of AD, by first year EGD PSTs, change after mediation? If so how? If not, why?	4	First year EGD PSTs (21) Thereafter 10	Think-aloud task 2, Individual Interview Collage making Focus group interview	Qualitative- content analysis –bearing research question in mind

5.8.1 Phases of data generation:

Phase 1: RQ1

The 41 PSTs wrote the Purdue spatial visualization test (PSVT) (see appendix C6) in order to establish their level of spatial visualization ability. Because it focuses on how first year EGD PSTs read and interpret AD, the PSVT test was used as a diagnostic tool to determine the spatial visualization ability of the pre-service teachers. The test was administered during the first week of semester one in 2018 before any formal lectures could commence. Students were briefed about the purpose of the test and my research, thereafter informed consent was sought.

Phase 2: RQ2

Twenty one first year EGD PSTs engaged with think aloud task one on AD at the beginning of the semester, before teaching could commence. See appendix C1 for task 1. During this process, the participants spoke aloud their mental thoughts as they engaged with the set think-aloud task.

Phase 3: RQ3

Twenty one PSTs were engaged in semi-structured interviews and collage making, in order to establish why first year EGD PSTs encountered challenges when they read and interpret AD.

Phase 4: RQ4

Phase 4 comprised four stages; that is, think aloud task 2, individual interviews, collages, and post collage group interview. Each stage was video recorded. In Stage 1, 21 first year EGD PSTs completed think-aloud task 2 (see appendix C2 for task two). Due to student protest actions the number of participants decreased to 10. These were engaged in Stage 2 (individual interviews), Stage 3 (collage making) and Stage 4 (focus group interview).

5.9. Data analysis

I engaged in qualitative data analysis. According to Cohen et al., (2018, p. 537), "Qualitative data analysis involves organizing, accounting for and explaining the data; in short, making sense of data in terms of the participants' definitions of the situation, noting patterns, themes, categories and regularities". Scholars such as, Creswell (2013), Babbie and Mouton (2001) and Cohen et al. (2013) consider that data analysis consists of the following tasks:

- Preparing and organizing the data,
- Reducing the data into themes, and
- Representing the data in figures, tables or discussions.

Whilst these three tasks were all undertaken in this study when answering the research questions, I was always aware that data analysis is not a linear process. Instead, it is, as Creswell (2013, p.228) says, inductive, iterative, eclectic and interpretive. In this study, data analysis entailed working with specific sets of data to develop general codes and patterns. The unit of analysis in this study is first year EGD PSTs and how they read and interpret AD. Data were analyzed in each phase of the study. In the sections below, I explain how data was analysed for each phase of data generation.

Phase 1: PSVT

The PSVT test was marked and the results were categorized according to the sections on rotations and isometric views, as they appear in the test itself. The analysis of rotations was separated from the isometric views section to give a clear picture of the first year EGD PSTs' strengths in terms of spatial ability. This enabled me to establish the PSTs' level of spatial skills. Results was analysed to represent the percentage pass per rotation for the three sections of the test. A comparison was made between results for the levels of spatial ability for male and female first year EGD PSTs.

Phase 2: Think aloud activity

The products from the think aloud activity was "marked" to identify areas of strengths and weaknesses in how PSTs read and interpret AD. Video recordings of the participants performing the think-aloud task was transcribed and subjected to content analysis so the responses and gestures could be probed during the interview. The individual interview transcripts were also transcribed verbatim and subjected to content analysis. Transcripts were sent to first year EGD PSTs for member checking to ascertain if what they said was indeed what they meant. Transcripts were read and re-read before coding could begin. To establish codes the following three questions were asked when reading the transcripts, What is foregrounded? How is it foregrounded? And Why it is foregrounded? The ZPD and MI constructs from my theoretical framework, were also used to interpret the data, in noting factors which impeded the development of spatial ability in terms of the first task.

Phases 3 and 4: collages, concepts maps, focus group interviews

The data from the collages were juxtaposed with the corresponding concept maps to note similarities and divergences. These similarities and divergences were probed during the post-collage focus group interview. The transcripts of the focus group interviews were transcribed verbatim and subjected to member checking. The transcripts were read and re-read before content analysis could begin. The constructs of my conceptual framework of ZPD and MI were used to identify challenges PSTs encountered when reading and interpreting AD.

Phase 4: Juxtaposing data

Analysis undertaken was identical to the steps undertaken in phases 2 and 3.

5.10. Ethics and gaining access

According to Durrheim and Wassenaar (2002), the code of ethics for research is concerned with the researcher's attempt to value human rights. Ethics entails moral justification for doing the right or wrong thing during interactions among humans, animals or the environment. As such ethics must be considered carefully at each stage in the research process (Miller & Brewer, 2003). In order to adhere to ethical standards during this research project, the following rights and responsibilities were assumed: the rights of participants taking part in the research, circumventing harm to participants, avoiding undue intrusion, obtaining informed consent, rights to confidentiality and concealment, and the rights of participants during data dissemination (Creswell, 2013).

In this study, sensitive information was gathered from first year EGD PSTs about how they read and interpret AD. As a result, the identities of both the first year EGD PSTs and the university needed to be protected. I ensured their anonymity and confidentiality by the use of pseudonyms. Ensuring these ethical considerations were adhered to gave the participants confidence in sharing their views and experiences of how they read and interpret AD without fear of exposure. Moreover, this assurance contributed to a trustworthy environment, which allowed high levels of participation and openness during the individual interviews and focus group interviews. As a result, participants were quite willing to be involved in the study and saw it as an opportunity to share their experiences of engaging with AD.

The rights of individuals (participants or respondents) taking part in a research study is expressed as informed consent, anonymity, privacy and confidentiality (Cohen et al., 2018). Informed consent entails ensuring that the participants taking part in a study must have the legal and mental capability to accept responsibility for taking part in a study, and also ensures their right to withdraw as and when they wish to, particularly if the purpose of the study was not clearly understood by the participants. I also informed all first year EGD PSTs about how I intended to collect data; which at that stage included the Purdue spatial visualization test, think-aloud task-based activities, collage making, focus group discussions and post interviews. To this end, permission to conduct the research was obtained formally from my university's research office. The certificate to this effect is included in this thesis. (See appendix A1 for ethical clearance certificate). Permission was also sought from the registrar of the DS University of Technology.

Then permission was also sought from the participants; first year EGD PSTs who were enrolled for the EGD module in semester 1 of 2018. This involved informing them about the background to and purpose for the study. Participants were assured that they could withdraw from the study at any time they chose to and they would also be guaranteed confidentiality and anonymity. A total of 41 first year EGD PSTs consented to participate in this study; however, as the study advanced the number of participants decreased due to contextual factors such as student protest action. I have come to realize that gaining access is an iterative process. It entailed dealing with various gatekeepers at each stage of the research.

Participants and gatekeepers were assured, in writing, that all data would not be used for any purpose other than the doctoral study and scholarly publications. They were further informed that the data would be stored for 5 years with my supervisor at the university and thereafter disposed of. Test, task based activity responses, interview transcripts would be shredded and all video and audio recordings would be incinerated.

5.11 Ensuring rigour in the research

Rigor entails all the steps taken in the study to ensure thoroughness or consistency. Therefore, a study is flawed if rigor is not ensured. Krefting (1991) states that the worth of any research study, regardless of the approach taken, is for the study to be critically evaluated by readers. Accordingly, the research report must be presented in a manner that it can be critiqued by readers or researchers. In this study, the use of multiple data generation methods, that is the PSVT, task based activities, individual interviews, collage making and concept mapping as well as post-collage focus group interviews were measures taken to ensuring research rigour. According to Mays and Pope (1995), issues of trustworthiness and validity inform rigour in research. Other measures taken in this study include participants’ reflection and member checking used during the data generation stage and data transcription processes, respectively. Also, audio data generated in the interviews was transcribed verbatim to ensure accuracy of participants’ response before developing themes. Trustworthiness is discussed next.

5.11.1. Trustworthiness

Trustworthiness is an element of rigor; it is a measure of whether the findings of a research study can be relied on by readers. It speaks to the processes followed in gathering data or information. Shenton (2004) suggests that trustworthiness in qualitative research can be ensured if appropriate research methodology is applied. As this study is a qualitative case study, I had considered the entire research design to ensure fitness of purpose. Using participants' personal reflections at the data generation stages (especially during the interview) was an important means of ensuring trustworthiness. In addition at the focus group interview participants could restate what they had previously stated, just to be sure that they meant what they had said. The interview questions were open ended in order not to impose opinions on the participants.

One of the key steps taken to ensure trustworthiness is known as 'member checking'. Creswell and Miller (2000) suggest that member checking is related to participant reflection, and "consists of taking data and interpretations back to the participants in the study so that they can confirm the credibility of the information and narrative account. A popular strategy is to convene a focus group of participants to review the findings, or have the participants view the raw data and comment on their accuracy" (p. 127). For this study, member checking was applied in phases 2 to 4 of data generation. Participants were asked to confirm whether what they said during the interview and focus group interview were what they had meant to say. In some cases, those who felt they had made errors in their responses during the individual or focus group interview or who were simply unsure of what they said, were given the opportunity to explain further what they meant. The essence of member checking is therefore to ensure participants can express their views accurately on the phenomenon being explored, and to avoid misinterpretation by the researcher.

5.11.2. Ensuring the validity of the research

Validity in qualitative research refers the overall authenticity of the research. Unlike rigor, validity speaks to the entire research report rather than merely the process of gathering information in the research. Creswell and Miller (2000) propose that one of the measures of ensuring validity is to include thick or rich descriptions.

Thick description, as described by Creswell and Miller (2000), is a procedure used to describe the setting, the participants, and the themes in a qualitative research. Furthermore, Denzin (1989) as cited in Creswell and Miller (2000) says that "thick descriptions are deep, dense, detailed accounts" (p. 128). Creswell and Miller (2000) further add that thick description speaks to the confidence that the readers feel; as if they had "experienced, or could experience, the events being described in a study. The process of writing using thick description is to provide as much detail as possible" (p. 129). In other words, thick description is the ability of the research to connect with every reader of the research report in the simplest and most comprehensible language. This procedure influenced my study at each step I took in describing the entire study.

5.11.3. Credibility

According to Merriam (1998) credibility deals with how aligned the findings of a study are with reality. To ensure the credibility of the findings of this study I used multiple data generation methods, engaged in member checking of interview transcripts and I triangulated data so obtained. Cohen et al. (2018) add that a study incorporating two or more methods of data collection displays triangulation. To further enhance the credibility of this study I had regular meeting with my supervisor – especially during data analysis to seek consensus and clarify misconceptions. I also shared my analysis during the Advanced Academic Development Leadership Program (AADLP) Ph.D. cohort sessions to obtain critique and comments from a wider inter university academic community.

5.11.4. Dependability

Dependability is achieved through the researcher detailing the research design and process so that potential researchers can follow a similar framework (Lincoln & Guba, 1985). Accordingly, in reporting this study, I have provided detailed accounts of the context, methods and methodology, sampling strategies and considerations related to analysis.

5.11.5. Triangulation

Triangulation is an important means of ensuring validity. It is done to increase credibility and check dependability, and is accomplished by using information from multiple sources to form themes (Creswell & Miller, 2000, p. 126), which should then contribute to a coherent 'picture'. To prevent bias and improve trustworthiness in this study, data were collected through the Purdue Spatial Visualization Test, two task based activities, collage making, individual interviews and post collage focus group interviews. These data were juxtaposed during analysis to look for convergences and divergences.

5.12 Limitation of this study

This study embraced a case study design and the findings cannot be generalized. To overcome this limitation rich thick descriptions were provided. In such a way the findings may be relevant in similar contexts.

5.13 Conclusion

In this chapter, I have discussed the methodology and process followed in the research. This included a description of the research design and data generation procedures and considered the fitness of data instruments for the purpose of the research. In the next chapter, I present data from the PSVT.

CHAPTER SIX

PRESENTATION OF FINDINGS AND DISCUSSION: RESEARCH QUESTION 1

6.1. Introduction

This chapter presents data in an attempt to answer Research Question 1, which is: What are first year EGD PSTs' level of spatial visualization ability? The Purdue Spatial Visualization Test (PSVT) was used as a benchmark to establish first year EGD PSTs level of spatial visualization ability. Spatial skills include the ability to visualize mental rotations of objects, the ability to understand how objects appear in different positions, the ability to conceptualize how objects relate to each other in space and the ability to understand objects in 3-D space (Sutton & Williams, 2008, p. 115). This means that mental rotation ability requires students to mentally transform or rotate two- or three-dimensional (2-D or 3-D) objects in whichever direction is indicated, through spatial visualization. The PSVT was described extensively in Section 5.7.1. and is given in Appendix C6. To recap, the test has are three sections, which involve the respondent mentally rotating an object once, twice or thrice, respectively. As mentioned previously in Chapter 5, the PSVT was taken by 41 first year EGD PSTs (16 males and 25 females).

The remainder of this chapter is organized as follows. I first present a grid with the composite results of the PSVT test followed by a discussion of the test items results involving one, two and three for rotations of an object, thereafter I use the literature to support the discussion. The chapter ends with a conclusion.

6.2. PSVT Test Results

Table 6.1, on the next page, is a composite grid which reflects performance for both males and females first year PSTs EGD in the three sections of the PSVT, involving, respectively, one, two and three rotations). In keeping with the university policy the pass mark is 50%; this means for the three sections the pass marks were 3, 8 and 4, respectively, and the overall pass mark out of 30 is 15.

Table 6.1: First year EGD PSTs' performance on three components of rotation

Participant (P)	One rotation: question 1-6: out of 6 marks	Two rotations: question 7-22:out of 16 marks	Three rotations: question 23-30:out of 8 marks	Total marks out of 30
1	1	3	0	4
2	2	2	1	5
3	2	2	1	5
4	1	2	3	6
5	1	4	1	6
6	0	5	2	7
7	4	2	1	7
8	3	4	1	8
9	1	5	2	8
10	3	3	2	8
11	4	2	2	8
12	1	6	1	8
13	1	5	2	8
14	3	3	2	8
15	2	2	4	8
16	2	5	2	9
17	1	4	4	9
18	4	3	2	9
19	4	4	2	10
20	2	4	4	10
21	3	4	3	10
22	5	4	1	10
23	3	5	2	10
24	5	4	2	11
25	5	6	0	11
26	5	3	3	11
27	5	4	2	11
28	4	6	2	12
29	5	6	1	12
30	6	3	3	12
31	4	4	4	12
32	6	7	0	13
33	4	6	3	13
34	3	9	2	14
35	4	6	4	14
36	**5**	**7**	**3**	**15**
37	**6**	**8**	**2**	**16**
38	**6**	**8**	**2**	**16**
39	**5**	**10**	**3**	**18**
40	**6**	**9**	**5**	**20**
41	**6**	**13**	**4**	**23**
Total pass	28	7	7	6
Percentage	**68%**	**17%**	**17%**	**15%**
Total fail	13	34	34	35
Percentage	**32%**	**83%**	**83%**	**85%**

Results for One rotation:

As can be seen in Table 6.1, a total of 28 (68%) first year EGD PSTs obtained at least the pass mark of 50% for this section of the test, that is three or more correct answers for questions 1-6 of the PSVT test. By implication 13 first year EGD PSTs (more than a quarter) are lacking, or rather have not as yet developed, foundational spatial visualization skills. Seven of the first year EGD PSTs got only one correct answer and one scored zero on this section. These results are startling, if not alarming, as these first year EGD PST have studied EGD at high school from Grades 10-12, in which they ought to have been exposed to activities that activated their spatial visualization skills. The scores obtained are reflective of first year EGD PSTs spatial ability.

Results for Two rotations:

Questions 7-22 of the PSVT test entailed mentally rotating the object twice. Only seven first year EGD PSTs (17%) managed to obtain a score of 50% and above (i.e. eight correct responses for this section of the test). Well over three-quarters of the first year EGD PSTs (83%) were unable to mentally rotate the object twice, yet again revealing the poor spatial visualization ability among first year EGD PSTs who have already spent three years studying EGD at high school.

Results for Three rotations:

As can be seen from Table 6.1, only seven first year EGD PSTs (17%) obtained more than four (50%) correct responses to questions 23-30, which entailed mentally rotating the object thrice. In results similar to those for the second section, 34 first year EGD PSTs (83%) were unable to mentally rotate the object thrice.

The results above indicate that majority of first year EGD PSTs (68%) can visualize 3-D objects if they rotated only once. Thus, it can be inferred that as the number of rotations increases these first year EGD PSTs found it more difficult to mentally visualize the rotations. This finding provides some insight into first year EGD PSTs spatial visualization ability, or lack thereof, as they embark on their training to become teachers of EGD and begin to engage with assembly drawings (AD) in greater detail. In the first two chapters, spatial visualization ability was clarified as a predictor of success in many technology-related fields, such as engineering and EGD. For engineering students, visualization skills are extremely important for understanding fundamental concepts of technical drawing or engineering graphics design

(Bertoline, Wiebe, Miller & Mohler, 2002). Therefore, the results above indicate that first year EGD PSTs are highly likely to find AD difficult because they entering the EGD teacher training programme with poor spatial visualization skills.

The above finding requires a response to the following question: what strategies do individuals use to mentally rotate 3-D objects? One view is that of Kozhevnikov, Hegarty, and Mayer (2002) and Kozhevnikov, Motes and Hegarty (2007), who contend that the difference between those with good and poor performance on mental rotation tasks lies in the type of information that good and bad rotators include as visual clues. They indicate that good rotators construct schematic spatial representations of the figures, which include metric information about their shapes but not visual details. By contrast, poor rotators construct detailed representations of these figures that include both metric shape information and distinct visual cues. A second explanation from Just and Carpenter (1985) indicates that the difference lies in the efficiency of the rotator. They modelled individual differences in strategies used by high and low spatial ability individuals (high- and low-spatials) to perform tasks such as cube comparison and mental rotation. They found that high-spatials were more efficient at the tasks. Just and Carpenter (1985) account for this when they say "high-spatial subjects use a more economical code to represent the figure that permits faster execution of the rotation and comparison" (p. 158). A different, but not incompatible, explanation of individual differences in mental rotation is that high-spatial and low-spatial individuals may use different information processing strategies to perform the rotation process. For example, one explanation of individual differences in spatial thinking is that individuals with high spatial ability have more spatial working memory resources than low spatial individuals (Miyake & Shah, 1999). Because of their smaller spatial working memory capacities, low-spatials might be limited to representing or processing only a part of the object at a time, thus affecting their strategy of mental rotation. For example in the previous study (Just & Carpenter, 1985), low-spatials reported that their mental image fell apart while they were rotating it. In summary, poor performance in mental rotation by low spatial individuals might be a consequence of the amount of irrelevant visual detail that they encode in their representations, in the use of piecemeal processes as a result of limited working memory capacity, or both. In other words, high- and low-spatials might differ in default data structures (schematic versus detailed mental representations), in algorithms that process those data structures (holistic or piecemeal rotation strategies), or both (Kozhevnikov et al., 2007).

In performing the rotations in the PSVT test, first year EGD PSTs needed to utilize two perceptual and cognitive processes. First, PSTs were required to represent a three dimensional object onto a two dimensional plane surface through multiple-view drawings. The second entails them to create three dimensional perspectives by working from the two dimensional representation of the object (Davies, 1973; Olkun, 2003). Both of these categories of learning constitute an integral part of the engineering graphics curriculum requiring a high level of spatial ability. In the assembly drawing lessons, the six best performing first year EGD PSTs (indicated in the shaded cells and in bold in Table 6.1) were requested by the lecturer to assist fellow first year EGD PSTs because their performances were better. The intention was to engage first year EGD PSTs by promoting socialization in the classroom and to enable students to work at their own pace or within their ZPD, as suggested by Vygotsky (in Chapter 4 of the study). Further, Moyer, Bolyard, and Spikell (2001) as well as Rafi and Khairulanuar (2009) studies indicate that spatial visual ability is dependent on amendable training.

6.3. PSVT Test Results- according to gender

As indicated in Section3.2.3. differences between the spatial abilities of males and females have been reported. Accordingly, the results from the PSVT were then analysed by gender, as shown in Table 6.2. The table shows the performance of males and females first year EGD PSTs on tasks where the 3-D object is rotated once, twice and thrice.

Table 6.2. Performance of PSTs in PSVT according to gender for each section of the test

Gender	**Number passed one rotation (Q1-6)**	**Number passed two rotations (Q7-22)**	**Number passed three rotations(Q 23-30)**
Male n = 16	11	2	3
Female n = 25	17	4	4

As indicated in the table that there were more females (25) enrolled to train as EGD PSTs than males (16). This means that more girls are enrolling in technology related subjects in high schools and subsequently choosing to pursue careers that embrace this technology. This finding differs from those of Slabbert (2014) and Mutekwei (2012), which found that boys have historically dominated technology related subjects both at schools and higher education institutions.

As can be seen in the table, with one rotation, 11 (69 %) of the males and 17 (68%) of the females performed above 50%. When the object was rotated twice, two males (12.5%) and four females (16%) obtained more than 50%. With three rotations, three males (19%) and four (16%) female obtained above 50%.

These results indicate very little difference between the performance of male and female for one or two rotations. This finding seems to concur with those from recent studies, which suggest that gender differences in cognitive tasks are getting smaller in recent years (Hyde, 2005; Roberts & Bell, 2000; Kang, David, Jean, & Jan, 2004; Sanz de Acedo Lizarraga & Ganuza, 2003).

In the third section of the test, once they had to mentally rotate the 3-D objects thrice both first year male and female EGD PSTs performed poorly. First male EGD PSTs performed slightly better than females, with 19% as opposed to 16% achieving the pass mark, indicating more males meet this standard of skills. Research focusing on mental rotation ability provides consistent evidence for gender differences that favour males (e.g., Linn & Petersen 1985; Voyer et al., 1995). Literature reviewed suggests at least five distinguishable factors that may explain the cause and the extent of these gender differences; namely, biological, strategic, experiential, affective, and test administration factors in the study.

Biological differences between females and males may contribute to gender differences in mental rotation ability. For example, Jordan et al. (2002) and Koscik et al. (2009) have attributed the observed gender differences to functional and morphological differences in the brains of males and females. Other researchers indicated that differences in performance on mental rotation tasks can be attributed to hormonal differences (Hausmann & Gunturkun, 2000) or genetic differences (Boles 1980; Harris 1978; Thomas & Kail 1991). The results of the meta-analysis by Linn and Petersen (1985) indicated that gender differences are related to the unique processes of biological development for each sex, and Geiser et al. (2008) supported their findings. Others have further suggested that biological sex differences lead to gender differences in cognitive processing and adopting a certain problem-solving strategy for metal rotation tasks (Geiser et al. 2008 Guay, 1976; Jordan et al., 2002; Thomsen et al., 2000). For example, males and females adopt different mental strategies to evaluate response options in each item (Hirnstein et al., 2009). Also, different strategies may be used by each gender when guessing plausible correct responses (Voyer & Saunders, 2004). As a result, males may perform better than females on mental rotation tasks.

Alternatively, the gender differences in mental rotation ability may be attributed to the amount of previous spatial experiences an individual has had. In other words, mental rotation ability can be fostered through activities involving spatial tasks (Feng et al. 2007; Ginn & Pickens, 2005). Researchers found that some activities related to spatial tasks may be more prevalent among boys than girls, such as playing computer or video games (Cherney 2008; Feng et al., 2007; Quaiser-Pohl et al., 2006), playing certain types of sports (Ginn & Pickens, 2005), or playing with building toys, such as Lego or blocks (Deno, 1995). These activities provide boys with more spatial experiences than girls, which may contribute to boys' superiority on mental rotation tasks.

Recent studies reported that an individual's affective state can also influence his or her performance on spatial tasks. This could be due to his or her level of confidence in solving of spatial tasks (Cooke-Simpson & Voyer, 2007). Other studies showed that when an individual's psychological state is shaped by common gender beliefs (Cooke-Simpson & Voyer, 2007; Moè, 2009; Moè & Pazzaglia, 2006) and/or gender stereotypes (Ortner & Sieverding, 2008; Sharps et al., 1994), the individual's performance on spatial tasks is affected. For example, gender differences in performance on mental rotation tasks increased when students were primed to believe that males had an advantage over females in successfully completing mental rotation tasks (Ortner & Sieverding, 2008).

6.4 Conclusion

This chapter presented analysis of the data from the PSVT and discussion of the results. The test results revealed that among the first year EGD PSTs, the level of spatial visualization ability is very low. Their mental rotational skill of 3-D objects was not firmly grounded, even after three years of studying EGD at high school. Their performance became worse as the test questions changed from simple to complex (1 rotation to 3 rotations). These results indicate very little difference between the performance of first year male and female EGD PSTs for one or two rotations, however males performed slightly better than females when the object was rotated thrice. This lack of skill would be expected to affect the first year EGD PSTs performance in assembly drawing. The challenges they experience in this regard are addressed in the next chapter as the second research question.

CHAPTER SEVEN

PRESENTATION OF DATA, ANALYSIS AND DISCUSSION: RESEARCH QUESTION 2

7.1. Introduction

Assembly drawings are essentially the transmission of instructions; to be able to read, interpret and understand these AD instructions requires good spatial visual skills. The data obtained from the PSVT illuminated that first year EGD PST have only partially developed spatial visual skills from their high school exposure to EGD in Grades 10 to 12. Further insight was needed on the challenges first year EDG PSTs encounter when they read and interpret AD. This is addressed in Research Question 2: How do first year EGD PSTs read and interpret AD? To generate data in response to this question, they were given a think-aloud task. In this chapter I present data from think-aloud task one, the individual interviews conducted with first year EGD PSTs (as described in Section 5.7.3).

The remainder of this chapter is as follows. First, I describe think aloud task one in terms of what first year EGD PST were expected to read and interpret from the task. Next, I present their performance in each aspect of task one. Thereafter I provide a diagnosis of their performance in terms of areas of challenges they encountered during the think aloud task. As described in Chapter 5, in order to provide a rich description of the challenges first year EGD PSTs encounter when they read and interpret AD, the data was analysed inductively and themes were derived. Direct quotations from first year EGD PSTs' responses are presented in verification of the emerging themes. The literature review and associated theoretical constructs are presented in support of the emerging themes. Finally, a summary of the chapter conclusions is given.

7.2. Think aloud task one

Think aloud task (see appendix C1) was undertaken individually as a paper and pencil exercise by 21 first year EGD PSTs (11females and 10 males). As mentioned in Chapter 5 the think-aloud tasks were video recorded. The duration of the task was one hour. The task comprised four sections A to D, which carried the following respective mark allocations 49 (A); 21(B); 15(C) and 13 (D), with a total of 98 marks. Section A consists of five parts, section B has three parts, and section C has four, while section D is the general assembly of all parts and centre lines. I describe next what information first year EGD PSTs needed to possess in order to be able to read and interpret the AD.

Section A is made up of parts 1, 4, 5, 7 and 8, which are the larger parts of the complete mechanical assembly drawing. PSTs were expected to:

- Identify the front view of these bigger components, 1, 4, 5, 7 and 8, using the two given views of each part and with the guidance of exploded isometric view.
- Recall SANS code of practice on how principle planes work.
- Identify all parts, use spatial visualization skills to mentally manipulate parts to see how they fit together and neatly assembly them.
- Draw all parts in 3rd angle orthographic projection as per given dimensions.
- Using the given scale, be able to measure accurately and draw as required.

Section B comprises parts 2, 3 and 6, which are the small parts of the complete mechanical assembly drawing. PSTs were expected to:

- Identify the small parts as per numbering.
- Identify the front view of each part with the aid of the exploded isometric view.
- Mentally rotate and visualize how and where parts 2, 3 and 6 could be assembled onto the combination of parts 3, 5, 6 and 8.
- Through drawing add small parts to large parts by following principle of 3rd angle orthographic projection as per SANS 10111 code of practice.
- Use all details of dimensions given and measure to appropriate accurately.

Section C is made up of part 9, 10, 11 and 12. It is a construction of bolt, nut and washer in front view as part of the complete mechanical assembly drawing. PSTs were expected to:

- Identify and differentiate between the bolt, nut and washer using all detailed views given and identify views of each part.
- Established how many sides of the bolts and nut must be included in the front view.
- Recall the construction of the bolt and nut using the table of standard hexagonal metric bolt and nut sizes.
- Measure accurately as per given dimensions and draw all parts in 3rd angle orthographic projection according to SANS 10111 code of practice.

Section D is the last part, which is the general assembly of all parts and centre lines positioning as part of the complete mechanical assembly drawing. PSTs were expected to:

- General assembly of all parts accurately.
- Correct use of line types.
- Draw all required centre lines as per each part in keeping with the SANS code of practice.

Processes to be followed

- The details in the title block should be perceived in order to gain the context in which the drawing is presented. The title box provides information on the following aspects: projection details, scale used in the drawings, name of the components or assembly, mass, and units used in the drawing.
- The notes in the drawing (outside the title block).
- The bill of materials (BOM). The bill of materials is a list of the components and the quantity of each that make up the general assembly. The BOM is tabulated on the task.
- Interpret the drawing to understand the views provided.
- Identify all parts, in order to differentiate the parts and their dimensions.
- Use spatial visualization skills to mentally manipulate parts to visualize all sides of the components and then visualize how they would fit together in order to be assembled.
- Use the sections and details as a starting point.
- Understand the difference between the visible lines, hidden lines and phantom lines.
- Identify and understand the projections, sections and details.
- View the drawing itself, disregarding the dimensions, and try to visualize how and what the assembly would looks in 3-D.
- Use the dimensions in the drawing to be able to grasp the size of the component or assembly; using a ruler to gauge the size.
- Recall SANS code of practice on how principal planes work.
- Use the BOM to try to find the components in the drawing in order to understand the role each component plays.
- Identify notes that have a leader (arrow) to the assembly; this information is usually vital to the assembly and its functionality.
- Draw all parts in 3rd angle orthographic projection as per given dimensions.
- Use the given scale to be able to measure accurately and draw as required.

- Plan the layout of the paper by identifying the position of each view as per question requirements following principle of orthographic projection e.g. 3rd angle.

7.3. First year EGD PSTs overall performance in think aloud task one

Table 7.1. below reflects the marks first year that the EGD PSTs obtained when they read and interpreted the AD in think aloud task one.

As can be seen from Table 7.1 below all first year EGD PSTs obtained a score below 50% in task one. This means that in terms of the university pass requirements all first year EGD PSTs failed think aloud task one. Thus, it could be inferred that they are not adept at reading and interpreting ADs. Specifically, all 21 first year EGD PSTs obtained some sort of score for section A and D, only one first year EGD PST obtained a score for section B, but not one of them scored above zero for section C. Because this was a think aloud task, it was possible to gain insight into the difficulties encountered by the EGD PSTs. In the next section, the common errors made by first year EGD PST when they read and interpret AD are highlighted thereafter evidence is provided for how first year EGD PSTs read and interpret AD.

Table 7.1: Think aloud Task one results

Student No.	**Section A: drawing large sectional FV part 1,4,5,7 &8 = 49 marks**	**Section B: drawing small sectional FV part 2,3 &6 = 21 marks**	**Section C: construction of bolt & nut and washer in FV part 9,10, 11 &12 = 15 marks**	**Section D:general assembly of all parts and centre lines = 13 marks**	**Total mark out of 98**
PST 1	6	0	0	1	7
PST 2	4	0	0	3	8
PST 3	6	0	0	2	8
PST 4	4	0	0	4	8
PST 5	7.5	0	0	2	9.5
PST 6	8.5	0	0	2	10.5
PST 7	7	0	0	4	11
PST 8	9	0	0	2	11
PST 9	8	0	0	3	11
PST 10	7	0	0	4	11
PST 11	9.5	0	0	2	11.5
PST 12	9.5	0	0	3	12.5
PST 13	9.5	0	0	3	12.5
PST 14	9.5	0	0	4	13.5
PST 15	9.5	0	0	4	13.5
PST 16	8.5	2	0	4	14.5
PST 17	10	0	0	5	15
PST 18	10.5	0	0	5	15.5
PST 19	10.5	0	0	5	15.5
PST 20	12.5	0	0	5	17.5
PST 21	16.5	0	0	5	21.5

7.4. Diagnosis of challenges encountered when reading and interpreting AD

Table 7.2 below captures the common challenges first year EGD PST s encounter when they read and interpreted AD during think aloud task one.

Table 7.2 Areas first year EGD PSTs encountered challenges when they read and interpreted AD

Challenges first year EGD PSTs encounter when they read and interpret AD	Number of first year EGD PSTs who experience the challenge
Inability to read and interpret information in title block	19
Inability to differentiate orthographic and isometric projection and visualize the different views	18
Inability to visualize, see spatial relationships between objects and rotate objects	21
Inability to measure accurately and apply SANS code of practice	16
Inability to assemble and recognize lines	16

From the 7.2. it is visible that first year EGD PSTs encountered difficulty in interpreting information contained in the title block, could not differentiate between orthographic and isometric projections, were unable to visual spatial relationships between objects or rotate objects, could not measure accurately nor apply the SANS code of practice and were unable to assemble and reorganize lines. Each of these challenges are discussed in greater detail in section 7.5.

7.5. Presentation of data and analysis

Data that emerged from the analysis of video recordings of think-aloud task one and the interviews with first EGD PSTs are presented next. First year EGD PSTs encounter five major challenges when they attempt to read and interpret ADs as shown in think aloud task one. These five challenges are elaborated upon next.

7.5.1. (In) ability to read and interpret information in the title block

Nineteen of out 21 first year EGD PSTs did not use all the visual and textual information in the title block when they attempted to read and interpret the AD in think aloud task one. The information contained in the title block included the title, a description of what the AD depicts, the type of projection, the drafting standard used, the scale of drawing and the dimensions. The excerpts below from the semi-structured interviews indicate how first year EGD PSTs used the information from the title block as well as their inability to read and interpret visual information:

"*I have forgotten, how to make sense of the given information, I remember my high school teacher saying that this is the starting point, but I don't know how or why, I tried looking around to see what other students were doing but it did not help, it is easier to read words rather diagrams*" P4 (Semi-structured Interview)

"I prefer task with words rather than diagrams, I have no visual skills, I learn by reading" P10 (Semi-structured interview)

"It is given that the isometric exploded drawing of the parts can be assembled, scale is 1: 1, it is in the third angle, but sometime, when you read these thing you just read them, the words remain foreign, you don't get any clue of how or where or when to use this information, these terms are so hard to understand and remember" P1 (Semi-structured interview)

The data from the recorded observation of the think-aloud task verifies the above view:

"*I got the title so I can recognize the drawing, that one mark, but what to do with the other information, I just get so stressed when I see all these drawings, where do I use it and how. I wish paid more attention at school, I barely passed EGD, it's so difficult to understand and read the diagrams*" P7 (Think aloud task)

From the above excerpts, it is clear that first year EGD PSTs encountered difficulty in reading and interpreting information from the title block. They were unable to recompose the information to make sense of it (*what to do with the other information, where do I use it and how).* In other words first year EGD PSTs were unable to decode, interpret, and evaluate text in the title block and use it to make sense of the accompanying visual text. Furthermore, first year EGD PSTs were unable to understand the concepts used in the title block and visual text (*the words remain foreign hard to understand and remember).* The aforementioned finding resonates with that of Tumkor et al. (2013) who noted students' difficulties in understanding concepts used in engineering graphic and design.

The recordings also highlighted that first year EGD PSTs' inability to process the information and understand the terms used in the title block causes them to be anxious (*just get so stressed when I see all these drawings).* The anxiety first year EGD PSTs encountered affected their ability to see the link to the visual text *(where do I use it and how)*. In a subdued way, the above findings bring to the fore first year EGD PSTs preference for written text (that is their preferred way of learning) (*is easier to read words rather diagrams)* and their anxiety about visual information. The above finding reinforces those of Azodo (2016) and Akash and Alias (2010), who found that first year engineering students have difficulties in reading and interpreting visual information and prefer tasks with written text.

Thus I make the case that the above excerpts also infers something about the first year EGD PSTs preferred learning style (*prefer text*) as well as the kind of intervention that needs to be provided for them in order to scaffold their learning and harness their visual skills. I am aware that a "one size fits all" teaching strategy cannot suit the diversity of learning styles among first year EGD PSTs, but, nevertheless, if I adapt how I teach AD and I am flexible in my teaching approach then it is possible for first year EGD PSTs to read and interpret AD.

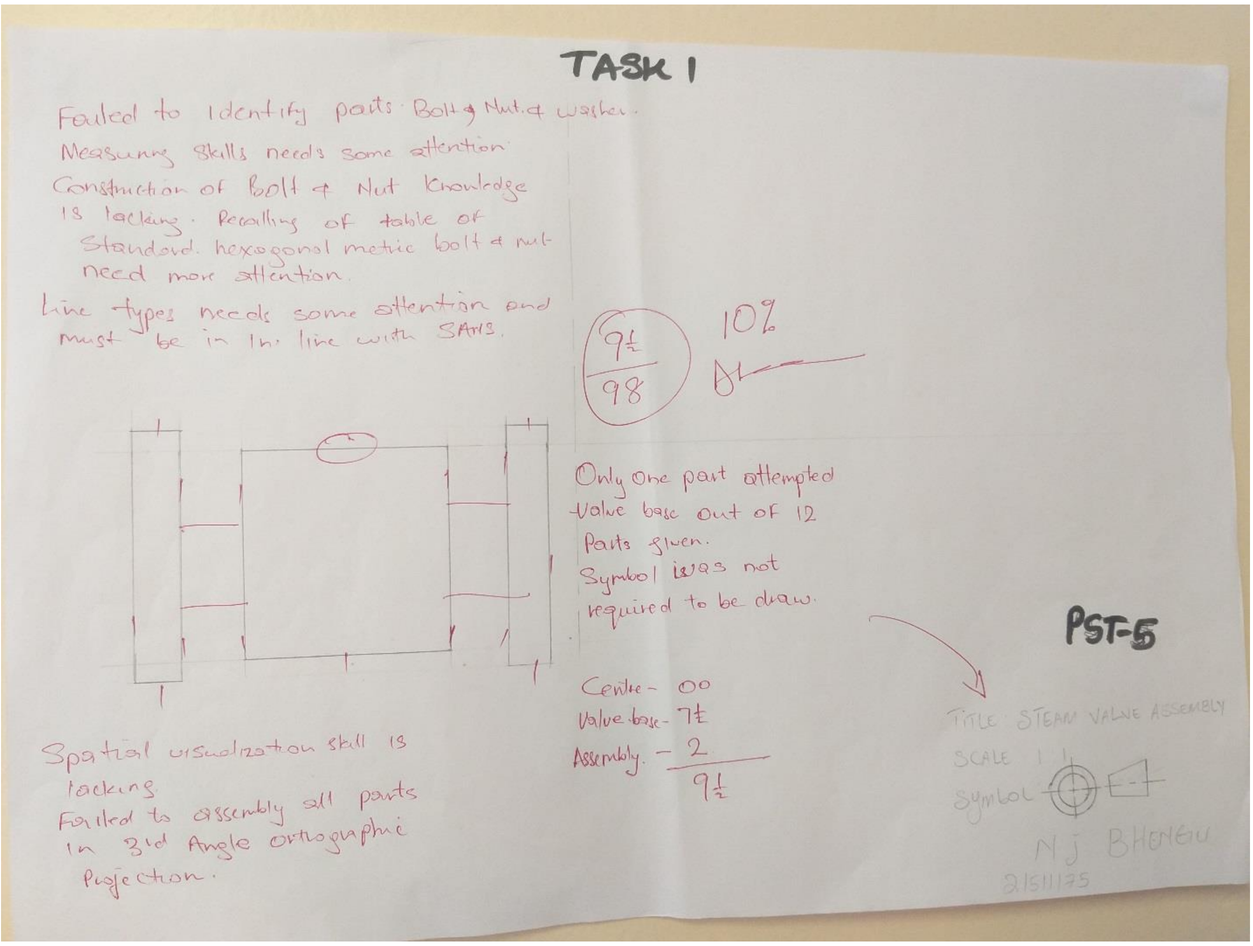


Figure7.1. First year EGD PSTs' response to think aloud task one-showing inability to read information from the title block

7.5.2. (In) ability to differentiate orthographic and isometric projection and visualize the different views

Eighteen first year EGD PSTs encountered difficulties in differentiating between the orthographic and isometric projections, as well as understanding the structure of 3-D objects from different views, as is evident in the excerpts below from the interviews.

"I find it very difficult to imagine drawings in 3-D, I try so hard, if someone could train me how to do this I will learn, what must I do first, I will go with my gut feeling, I don't have a strategy to solve this" P3 (semi-structured interview)

"I lack imagination, I can't see things mentally, I need to see an object physically to understand its structure in different views, I will try and see what works, it's frustrating not knowing for sure" P14 (Semi-structured interview)

Similar views were expressed during the think-aloud task:

"How, how do I imagine a drawing in 2-D to its 3-D form, and how must I draw from a certain angle when I can't imagine the shape, I need to know what steps I must follow, I didn't learn this at school, this is # F…$...(breaks his pencil and swears)" P15 (Think aloud task)

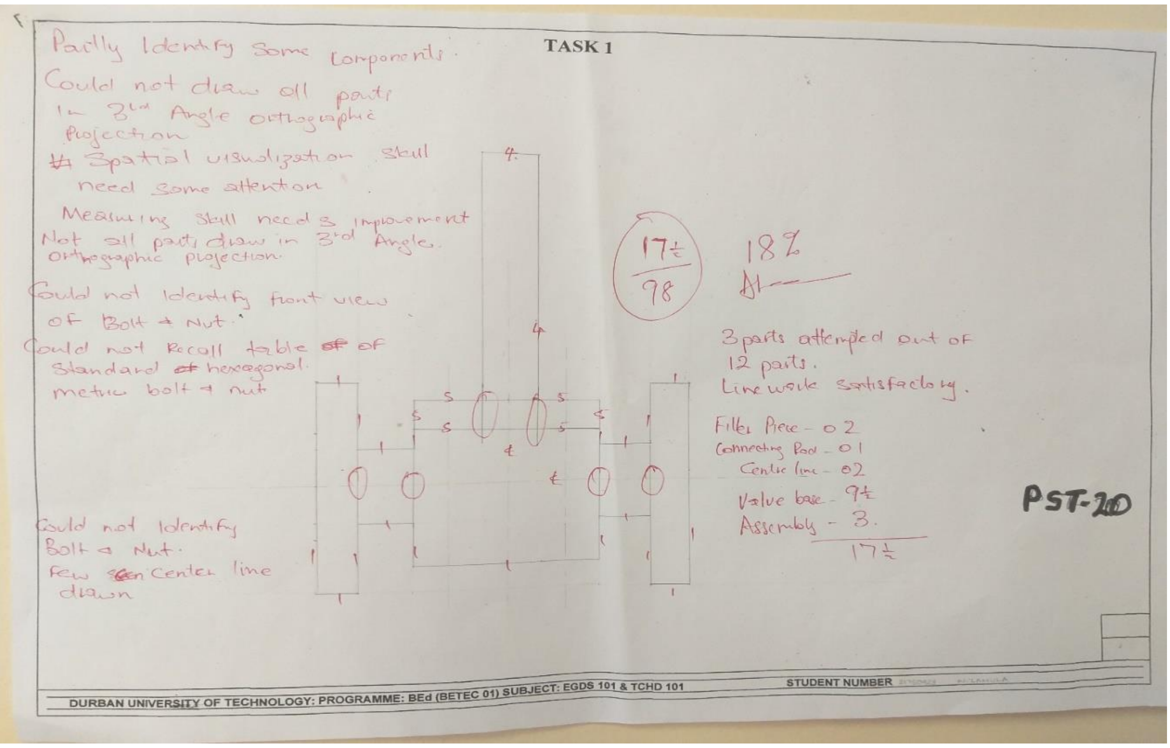


Figure 7.2. First year EGD PSTs' response to task one- showing inability to visualise different views

The above excerpts illuminate three challenges first year EGD PSTs encounter when they read and interpret AD. The first challenge is their lack of familiarity with the nomenclature of EGD, which results in the inability to differentiate between basic concepts such as orthographic and isometric projection, as well as 2-D and 3-D drawings. First year EGD PSTs' inability to understand foundational concepts points to the kind to knowledge base and skill (or lack thereof) they bring with them into the first year EDG teacher-training course. In my opinion, understanding the basic key concepts in EGD is the foundation for all future learning in EGD. Without this, further learning is impeded. Thus, the absence of understanding basic concepts in EGD alludes to the kind of teaching and learning activities that are needed to scaffold their learning and raise their ZPD.

The second challenge is of visualizing images given to them in different views when they attempt to read and interpret AD. Eighteen first year EGD PSTs were unable to visualize or comprehend visual information (*How, how do I imagine)*. Visualization is a way of thinking whereby mental images are formed. This means that for first year EGD PSTs to be able to visualize objects they need to have the ability to imagine objects mentally, in different views. In this regard it is worth noting that Felder and Silverman (1998) asserts that the formation of mental images is dependent on a person's mental schema. Thus, it can be argued that these 18 first year EGD PSTs either do not have or are unable to use their mental schema to visualize and develop the view or image/s of the object in task one.

The third challenge is the lack of a systematic method of processing and analyzing visual information among first year EGD PSTs, as is evident from the excerpts above (*what must I do first, I need to know what steps I must follow)*. Further, first year EGD PSTs confirm that they do not have a problem-solving strategy in place (*I don't have a strategy to solve this)*, and that they use the trial-and-error strategy (*try and see what works)* or they rely on intuition (*my gut feeling)* when they have to read and interpret AD. In my opinion, the lack of a strategy or method to deal with visual information is frustrating to first year EGD PSTs and increases their sense of helplessness when reading and interpreting AD. It further compounds their inability to read the AD. In other words, they are unable to visualize the details, and deconstruct the images while using the projection representation to interpret the AD and respond to the question posed.

The inability among these first year EGD PSTs' of differentiating between orthographic and isometric projection and the different views confirms that they have inadequate visualization skills, which hinders their visualizing process in learning AD. As alluded to earlier, visualization is a quintessential skill for understanding fundamental concepts in engineering drawings, hence I argue that if first year EGD PSTs are unable to visualize, they will not be able to master the remaining content of the module. The above findings resonate with results from studies by Azodo (2016), Ali and Nordin (2012), as well as Garmendia, Guisasola and Sierra (2007), which similarly highlight that first year engineering students encounter difficulties with visualization when engaging with engineering drawings in spite of having studied EGD at school level. Azodo (2016) elaborates that the predominant challenges engineering students encounter in engineering drawing are difficulties of seeing an image in three dimensions, understanding of projection view methodology, producing drawings of professional quality, and reading and interpreting engineering drawings. In a similar vein, the Luzzader and Duff (1986) study shows that most students following elementary graphics courses find it very difficult to visualize an object from two or more views and they lack strategies needed to analyse complex shapes. However, it is worth noting that the Garmendia et al. (2007) study reveals that the inability to visualize could be attributed to the teaching strategy used in most classrooms, which consists of visualization problems followed by the solutions to those problems, without explaining how to solve them or the reasoning needed during the problem-solving process. In the current study, the first year EGD PSTs alluded to the mismatch between their learning style and the teaching strategies they encountered at high school *(could train me*).

7.5.3. (In) ability to visualize, see relationships between objects and rotate objects

As alluded to earlier in Chapter 3 (literature review) the ability to visualize objects and situations in one's mind and see the relationships between objects, as well as the ability to manipulate those images is vital in EGD. Engineers use visualization and spatial reasoning in tasks like the design and documenting of parts to be assembled. All 21 of the first year EGD PSTs struggled to visualize and see spatial relationships between objects and in rotating objects. The excerpts below from the semi-structured interviews, illustrate this point.

"*I can see the one view that is drawn, but I battle to imagine the sides that are not drawn, I also cannot see the relationship between some objects, I am hopeless, I want to quit this course before we get any further and it becomes more difficult, this 2-D /3-D stresses me* " P11(semi-structured interview)

"*I can physically flip an object that is in physically front of me, I cannot mentally flip an object nor can I image the hidden sides of an object or imagine how they fit together, with large objects I can try but the smaller object that is almost impossible, I can't imagine* how to *assemble the small part, it's easier to do it physically*" P17 (semi-structured interview)

*"It is hard to draw from certain angle as I cannot imagine the shape or view required"*P6 (semi-structured interview)

The data from the recorded observations of the think aloud task confirm the same challenges first year EGD PSTs encounter when they read and interpret AD.

"*Oh God how I hate these drawings, it is a disaster, (bangs the table looks around, shakes his head), I also find it hard to see the movement of all these parts in my head. It not so easy to imagine how the parts will fit together"* P4 (Think aloud task)

"I can recognize a washer here, but I am not sure how to rotate this, I see the difference between the bolt and nut now. I am not sure which sides of the bolt and nut to draw in front view to produce 3rd angle as required by the question. I will lose marks in this section, this is hell" P8 (Think aloud task)

The excerpts above illuminate that engineering graphics requires advanced visualization skills as well as the ability to see the relationship between the objects portrayed in the diagram and the ability to mentally rotate objects. The excerpts also show that first year EGD PSTs who lack the aforementioned skills encounter difficulties in imagining or visualizing the objects or views. They are unable to use the visual information in task one to exercise visual discrimination, visual figure ground discrimination, visual sequencing, visual motor processing and (re)organize the information to create an understanding of meaningful patterns. First year EGD PSTs' inability see the relationship between the objects portrayed in the diagram and to mentally rotate objects had a negative impact on their performance in think-aloud task one. It also affected their emotional state. The trauma (*hate drawing, hell, disaster*) as well as the severe challenge first year EGD PSTs encounter when they read and interpret AD (*almost impossible, hopeless*) impedes their ability to form mental imagery and translate such into drawings. In other words, first year EGD PSTs are unable to construct pictorial images of the objects in their mind and translate the images into engineering sketches and multi-view drawings. Further, it contributes to their inability to differentiate between small and large parts. The aforementioned finding pertaining to visual skills, mentally rotating objects and drawing resonates with that from Gorska and Sorby's (2008) study, which highlights that the predominant challenges engineering students encounter in engineering drawing are difficulties in seeing an image in three dimensions and to mentally manipulate objects. In addition, the visual skills needed for small and large objects seem to differ (*with large objects I can try but the smaller object that is almost impossible*). The mental rotation includes both two dimensional and three dimensional objects. First year EGD PSTs' failure to mentally visualize and manipulate objects ties in with results from other international studies (McKim 1980, Luzzader & Duff, 1986; Potter & Merwe, 2003; Potter et al., 2006). In this regard, Riza and Seda, (2017), argue that to be able to draw objects correctly from different views requires an understanding of the relationship between shape and form. Along similar lines, Fenghong and Chikun (2011) contend that engineering students have problems in building the space conception while selecting the correct expression of parts. Nincarean et al. (2013) also explain that a common problem faced by engineering students is visualizing a phenomenon that is difficult view in real life. In other words, models could help nurture the spatial ability of engineering students and help them to visualize things. Spatial ability as argued earlier, in section 3.2 to 3.4., is not a fixed innate quality, as proposed by Piaget (1970) but rather it is malleable in people of all ages, and training generally has a positive and continuous impact on them (Uttal & Cohen, 2012).

Furthermore, Samsudin, Rafi, and Hanif (2011) found that secondary school students performed better at a given orthographic drawing task after they had received spatial visualization training. The authors explained that many studies (Kajiyama, 1996; Olkun, 2003; Rafi & Khairulanuar, 2007; Sorby & Baartmans, 2000; Strong & Smith, 2001) found spatial ability to be a predictor of success in engineering drawing courses.

First year EGD PSTs in this study have poor spatial visual skills; they are not visual learners. These finding allude to the kind of spatial visualization training they require in order to scaffold their learning.

7.5.4. Inability to measure accurately and recall the SANS code of practice

The skill of measuring accurately and applying the SANS code of practice is very poor among 16 of the first year EGD PSTs, as illustrated by the excerpts below:

"It would have been easier, if you were to just draw as you see it on the exploded drawing, but now the problem, is that you have to construct the bolt, you need to know how to construct the nut measurements must be accurate, so it becomes a bit complicated when it comes to that" P2 (semi- structured interview)

"This task is bit difficult and I am not able to remember the … I can see here I am required to do construction of bolt and nut. Eish I cannot remember how to do calculations in order to do the construction of bolt. Don't know where to start now" P5 (semi-structured interview)

The data from the think-aloud task confirms the challenge encountered when measuring and applying the SANS code of practice.

"Shucks, do I measure from the edge of the rule or the first marking on it, I always measure from the edge of the ruler but I think this teacher was saying from the first marking on the ruler,(flings his ruler on the desk in frustration) this is confusing, I wish I could quit. I also don't know this SANS code." P19 (Think aloud task).

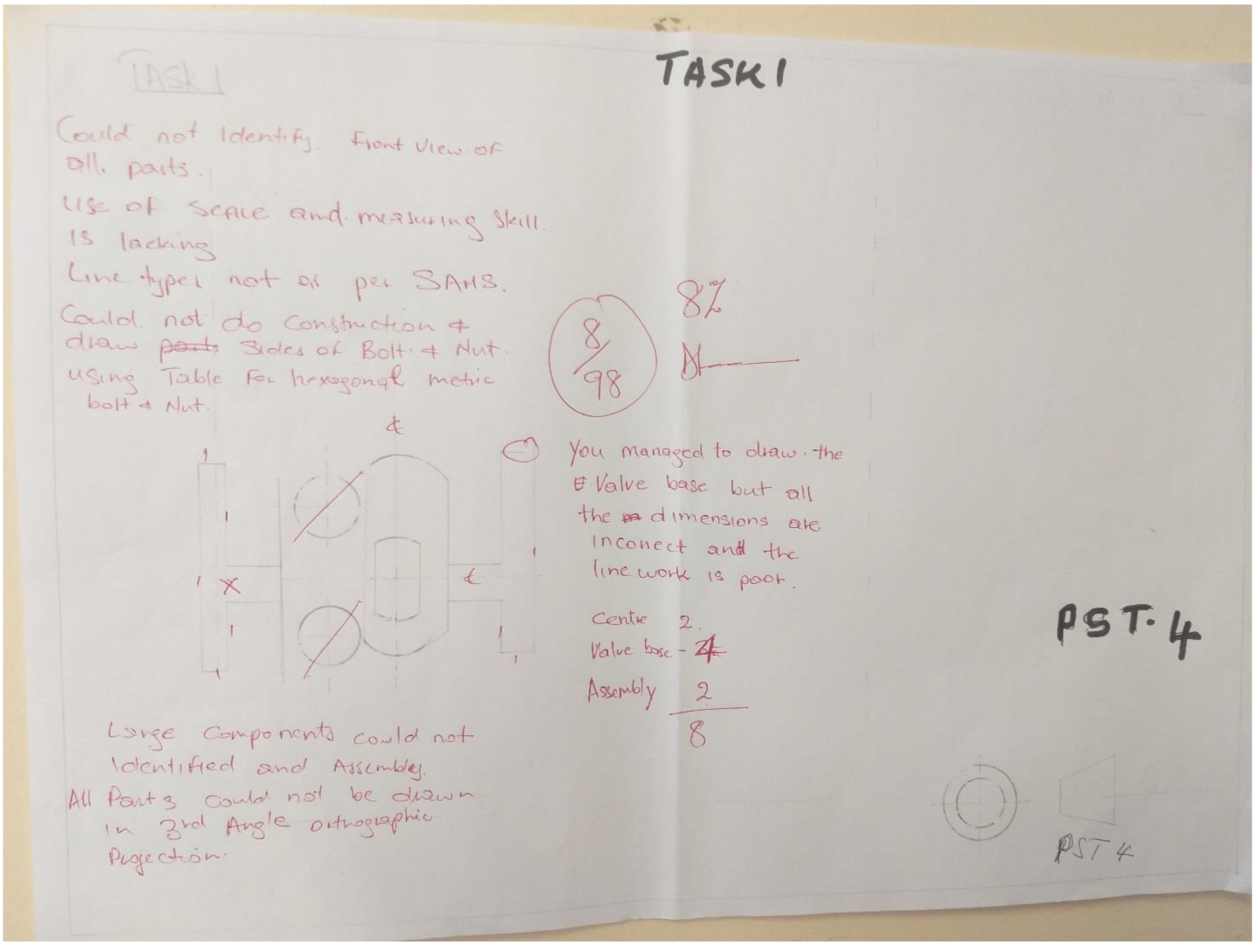


Figure 7.3. First year EGD PSTs response to task one-showing inability to apply SANS code of practice to lines

The excerpts above confirm that first year EGD PSTs encounter difficulties with measurements and recalling the SANS codes. Any engineering drawing depends fundamentally on accurate measurement. The above finding has implications for the kind of teaching strategies and knowledge base that needs to be developed among first year EGD PSTs in order to scaffold their learning with regard to reading and interpreting AD.

7.5.5. (In) ability to assemble parts and draw different lines

Lines in EGD can be construed to have meaning as do letters in written text. Lines enable a person to describe the external as well as the internal features of an object. As each symbolic line in the drawing represents a particular aspect, it is very important that they are drawn in a standardized format. First year EGD PSTs were expected to know lines type given in the SANS code of practice. The excerpts below bring to the fore the challenges that EGD first year PSTs encounter with line work.

"I can see that there are centre lines but I have no idea where to draw the other lines. Physical components can help to see this thing…." P1 (semi-structured interview)

A similar view was expressed by other first year EGD PSTs during the think aloud task.

"Drawing centre lines is not that difficult but I need to I identify how many that I must draw such that they are seen as centre line and in correct position in the whole drawing. I might get some mark for these part assembled, but I am worried about my line work, erasing them and starting all over again might take time." P20 (think aloud task)

These excerpts are an indication that teaching should to pay more attention to lines work so that EGD students are able to find the connection between each part of the complete mechanical assembly drawing.

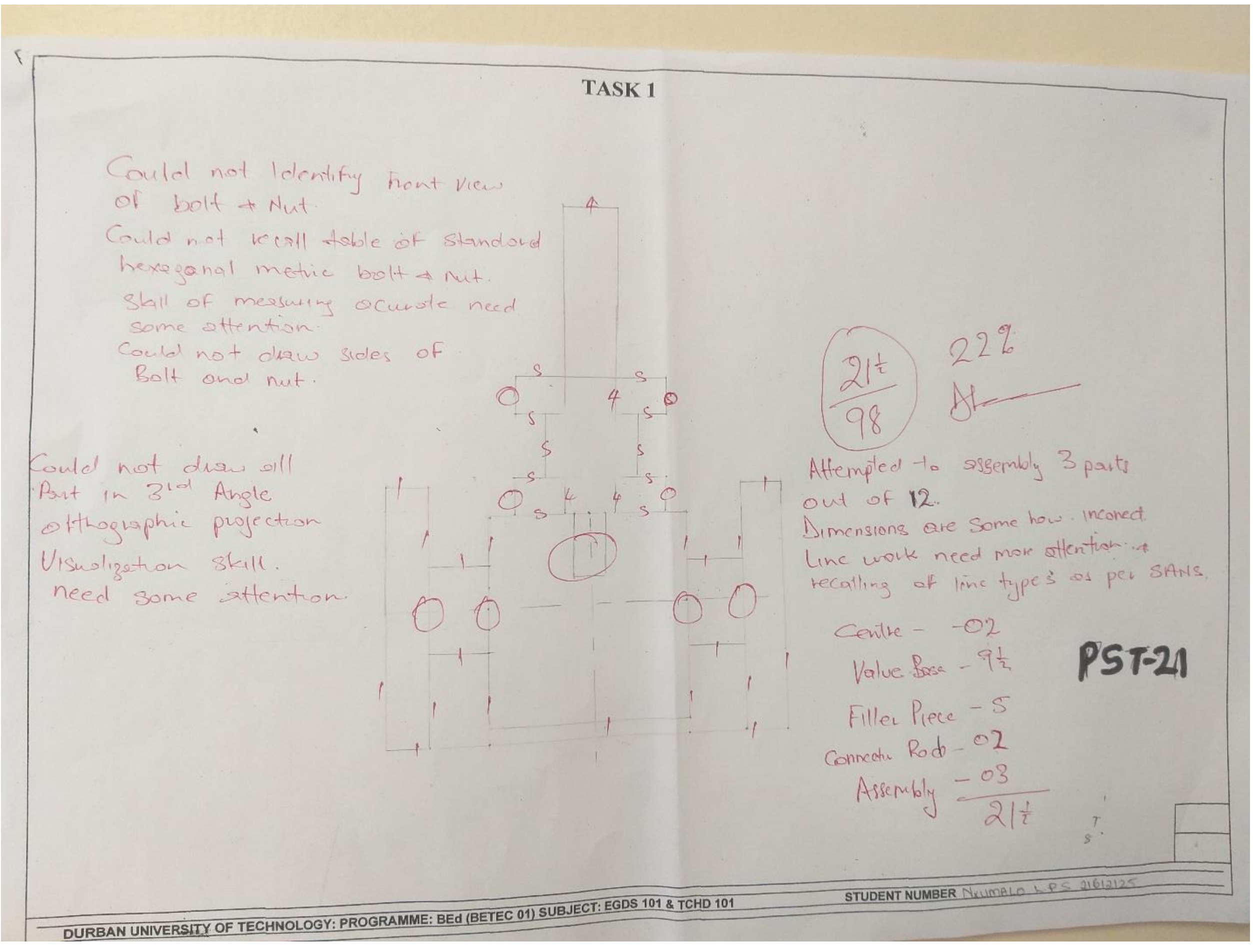


Figure 7.4. First year EGD PSTs response to task one-showing inability to assemble parts

7.6. Conclusion

In this chapter, data from think-aloud task one and the individual interviews was presented in response to Research Question 2, which was: What challenges do first year EGD PSTs encounter when they read and interpret AD? First year EGD PSTs were found to encounter five key challenges when trying to read and interpret AD. These were their inability to:

- read and interpret information in the title block,
- differentiate orthographic and isometric projections and visualize the different, views,
- visualize spatial relationships between objects and mentally rotate objects,
- measure accurately and apply SANS code of practice, and
- assemble lines and recognize their intended meaning.

The challenges encountered by first year EGD PSTs are inextricably linked to their poorly developed visualization skills, which is manifest in their lack of knowledge of how mental images are defined, produced or transformed. As was highlighted in Section 3.2.2., spatial skills, are according to Sorby (2001), are higher-level thinking, reasoning, and creativity skills that are related to spatial abilities such as spatial visualization, mental rotations and spatial perception. The challenges first year EGD PSTs encounter when they attempt to read and interpret AD indicate the kind of teaching and learning strategies that should be used to nurture first year EGD PSTs' spatial visual abilities. I argue that spatial visual ability is not a fixed or innate entity, but rather with proper guidance and training first year EGD PSTs can improve their spatial visual abilities and improve how they read and interpret AD. In other words, expose to different learning experiences can influence how the first year EGD PSTs processes visual or graphic information.

The answers to first research question indicated that the first year EGD PSTs had poorly developed visual spatial skills. In this chapter, there is evidence that these poorly developed skills directly affected the performance of the participants in an assembly drawing exercise. The question then is: Why do they experience such difficulties? Accordingly, in the next chapter, I present data in response to Research Question 3.

CHAPTER EIGHT

PRESENTATION OF DATA, ANALYSIS AND DISCUSSION: RESEARCH QUESTION 3

8.1. Introduction

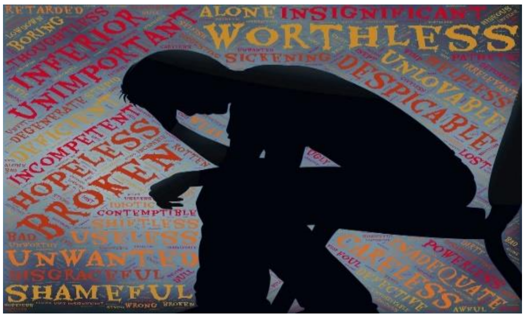
In this chapter, I present data and its analysis in response to Research Question 3, which is: Why do first year EGD PSTs encounter challenges when they read and interpret AD. Data generated through the semi-structured individual interview, the collages and post collage focus group interviews are used to respond to Research Question 3.

As mentioned earlier in Chapter 5, the relevant video recordings were transcribed verbatim and the transcripts were read and re-read several times before data they contained it could be organized into categories and themes. In order to provide a rich description, of why first year EGD PSTs encounter challenges when they read and interpret AD the data was analysed inductively and themes were derived. Direct quotations from first year EGD PSTs' responses in the individual interviews, focus group interviews, references to the collages and concept maps are presented in verification of the emerging themes. The literature review and associated theoretical constructs are presented in support of the emerging themes. The collages and associated concept maps for the four groups are given next. Then four sections show the four broad themes that emerged from the data. Finally, the main conclusions from the chapter are presented.

COLLAGE 1- GROUP A

Playing with stimulating toys

Teachers: Poor teaching method, lack knowledge of subject



Learner: lost, cannot cope with EGD

large class: teacher & learners want to quit cannot cope

Family tension

Discipline at school: no rules

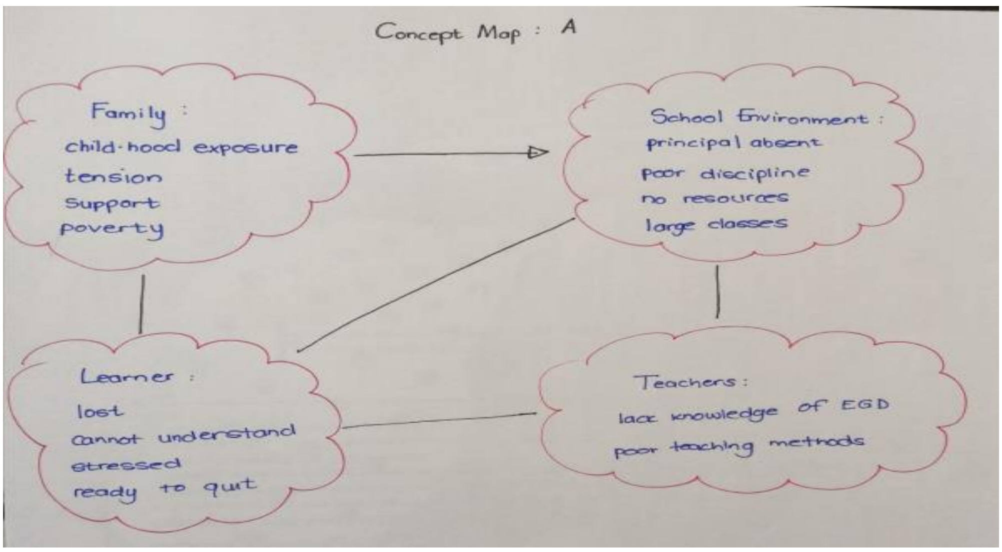


Figure8.1: Group A Collage and concept note

COLLAGE 1- GROUP B

Bad teacher- poor teaching methods Feel Stupid when learning EGD

Resources needed but absent Gangs at school- violence/disruptions

Family pressure **Poverty**

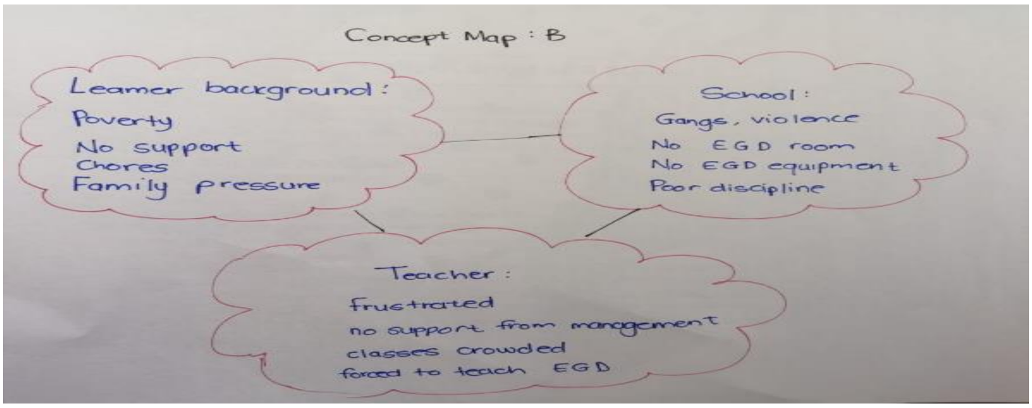
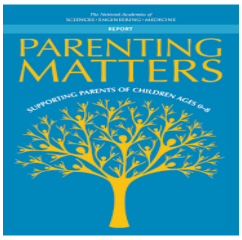


Figure 8.2: Group B collage and concept note

COLLAGE 3- GROUP C



Home:Parents uninvolved

School rules-not follwed

Need competent teachers

Pressure

School culture

Time management

Child headed household

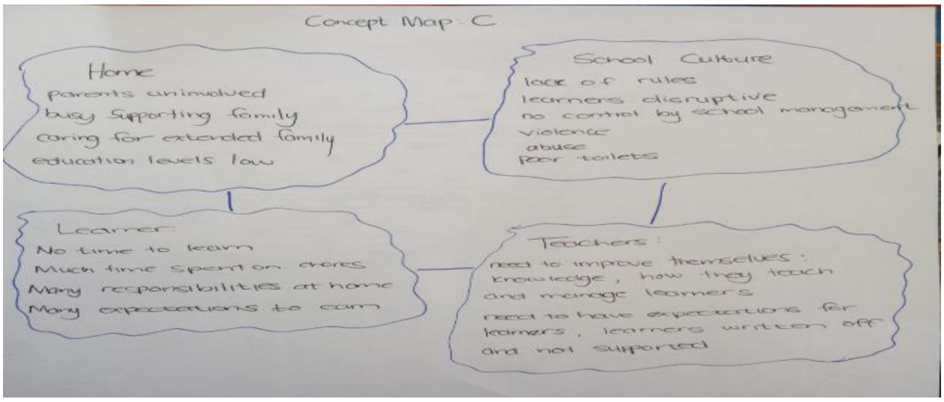


Figure 8.3 Group C collage and concept note

COLLAGE 4- GROUP D

Teacher centerd

school set up

Drug sold and smoked openly

Struggling: cannot ask for help

Poverty : walk to school **Language of EGD is difficult** English medium

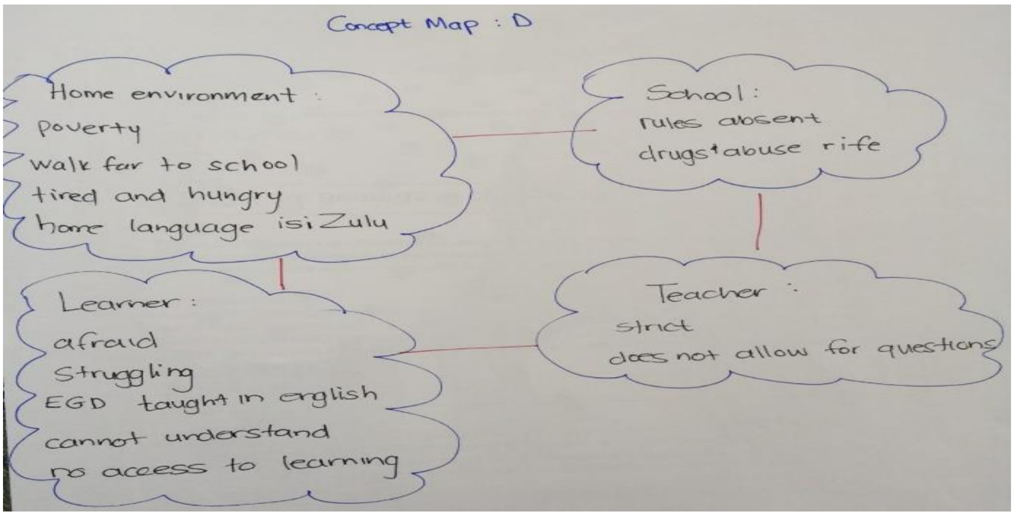


Figure 8.4 Group D collage and concept note

8.2. Presentation of data and analysis

Analysis of data from the collages, individual interviews, concept maps and post collage focus group interviews (FGIs) resulted in the following four broad themes: school challenges, teacher challenges, parent challenges and learner challenges. These challenges arise from the experiences of first year EGD PSTs when they were high school learners.

8.2.1. School Challenges

Three barriers to learning emerged under the theme of school challenges; namely, management and rules, violence, and lack of resources. There three factors are intertwined and intersect in multiple ways resulting in compromised learning and teaching. The excerpts below attest to the lack of schools rules or suitable discipline policy.

" *there was a discipline policy in paper – it was not followed at all, it's like it never existed, late coming, absconding, fights, disruptions were normal at the school I attended – lessons were often cancelled and teacher would sit in the staffroom, or he would get an ex-student to teach us".* P13 (Individual interview)

"Our principal was hardly in school, he was running his taxi business and tavern which was 500m from the school, he was not interested in rules or discipline, the learners used to hang around the tavern and only come to school for girls or to fight." Group B (Focus group interview)

These two excerpts make clear the indiscipline that results from a disjuncture between a discipline policy on paper (theory) and a discipline policy in practice (operational). Within the South African context, the Department of Basic Education entrusts principals with, amongst other duties, overseeing implementation of policy, monitoring school discipline and the academic progress of learners and ensuring that the school environment is conducive to both teaching and learning. Principals are the custodians of their schools; it is their job to ensure teachers are teaching for the full duration of the school day, without unnecessary disruptions, and that learners attend lessons and learn. The absence of the principal and the operational discipline policy as well as its influences on the teaching and learning process is clear. The principal's absence, furthermore, creates space for various forms of violent behaviour, as it indicated by the excerpts below:

"There were gangs coming to school and fights would occur daily, the lessons will stop, teachers will run to the staffroom, learners will run home" Group A (Focus group interview)

P15 expressed a similar sentiment during the individual interview:
"Yes, I swear a lot, fighting, swearing, guns this is normal and acceptable where I come from, we used to swear at school during lessons to protect ourselves, Swearing makes you look tough and hard, I was caught up with this image of thug life, I spent more time out of class than in class" P15 (individual interview)

A bleak picture of the violence first year EGD PSTs had encountered as high school learners and the general disfunctionality of their schools comes to the fore in the excerpts above. The pictures contained in the four collages and the school node of the concept maps also confirm that this violence has disrupted these first year EGD PSTs' learning when they were in high school. It is evident that the school environment has played a significant role in shaping the first year EGD PSTs lives. For example, the notion that violence is both normal (*occur daily, guns this is normal where I come from)* and acceptable (*acceptable where I come from)* is perpetuated. Instead of the school environment being a caring and safe space for effective teaching and learning it becomes a hostile space (*the lessons will stop, teachers will run to the staffroom, learners will run home)* or arena for enacting out aggressive and violent behaviour (*we used to swear at school during lessons to protect ourselves).* The above finding resonates with that of Mncube and Harber (2013), who found that violence is escalating; schools in townships are regularly prey to gangsterism due the availability of guns, and both teachers and learners there live in constant fear, which impinges on learning. First year EGD PSTs indicated their learning had been impeded by their having to deal every day with unruly behaviour, aggression, abuse and violence. By contrast, a supportive and favourable school environment is needed to make learners comfortable and to facilitate learning.

Added to the hostile atmosphere they endured, the first year EGD PSTs in this study had also encountered overcrowded classrooms, and a lack of textbooks, relevant equipment and models when they were learners in high school, as indicated in the excerpts below.
"*We had 10 textbook to share among 45 students, it was hard to read and study – the terms in EGD are confusing, there were no models to see what the teachers was talking about, so you could then imagine the views of it*" P 5(individual interview)

"There was one toilet for over 400 girls, can you imagine how hard it was for girls, it was always dirty, girls always left school when they needed to use the loo" P7 (individual interview)

The multiple ways in learners are left behind by the school environment and the numerous ways in which their learning is compromised become obvious in the above excerpts. The dehumanizing encounters (*one toilet for over 400 girls always dirty, girls always left school)* of female first year EGD PSTs (when they were learners) comes to the fore. The lack of proper ablution facilities constrained the learning opportunities and choices (*always left school when they needed to use the loo*) available to females. The above finding raises keys questions about the day-to-day interaction between learners, their learning, and safety within the school environment. The confounding question is how can learners be expected to learn when they are griped with fear and their basic needs are not met? Can one expect learners to develop spatial visual skills in such a school environment?

8.2.2. Teacher challenges

There are several teacher challenges within the school environment that impact teaching and learning, such as lack of support within school, poor quality of teaching and lack of positive expectation of learners. These factors are interconnected and impact each other as is visible in the excerpts below:

"My teacher was not qualified to teach EGD, he was a technology teacher, he was forced to teach when the EGD teacher quit his job to start a business, the technology teacher was so strict, you could not ask something if you didn't understand, all he used to say was you'll are going to fail." Group D (Focus group interview)

"*there were no resource to teach, the teacher made no effort to explain or get models for us to see what he is talking about, when we used to mark our work, he will go over the easy example and leave out the ones we could not do, so in the exams I attempted the easy question on AD – I passed EGD because of PAT (practical assessment task)"* Group C (Focus group interview)

Similar views were expressed by P 9 during the individual interview

"how can learner learn if the teacher does not know the content, does not come to class of time, does not care if learners come to class, his famous line was I will still get paid even if you fail" P9 (Individual interview)

The quality of teaching (or lack thereof) is an important factor affecting learners' learning. From the excerpts above it is clear that first year EGD PSTs considered their teachers' lack of content knowledge (*the teacher does not know the content, was not qualified to teach EGD)* as an impediment to their learning of EGD. Furthermore, the teachers' lack of content knowledge impacted how the teacher taught (*go over the easy example and leave out the ones we could not do, you could not ask something if you didn't understand).* The above excerpts show that what teachers do in the classroom is dependent on what they know. The above finding are in line with that of Baumert et al. (2010), who assert that the only type of knowledge teachers need to be effective is content (what to teach) and pedagogy (how to teach). I am aware of studies which posit that there is no significant differences between teacher certification, their content knowledge and learners' progress. However, in this study the lack of teachers' content knowledge clearly disadvantaged the learners as it created gaps in their learning (*I attempted the easy question on AD – I passed EGD because of PAT)*. Teaching of poor quality as reflected above fosters an autocratic teacher-centred atmosphere where learners are afraid to ask questions *(you could not ask something if you didn't understand*) and shatters the learners confidence and morale (*you'll are going to fail).* Thus, it can be argued that teachers are an essential link between the curriculum and learners' success: it is teachers who filter the curriculum through to the learners. The above finding mirrors that of Chetty, Friedman, and Rockoff (2014) and of Evans and Popova (2015), which indicated that teacher quality has a large effect on children's success in school and in adulthood.

8.2.3. Parent challenges

Parental involvement can have significant negative or positive impact on learners' school performance. Frequently, in poor socio-economic contexts, parents' role in their children's learning is limited or is inconspicuous, as indicated in the excerpts below.

" my mum is a single parent, she take care of her siblings, their children as well as my brother and I, She works hard, seven days a week as a cleaner, to support us, there is no time, she cannot help me with my EGD, she only went to primary school" Group B (Focus group interview*)*

"my parents died, my sibling and I live with our gran, she is old, we survive on her pension, she is sickly, I used to stay away from school to take her to the clinic" Group A (Focus group interview)

The excerpt from an individual interview below reflects similar sentiments.

"We are poor, I walk to school to save money, after school I cook and clean, take care of my siblings, My mother works as a machinist at a clothing factory. She wants me to become an engineer so we can live a better life" P 12 (Individual interview)

The harsh realities and challenging socio-economic factors that learners experience daily becomes explicit (*a single parent*, *my parents died*, *I walk to school to save money, to stay away from school to take her to the clinic)* in these excerpts. The overt absence of parents' involvement in their child's learning is not due to a lack of desire (*to become an engineer so we can live a better life)* but is rather due to their struggling to juggle many responsibilities (*single parent, she take care of her siblings*, *She works hard, seven days a week as a cleaner).* Other ways in which poverty affects school attendance also show (*to stay away from school to take her to the clinic).* How can learners have time to focus on schoolwork when they are saddled with so many adult responsibilities? The above finding resonates with that from the Kgaffe (2010) study conducted in North West province of South Africa, which indicated that barriers to parents' involvement in and collaboration with their child's learning included lack of time, lack of transportation, poverty and being single working parents.

8.2.4. Learner challenges

There are several barriers to learning among the learners themselves; for example, disruptive behaviour, lack of time for schoolwork due to household chores, and inability to access learning in EGD. First year EGD PSTs bemoaned the lack of discipline at their school; the excerpts below attest to challenges encountered due to disruptive behaviour.
"there was always violence at school, discipline was not put in place by the principal or teachers, I was always stressed about getting hurt at school, I take care of my younger siblings, I cannot get caught in the violence" Group B (Focus group interview)

"The fights, smoking of drugs prevented many of us from focusing on learning we were always trying to survive the school day to go home to our family responsibilities" P 15 (individual interview)

The unnecessary anxiety and stress that learners encountered is conspicuous in the above excerpts. Violence, ill discipline and the lack of enforcement of the school discipline policy or school code of conduct by teachers or the principal are factors that impede learning. How can learners be expected to pay attention and learn when they felt anxious, unsafe and are worried about their other responsibilities *(I take care of my younger siblings*)? The multiple responsibilities that first year EGD PSTs had to deal with while still at school, over and above coping with learning, is explicit in the excerpts that follow.

"We are poor, my mums is sick, after school I worked at the scrap yard to help put food on the table, that's physical work, I just never had time to study, sometime in our culture you are a child with adult responsibilities" Group D (Focus group interview)

"When I got home I had to clean, cook, wash, take care of my siblings, there was no time to study. I used to get up early, get my siblings ready for school then walk 5 km to school. I was always tired, my mum died and left me to bring up 4 children" P18 (Individual interview)

The excerpts above show that due to insufficient time and multiple social responsibilities learners in schools struggle to access learning in EGD.

"I prefer languages, and written text, the owner of the scrap yard encouraged me to do EGD, and my ward counsellor promised me a teaching post at my school once I qualify but I'm struggling, I also struggled at school the terms are difficult, the lesson is in English, EGD has its own language and I speak isiZulu – how confusing this is" Group D (Focus group interview)

"The terms are so confusing, I really find EGD hard as I don't know how to visualize and move objects mentally. P 20 (individual interview)

Accessing information and learning in EGD is an obstacle (*I also struggled*) for the non-visual learner (*I prefer languages, and written text).* The struggle is further intensified by the language of instruction *(English)* the difficult nomenclature of EGD (*EGD has its own language, terms are so confusing)* and the learners home language (*I speak isiZulu).* The above excerpts make evident the stark reality of language as a barrier to learning and that many learners continue to learn in a second language that feels foreign (*I speak isiZulu*). The language issue can be viewed from two perspectives.

In the first perspective, language is part of obtaining EGD literacy. Learners must be taught to read and write EGD texts, as well as to be knowledgeable about and able to understand EGD content (Fung & Yip, 2014; González-Howard & McNeill, 2016). This involves gaining access to the discipline content, as it is this content that inherently guides how texts are written, and thus how they must be read (Bharuthram & Clarence, 2015; Rollnick, 2000).

Furthermore, students from non-technical high schools have little or no real knowledge of engineering applications (Willmot & Perkin, 2012) and they are usually poor in both engineering graphics fundamentals and illiterate in CAD. The second perspective views language as the "symbolic representation of culture" within the EGD context (Fung & Yip, 2014, p. 1221), whereby the common socio-cultural practices dictate the accepted ways of talking, reading, writing, knowing, and doing (González-Howard & McNeill, 2016). Within South Africa, many textbooks are written from a western industrialized viewpoint, which can shape the vocabulary, examples, and phrases used, so that they may not be familiar or easily understood by a learner, or teacher, from an African language background (Rollnick, 2000). Nevertheless, English is known to be indispensable for explanation of concepts and for international scientific communication (Fung & Yip, 2014; Rollnick, 2000). This means that English proficiency is a prerequisite for success (Probyn, 2009). Therefore it is likely that English will continue to be the dominant language in EGD education, but this poses an arduous task for second-language learners learning in English, who must master, not only the EGD discourse and content, but also the western discourse and the English discourse,(Fung & Yip, 2014). In order to explore the poor achievement of South African learners, further investigation is required to ascertain the degree of influence that the mismatch between home language (HL) and the language of learning and teaching (LoLT) has on EGD achievement among South African learners.

8.3. Conclusion

In this chapter, data was presented from collages, concept maps, individual interviews and focus group interviews in order to answer Research Question 3: Why do first year EGD PSTs encounter challenges when they read and interpret AD. Four themes emerged to account for the challenges that first year EGD PSTs experience when they read and interpret AD at tertiary level. These were school challenges, teacher challenges, parent challenges and learner challenges.

School related factors that mitigate learners' performance include the absence of management and rules, the presence of violence and lack of resources. There three factors are interconnected and all compromise learning and teaching. Teacher challenges include the poor quality of teaching and lack of positive expectation of learners, which have a negative impact on learners' learning. Parent challenges, largely due to a poor socio-economic background, impact negatively on the time learners have to study due to the increased responsibilities learners have to shoulder. Learner challenges, for example disruptive behaviour, lack of time for schoolwork due to household chores, and inability to access learning in EGD, jointly affect learning of EGD.

Chapter 7 focused on the challenges first year EGD PSTs encountered when they read and interpret AD and in this chapter attention was paid to the reasons behind these challenges. Chapter 9 will explicate the teaching intervention used to scaffold first year PSTs' learning in EGD with the aim of enhancing their ability to read and interpret AD.

CHAPTER 9

MEDIATION PROGRAMME TO SCAFFOLD READING AND INTERPRETING OF AD

9.1. Introduction

In Chapter 8, the analysis revealed that first year EGD PSTs attributed the challenges they encountered when they read and interpret assembly drawing (AD) to four factors; namely, school challenges, teacher challenges, parent challenges and learner challenges. With regard to learner challenges, understanding the difficulties first year EGD PSTs have in terms of reading and interpreting AD is fundamental to developing pedagogical strategies to promote their success. My analysis in Chapter 7 also revealed that first year EGD PSTs faced five challenges when they attempted to read and interpret AD.

According to Metraglia, Baronio and Villa (2015), learners need to acquire appropriate tools for them to be able to mentally create and edit graphic information, read and make engineering drawings, gain knowledge in both two and three dimensional geometry, reason spatially and learn a graphical language. Along similar lines, Meneghetti, Borella and Pazzaglia (2016) argue that visualization skills are skills that can be improved by appropriate training. Graphic languages involve seeing the spatial relations between all relevant signs. Thus, in planning my teaching intervention to scaffold first year EGD PSTs in reading and interpreting AD, I was guided by the aforementioned scholars and the five challenges identified among the first year EGD PSTs. In this chapter, I describe my mediation (or teaching) intervention programme to address these challenges.

9.2. Mediation intervention

For the mediation (teaching) intervention to be effective, appropriate equipment was needed. I had observed during the execution of task one that few first year EGD PSTs used a clutch pencil for the drawing. The majority used an ordinary HB pencil, which needed to be repeatedly sharpened when blunt. Moreover, these first year EGD PSTs did not carry a pencil sharpener with them. But for these students to be able to make sense of the sketches they drew and participate in teaching and learning activities, they needed proper equipment. Therefore, before the intervention could begin I acquired sponsorship to supply the first year EGD PSTs with appropriate pencils, rulers, and drawing instruments in order to facilitate both the teaching and learning of AD.

In response to the five challenges that the EGD PSTs experienced with AD, I planned to scaffold their learning of AD. Findings from Chapter 7 indicated that the EGD PSTs were unable to:

- read and interpret information in the title block,
- differentiate Orthographic and Isometric Projection and visualize the different views ,
- visualize, see relationships between objects and rotate objects,
- measure accurately and recall the SANS code of practice, and
- assemble parts and draw different lines.

In the sub-sections below I outline the steps taken to address each of the challenges.

9.2.1. Title block

I created a power point presentation on the title block, highlighting the type of information contained in the title block and how to read, make sense of, and use the information. As a follow-up activity first year EGD PSTs were given many examples of title blocks with accompanying short tasks. They were required to work in pairs and present to the class the information contained within the title block and state how the information would be used. Such information, with the relevant skills is shown below in Table 9.1.

Table 9.1 information in the title block and its use

Skill	**Knowledge and activity**
Identification of projection	Find projection to be used between first angle and third angle orthographic graphic projection Recall how principle plane works Find connectivity between given exploded isometric view (3-D) and projection views (2-D).
Mental interpretation	Freehand sketching and find the connectivity of each component. Combine or assembly 3-D and 2-D drawings to find the complete outline of machine drawing. Use the given cutting plane to mentally see the position where cutting plan will run through each component.
Measuring and drawing	Using the given scale with drawing instruments, accurately assemble through drawing all given components as per dimensions. Recall meanings of different type of lines knowledge from SANS 10111 code of practice. Use the given cutting plane to determine the position where each component should cut. Recall method of construction for the bolt and nut. Recall how components should be sectioned and which should not be sectioned.

9.2.2. Inability to differentiate between Orthographic and Isometric Projections and visualize different views

Like the first year EGD PSTs in this study, Kajiyama (1996) and Olkun (2003) found that freshman engineering students committed numerous errors in interpreting multi-view drawings. These students had demonstrated a poor ability to put a given view on its plane of projection accurately, to imagine spatial coordinates, and to calculate a geometrical relation of the point of intersection and vertex of an object. All these errors were attributed to low spatial ability, which was needed for learning the subject matter. The remedy as suggested by Olkun (2003) was for students to use both perceptual and cognitive processes when learning the subject matter, which falls into two categories. First, students are required to represent a three dimensional object on a two dimensional plane surface through multiple-view drawings. The second requires them to create three dimensional perspectives by working from the two dimensional representation of the object. To develop visualization skills, careful selection of teaching strategies and tools was used.

First year EGD PSTs were first introduced to the nomenclature of EGD, thereafter they were tested repeatedly on the nomenclature. Models and drawing were used to demonstrate the different views or projections. Paper marked with a grid of dots or squares was used as a drawing template for basic isometric and orthographic drawings, in order to get first year EGD PSTs to see the difference between orthographic and isometric drawings. They also had the opportunity to use models to do free hand sketching. The reason for teaching free hand drawings was for the students to understand how a drawing is constructed, to train them to visualize something on paper, to learn about isometric views and projections, and how to label drawings. A study by Kudrowitz and Wallace (2013) showed the importance of sketching as a basic tool for solving visual problems in engineering, arguing that it allows for externalization and representation of design problems. Hence, I created numerous opportunities for first year EGD PSTs to sketch and perceive three dimensional shapes in a sketch-based modelling environment. I argue that getting first year EGD PSTs to engage in sketching improves their spatial ability as they acquire the ability to "see" ideas in the mind, manipulate objects and render them into drawings. Scholars such as Chester (2007), Delahunty et al. (2013), McLaren (2008) as well as Mohler and Miller (2008) support the notion that sketching or drawing improves spatial ability.

Based on this argument, sketching should be an integral part in the EGD teacher training curricula. If first year EGD PSTs know the nomenclature of EGD, if they can draw and differentiate between orthographic and isometric projection and visualize different views, then they ought to be able to teach their learners these skills. Sketching has the carryover effect of improving the ability to visualize. Some of my own sketches are shown as examples in Figure 9.1 below. Sketch A shows a freehand isometric drawing and B shows a front view in orthographic projection.

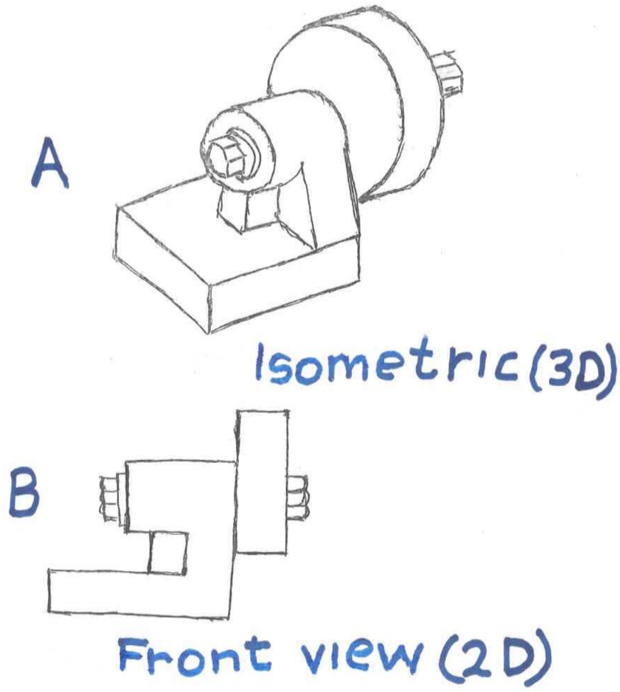


Figure 9.1 Freehand isometric drawing (A) and front view of orthographic projection (B)

9.2.3. (In) ability to visualize, see relationships between objects and rotate objects

As mentioned earlier first year EGD PSTs who are exposed to hand-drawings acquire the ability to "see" objects in the mind, manipulate the objects and render them into drawings. This means that sketching aids abstract concept representation and it allows students to refine their cognitive processes and to better explore new concepts (Delahunty et al., 2013). To aid and develop first year EGD PSTs ability to visualize objects, rotate objects and see relationships between them I used models (example nuts, bolts etc.) in class. Bertoline *et al.* (1997) contend that the way to improve a person's skill in visualizing a 3-D object or scene is by making that experience as realistic as possible. They argue that some students may have difficulties related to an object's spatial reality and its corresponding plane representation but by interacting with the physical object, these comprehension difficulties are reduced. Accordingly, in my teaching, I encouraged first year EGD PSTs to locate the horizontal or the vertical plane in a stationary display while ignoring distracting information and thereafter to imagine how objects would appear when rotated in two or three dimensional space.

9.2.4. (In)ability to measure accurately and recall the SANS code of practice and (In) ability to assemble parts and draw different lines

Scholars such as McLaren (2008) and Abdullah et al. (2011 a & b) have noted that engineering students seem to have a poor understanding of the fundamentals of constructing a drawing, they lack confidence in sketching, and they do not appreciate the need to comply with rules, conventions and standards. To address first year EGD PSTs inability to measure accurately and their inability to apply the SANS code of practice, I set simple tasks on measurement and the SANS code of practice that involved individual and group work. I demonstrated how a ruler ought to be used. I also taught first year EGD PSTs about scales: how to read, interpret and calculate scales for their drawings. I designed lesson activities where opportunities were created for sharing among first year EGD PSTs through small group discussions of their background knowledge of types of lines, different scales and dimensioning.

These class activities catered for group discussion to allow first year EGD PSTs to learn from one another. First year EGD PSTs, working in small groups, were given a copy with line types, extracted from the SANS code of practice. Each member per group chose at least two line types, learned about it and then they took turns to explain their understanding of each line they had been learning about. This strategy embraced Vygotsky’s ZPD concept as it promoted group work and allowed peers to learn together and scaffold each other’s learning.

A follow up lesson was conducted where first year EGD PSTs were given a task in small groups. Each group was provided with an actual object and its components, and a detailed isometric drawing (exploded view) that represented the object. Their task was to identify the objects and its components and then assemble it. This means that each group of first year EGD PSTs had the real object to physically manipulate and assemble from the components, while being able to discuss with their peers issues on dimensioning and measuring. During the task, first year EGD PSTs were actively involved in problem solving and information sharing with peers and I moved from one group to the other providing support when the students required assistance or clarity.

In another exercise, the first year EGD PSTs were required to bring a hexagonal bolt, nut and washer to the classroom. Each group were provided with a copy of the table of standard hexagonal metric bolt and nut sizes. PSTs were given an opportunity manipulate the objects and then read and interpret the table with the lecturer, thereby identifying the sizes of bolt, nut and washer.

The intervention activities incorporated Vygotsky's ZPD and Gardner's (2004) Multiple Intelligence (MI) theory. First year EGD PSTs were all actively involved in peer-to-peer learning, in which every first year EGD PSTs was a participant within the society, which connects him or her with all community activities. In addition, these activities embraced interpersonal, visual-spatial and bodily-kinesthetic aspects of Gardner's MI theory. Group work catered for the interpersonal aspect (through mixing with other people, understanding, interacting with others). These first year EGD PSTs learnt through interaction with their peers. Here the theories of multiple intelligence (MI) and Vygotsky ZPD coalesce as the first year EGD PSTs were taught through physical activity, hands-on learning, where they could touch and manipulate the objects, and then discuss with peers before answering the questions posed in the task.

9.3. Conclusion

In this chapter, I presented the intervention programme that I developed to assist first year EGD PSTs to overcome their inability to read and interpret AD. First year EGD PSTs had identified five challenges that confronted them when they attempted to read and interpret AD. The intervention provided learning experiences directly linked to these challenges. The effectiveness of the intervention was evaluated in the second think-aloud task. In the next chapter, I present data, analysis and findings from this task.

CHAPTER 10

PRESENTATION OF DATA, ANALYSIS AND DISCUSSION: RESEARCH QUESTION 4

10.1. Introduction

In this chapter, I present data and analysis in response to Research Question 4, which was: Does the reading and interpreting of AD, by first year EGD PSTs, change after mediation? If so how? If not, why? Data that had been generated via think-aloud task two, semi-structured individual interviews, collages and post collage focus group interviews were used to respond to Research Question 4. As mentioned earlier in chapter 5, (section 5.7.3, 5.7.4 and 5.7.6) first year EGD PSTs were involved in collage making (2 collages were made), individual interviews and post collage focus group interviews (2 focus group interviews were conducted) after being exposed to mediation (teaching).

As mentioned previously in Chapter 5, transcripts was read and re-read several times before the data could be inductively analysed and organized into categories and themes. Direct quotations from first year EGD PSTs' responses to the individual interviews, focus group interviews and references to the collages are presented here in verification of the emerging themes. The literature and associated theoretical constructs are presented in support of the emerging themes. Three broad themes emerged, namely teaching strategies, tools of the trade (understanding the demystified terminology, measure, rotate and assemble), and step by step support. Think aloud task two is explained in detail. Then data related to the EGD PSTs performance on the task is analysed, and then the three themes that emerged from the data are presented.

10.2 Think aloud task two

Think aloud task two totalled 95 marks (see appendix C2). This task was undertaken by 21 first year EGD PSTs (9 females and 12 males). Students were given pencils and drawing instruments to complete the task individually. As mentioned in Chapter 5 think-aloud task two was video-recorded, as had been task one. The duration of the task was one hour. The task comprised five sections A, B, C, D and E, the sections carried a mark allocation as follows 36 (A); 9(B); 24.5(C), 11, 5 (D) and 14(E). In the following sub-sections, I describe for each part, the information that the first year EGD PSTs needed to process in order to be able to read and interpret the AD.

Section A comprised parts 2, 4, 7 and 9, which are the larger parts of the complete mechanical assembly drawing. First year EGD PSTs were expected to:

- Identify front view of these bigger components 2, 4, 7 and 9 using the given two views of each part and with the guidance of exploded isometric view.
- Recall SANS code of practice on how principle planes work.
- Identify all parts, use spatial visualization skills to mentally manipulate parts to see how they fit together (2, 4, 7 and 9) and assembly them.
- Draw all parts in 3rd angle orthographic projection as per give dimensions.
- Using the given scale, be able to measure accurately and draw as required.

Section B consisted of four parts: 3, 5, 6, and 8, which are the small parts of the complete mechanical assembly drawing. First year EGD PSTs were expected to:

- Identify the small parts as per numbering.
- Identify the front view of each part with the aid of exploded isometric view.
- Mentally rotate and visualize how and where parts 3, 5, 6 and 8 can be assembled onto the combination of them all.
- Through drawing, add small parts to large parts by following the principle of 3rd angle orthographic projection as per SANS code of practice.
- Use all details of dimensions given and measure accurately.

Section C paid attention to parts 1, 10 and 11, which is the construction of bolt, nut and washer in front view as part of the complete mechanical assembly drawing. First year EGD PSTs were expected to:

- Identify and differentiate between the bolt, nut and washer using all detailed views given and identify views of each part.
- Established how many sides of the bolts and nut must be included in the front view.
- Recall the construction of the bolt and nut using the table of standard hexagonal metric bolt and nut sizes.

- Measure accurately as per given dimensions and draw all parts in 3rd angle orthographic projection according to SANS code of practice.

Section D is a complete left side view of machine drawing, which is made up of six components (1, 2, 3, 4 and 9). First year EGD PSTs were expected to:

- Identify all parts that would be visible when a machine is drawn in the left side view. Also identify the small parts as per numbering.
- Identify side view of each part with the aid of the exploded isometric view.
- Mentally rotate and visualize how and where parts 1, 2, 3, 4 and 9 fit in on the left view.
- Draw all the outside parts of the left side view in 3rd angle orthographic projection as per SANS code of practice.
- Use all details of dimensions given and measure accurately.

Section E was the last section, which is the general assembly of all parts and centre lines positioning as part of the complete mechanical assembly drawing. First year EGD PSTs were expected to:

- Make a general assembly of all parts accurately.
- Use correct line types.
- Draw all required centre lines as per each part in keeping with the SANS code of practice

Accomplishing this think-aloud task, involved many processes. The EGD PSTs would need to:

- Interpret the details in the title block in order to gain the context in which the drawing should be perceived. The title box provides information on aspects of projection details, scale used in the drawings, name of the components/assembly, mass, units used in the drawing.
- Interpret the notes in the drawing (outside the title block).
- Use the bill of materials (BOM), which is a list of the components and the quantity that makes up the general assembly. The BOM is tabulated on the task.
- Interpret drawing to understand the views provided.

- Identify all parts in order to differentiate the parts and their dimensions.
- Use spatial visualization skills to mentally manipulate parts so as to visualize all sides of the components and then visualize how they would fit together in order to be assembled.
- Use the sections and details as a starting point.
- Understand the difference between the visible lines, hidden lines and phantom lines.
- Identify and understand the projections, sections and details.
- View the drawing itself disregarding the dimensions and try to visualize how and what the assembly would look in 3-D.
- Use the dimensions in the drawing to appreciate the size of the components and assembly and use a ruler to gauge the size.
- Recall SANS 0111 code of practice on how principal planes work.
- Use the BOM to try to find the components in the drawing in order to understand the role each component plays.
- Identify notes that have a leader (arrow) to the assembly; this information is usually vital to the assembly and its functionality.
- Draw all parts in 3rd angle orthographic projection as per give dimensions.
- Use the given scale to be able to measure accurately and draw as required.
- Plan the layout of the paper by identifying the position of each view as per question requirements, following the principle of orthographic projection e.g. 3rd angle.

10.3. Does the reading and interpreting of AD, by first year EGD PSTs, change after mediation

To answer the first part of Research Question 4, I use the data from the second think aloud task. Table 10.1, on the next page, reflects the marks first year EGD PSTs obtained when they attempted to read and interpret the ADs in think aloud task two. According to the DS University's criteria, a mark of 48 would be above the pass mark of 50% for think aloud task 2.

Table 10.1 first year EGD PSTs' performance in think aloud task

Student No.	Section A: drawing large sectional FV part 2,4,7 &9 = 36 marks	Section B: drawing small sectional FV part 3,5,6 &8 = 9 marks	Section C: construction of bolt & nut and washer in part 1,10 &11 plus hatching of all parts = 24.5 marks	Section D: Left Side View part 1,2,3,4,7&9 = 11.5 marks	Section E:general assembly of all parts and centre lines = 14 marks	Total mark out of 95
PST 1	14.5	2	6.5	2	6	31
PST 2	16	1	4	1	6	28
PST 3	19	3	15	6	8	51
PST 4	22	2	14	5	7	50
PST 5	21	3	13	4	7	48
PST 6	20	2	14	6	7	49
PST 7	23	3	15	7	6	54
PST 8	24	3	16	7	6	56
PST 9	7	1	2	1	6	23.5
PST 10	22.5	3	18	6.5	7.5	57.5
PST 11	21.5	3	17.5	8	7	57
PST 12	24.5	5	18	7	6	60.5
PST 13	20	1	6.5	2	7	36.5
PST 14	24	5	17	6	8.5	60.5
PST 15	7.5	1	2	7	10.5	28
PST 16	9.5	1	5.5	2	6	24
PST 17	18	5	15	7	6	51
PST 18	26.5	5	16	8	7.5	63
PST 19	24	5	13.5	8	8	58.5
PST 20	26	5	15.5	7	7.5	61
PST 21	29	5	18	7	9	68

As can be seen from the table above, for Section A, 16 (76%) first year EGD PSTs obtained scores above 18 out of 36 for section A (18 will be the pass mark for section A as per DS university of technology requirements). These 16 first year EDG PSTs were able to:

- Identify front view of the bigger components using the given two views of each part.
- Recall SANS code of practice on how principle planes work.
- Identify parts 2, 4, 7 and 9, and use spatial visualization skills to mentally manipulate parts to see how they would fit together and assembly them.
- Attempt to draw all parts in 3rd angle orthographic projection as per give dimensions.
- Use the given scale be able to measure accurately and draw as required.

Six first year EGD PSTs did not obtain above 50% for section A. These first year EGD PSTs were evidently still grappling with the key aspects that section A foregrounded, as outlined in the bulleted points above.

In section B, which foregrounded small parts on the mechanical assembly, 7 first year EGD PSTs obtained at least 50% (a mark of 5 out of 9), but the majority (14) of the first year EGD PSTs obtained a score below 50%. Despite not passing, this was still an improvement over the performance in think- aloud task one. Here in Section B of task two all 21 first year EGD PSTs obtained a score above zero, whereas in the first task, all but one PST had obtained a score of zero. This shows a marked improvement in first year EGD PSTs performance; they could now:

- Identify the small parts.
- Identify front view of each part.
- Mentally rotate and visualize how and where parts 3, 5, 6 and 8 could be assembled into the combination of parts 3, 5, 6 and 8.
- Drawing of the additional small parts with the large parts by following principle of 3rd angle orthographic projection as per SANS code of practice.
- Use all details of dimensions given and measure accurately.

First year EGD PSTs' performance in section C indicates that 15 (71%) first year EGD PSTs obtained a score above 50 % (more than 13 out of 24.5) while 6 (29%) would have failed this section with a score below 50%. In the corresponding section of think aloud task one, none of the first year EGD PSTs had obtained a score above zero (see Table 7.1. Chapter 7). When the scores for section C in think-aloud tasks one and two are compared, it is evident that nearly three-quarters of the first year EGD PSTs were now able to:

- Identify and differentiate between the bolt, nut and washer using all detailed views given and identify views of each part.
- Establish how many sides of the bolts and nut must be included in the front view.
- Recall the construction of the bolt and nut using the table of standard hexagonal metric bolt and nut sizes.
- Measure accurate as per given dimensions and draw all parts in 3rd angle orthographic projection according to SANS code of practice.

However, 29% of the first year EGD PSTs are still acquiring the skills needed to engage with the construction of a bolt and nut and washer in front view as part of the complete mechanical assembly drawing.

Section D paid attention to a complete left side view of machine drawing, which is made up of six components. In this section, 13(62%) first year EGD PSTs obtained a score above 50 % (6.5 marks out of 11.5) but 8 (38%) obtained a score below 50%. This means that well over half of the first year EGD PSTs were now able to:

- Identify parts that were visible when a machine was drawn in the left side view and identify the small parts as per numbering.
- Identify side view of each part with the aid of the exploded isometric view.
- Mentally rotate and visualize how and where parts 1, 2, 3, 4 and 9 fit on the left view.
- Draw all the outside parts of the left side view in 3rd angle orthographic projection as per SANS code of practice.
- Use all details of dimensions given and measure accurately.

The results for Section D show that 38% of the first year EGD PSTs still experienced challenges when dealing with a complete left side view of machine drawing that is made up of six components.

All first year EGD PSTs obtained a score for section E of think aloud task two. This means that all of the first year EGD PSTs were now able to:

- assemble all parts.
- use correct line types.
- Draw the required centre lines as per each part in keeping with the SANS code of practice.

The scores obtained in think aloud task two indicate that first year EGD PSTs' reading and interpreting of AD had improved after the teaching mediation program. In other words first year EGD PSTs were better able to perform in think aloud task two as compared to task one. It can be construed that the positive change was due to their improved learning and level of development in spatial visualization reasoning, which had been scaffolded during the teaching intervention. During the mediation intervention, first year EGD PSTs had multiple opportunities to participate in activities individually, collaboratively with peers as well as with the EGD lecturer, in order to develop mastery of practice in their ability to:

- Read and interpret the title block
- Differentiate orthographic and isometric projection and visualize the different views,
- Visualize, and see relationships between objects and rotate objects,
- Measure accurately and recall the SANS code of practice, and

- Assemble parts and draw different lines.

In Figure 10.1 below I illustrate the state of the first year EGD PSTs’ ability to read and interpret AD as “familiar”. This is the stage in which he or she relies on their pre-knowledge of EGD obtained in high school before the teaching/mediation intervention at DS university of technology (to complete think-aloud task one). The ZPD represents the region in which the first year EGD PSTs could comprehend how to read and interpret AD after the mediation sessions with more knowledgeable persons. The ZPD reflects the first year EGD PSTs level of development in think aloud task two. The section labelled as “unfamiliar” depicts the region where knowledge is too difficult for the first year EGD PST to acquire at the time. In other words, those aspects that they still found challenging in think aloud task two and which resulted in poor scores for the relevant sections – see Table 10.1.

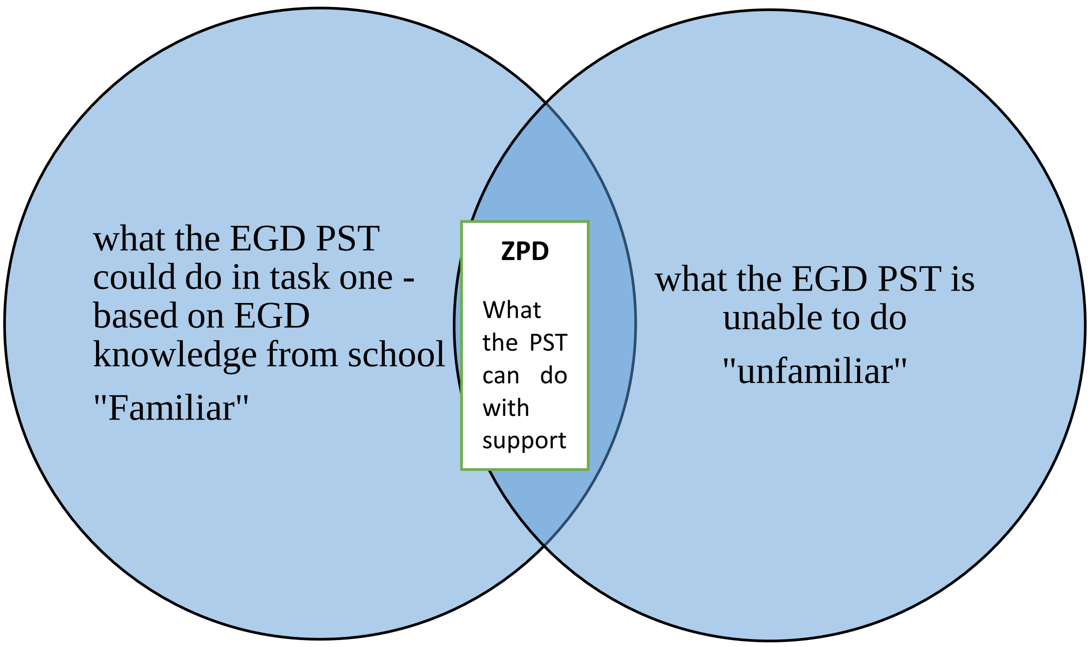


Figure 10.1: Mediation process

In answer to the first part of Research Question 4, exposure to the mediation program transformed first year EGD PSTs' skills from lower to higher cognitive functions as the first year EGD PSTs progressed from prior to new knowledge forms. The mediation process had allowed for social interaction whereby first year EGD PSTs learnt the cognitive and communicative tools and skills of EGD by constructing, deconstructing, and reconstructing their knowledge base. Their reading and interpreting of AD changed for the better after mediation. It is therefore appropriate to present answers to the second part of Research Question 4, which asked: If so, how? The data from the collages and focus group interviews are presented to answer this sub-question. There is no need to answer the third part of Research Question 4: If not, why?

10.4. If so, how?

To answer the second part of Research Question 4, data gathered during Phase 4 of the research, that is from individual interviews (10 first year EGD PSTs) two collages (2 groups of 5 first year EGD PSTs), and post collage focus group interviews (10 first year EGD PSTs), are used. As mentioned earlier in Chapter 5, the attendance of first year EGD PSTs was very low for Phase 4 of data generation due to looming student protest action. In this regard, first year students are often the easiest to target and are intimidated by more senior students in their third and fourth year of study. Analysis of the data from the individual interviews and post collage focus group interviews showed the emergence of three themes of:

- Teaching strategies,
- Tools of the trade: Understand demystified terminology, measure, rotate, assemble,
- Step by step support.

After presentation of the group collages, each theme will be discussed. The, first year EGD PSTs' responses in the individual interviews, focus group interviews and references to the collages are presented in verification of the emerging themes. The literature and associated theoretical constructs are presented in support of the emerging themes.

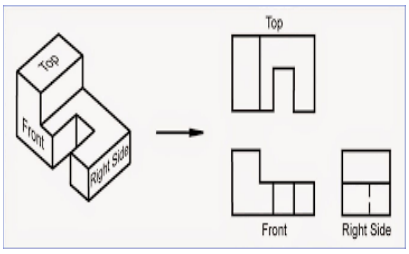
Collage : Group A

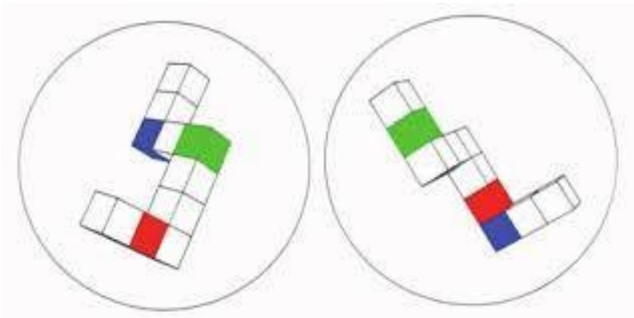
Read and interpret diagrams

materials to suit learning style

Motivated the learn
/visualise

learning to think spatial





understand terminology
manipulate objects

: know different views mentally

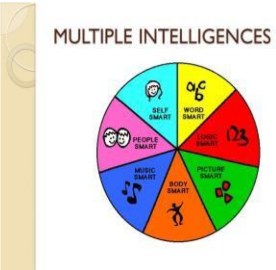
Measure /use scale

Assemble parts

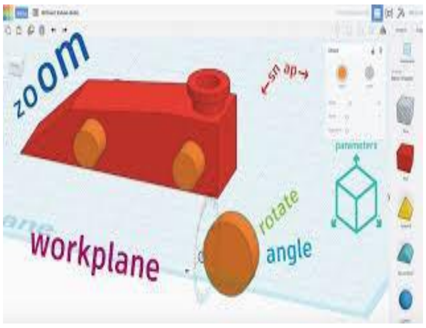
Figure 10.2. Group A collage

Collage Group B

Tools of the trade: equipped to deal with subject terms demystified/ different strategies



Teaching cater for all learners teaching and learning hands on



Learning supported– step by step measure, rotate, assemble

Figure10.3. Group B collage

10.2.1. Teaching strategy

All 10 first year EGD PSTs expressed similar sentiments about the teaching strategy used during mediation, typified by the excerpts below:

" I never experience EGD like this in high school, the lecrturer is easy going, he knows his content and the curriculum, you can ask as many quesations pertaining to the lesson and he take the time to explain, I'm starting to enjoy, he gives feedback to show where you are wrong EGD, In school you could not ask questions, the teacher just taught and left , he was not bothered if we understood" P1 (individual interview)

These sentiments were evident even among those who had achieved less that 50% in think-aloud task two, as shown by the ideas on teaching strategy shared by P16.

" *I always foud it difficult to deal with diagrams, I am just stating to get to grips with it, this lecturer realizes that we are all not the the same and we have dfifferent learning styles and methods of learning, he has different types of tasks to cater for us for example demonstrations, practical hands on activites, join the dot acrtivities, it has helped me, and he does not ridicule us when we get things wrong, he encourages and motivates us*" P16 (individual interview)

Comparable feeling were recounted by P9 during the focus group interview:

"*I was always afraid to try in EGD at school my teacher was a terror, but now my confidence is improving, the classroom atmosphere is relaxed, the lecturer encourages us, he used different teaching methods to help us undertand the work, different types of assessment to help us learn, I look forward to EGD lectures*" P9 (Focus group interview)

In the above excerpts it is evident that first year EGD PSTs are encountering a learning environment that is favourable (*is easy going, he take the time to explain, gives feedback to show where you are wrong, does not ridicule us when we get things wrong, he encourages and motivates)* and antithetical to the one they had experienced in high school (*just taught and left , he was not bothered if we understood, always afraid to try in EGD at school my teacher was a terror).* Learning is here viewed as a transactional process, in which both first year EGD PSTs and lecturer learn how to understand and communicate with each other, and in which trust creates conditions for reduced anxiety, as well as greater striving and motivation (Felner et al., 2007, Osher et al., 2018). Moreover, the excerpts reveal that a conducive, relaxed classroom atmosphere fosters a sense of safety, mutual respect and increased confidence among first year EGD PSTs, one where they are comfortable to ask questions in order to increase their level of development to be able to read and interpret AD.

Hence it can be infered from the above excerpts that an environment conducive to learning can help increase intellectual activities, encourage cooperation and support among first year EGD PSTs, and at the same time, promote learning, growth and development. A study conducted by Darling-Hammond, Flook, Cook-Harvey, Barron and Osher (2019) reported that learners' development and learning are shaped by interactions among three aspects: the learning environment, relationships with peers and teachers, and learning opportunities they experience. Furthermore, these scholars contend that emotions can trigger or block learning; positive emotions facilitate learning opportunities and negative emotions constrain them.

The lecturer's approach is also noteworthy in the above excerpts. He evidently has a deep understanding of first year EGD PSTs' spatial visualization ability and their (in)ability to read and interpret AD. Accordingly, he is able to present the content appropriately, to modify the materials and instruction to suit the learning styles of the first year EGD PSTs. This deep understanding of first year EGD PSTs' ability or inability to read and interpret AD is the key to adjusting instructional strategies in order to support and scaffold their learning so they can move from a familiar state into their ZPD. In the above instance, teaching and learning are not construed as separate entities but as an intrinsically interconnected activity that are mutually dependent, where the kind of teaching shapes the kind of learning and the kind or level of learning feeds back into the kind of teaching. The above finding resonates with that from the study by Coe, Aloisi, Higgins, and Major (2014) on teacher effectiveness, which identified content knowledge (CK), knowledge of learner, familiarity with the curriculum as being the three most significant factors impacting student progress.

10.2.2. Tools of the trade: understand demystify concepts, measure , rotate and assemble

The mediation has provided first year EGD PSTs with the necessary "tools" needed to copy with EGD, as shown in the excerpts below:

"*I can now understand the jargon terms that were so difficult to understand in high school, the lecturer went all out to explain the terms in terms he breaks it down, he gave us short task on these difficult terms,we get mutliple opportunities to engage in different types of task, he* *provides feedback so you know what is wrong and can correct it, once this happens then you can understand the questions posed and respond to it*" P1 (individual interview)

"*He has spent a lot of time equipping us with the basic terms in EGD which we did not understand in high school, gave us many chances to work with the different views individually and in group he has even provided us with pencils and equipment that we need for EGD*" P13 (individual interview)

"I learnt how to make sense of the information in the title block and use the information to address the questions posed, the lecturer has gone the extra mile in making us understand the jargon terms, different views, line types so that we can at draw and visualize what is required in the questions posed. We work individually and in pairs in this way more PSTs are developing the spatial visual reasoning skills needed in EGD." P21 (Focus group interview)

The above excerpts illustrate how teaching should build on and expand first year EGD PSTs' prior knowledge and experiences, both to scaffold learning effectively as well as expand it to new areas of content and skills. The lecturers' awareness of first year EGD PSTs' prior knowledge (or lack thereof) was used to structure their instruction and related learning activities for optimal learning. As was discussed in Chapter 7, the data from think-aloud task one illustrated that first year EGD PSTs were unfamiliar with the nomenclature of EGD (*jargon terms that were so difficult to understand)* as well different views and line types used in AD. Hence they were unable able to process the information provided, which is needed to be able to read and interpret AD. Based on this knowledge the lecturer deconstructed the learning activities, or rather broke them down into smaller or shorter tasks. According to Darling-Hammond et al. (2019) smaller and shorter tasks allow teachers to give more attention to each student and to engage in more in-depth teaching practices. Having shorter tasks ensured that first year EGD PSTs had multiple opportunities to learn and master key terminologies, to practice and develop the competencies needed to enhance the development of their spatial visualization skills, as well as to experience success in the completion of the tasks. The age-old adage "practice makes perfect" comes to mind in the given excerpts. Furthermore, more opportunities for collaborative learning encouraged first year EGD PSTs to question, explain, and elaborate their thoughts and co-construct solutions, whilst ongoing diagnostic assessment and opportunities to receive timely feedback provided opportunities for self- and peer-assessment to improve skills and competencies, and allow reflection on learning.

The excerpts above contain clear examples of how the lecturer used what was known about the PSTs (lack of terminiology, inability to differentiate different views, etc.) with what first year EGD PSTs need and want to learn (ability to read and interpret AD). In being taught the nomenculture of EGD and how to interpret different views, the first year EGD PSTs were equiped with the “tools” needed to read and interpret AD. The aforemention strategy to teach reading is supported by Pearson, Cervetti, and Tilson (2008).

All 10 first year EGD PSTs also indicated that their ability to measure, mentally rotate objects, see the relationship between parts of an object, and assemble parts on a drawing was improving, as illustrated by the excerpts below.

“ I am unashamed to state I battled with scales and dimensioning in EGD, but now I have mastered how to use a ruler properly, I can draw to scale, can read drawing, identify part, flip them in my mind and put or assemble them together, I seek this information when I draw” P21 (individual interview)

“with all the support provided in the mediation and the learning commmunity formed I have improved my visualization skills, I can figure the relationship between parts of an assembly” P3 (Focus group interview)

I always struggled with mental rotation, but with all the excerises and assessments we did on these aspects I have gained enough experience to master it. P5 (Focus group interview)

The marked improvement in first year EGD PSTs ability to measure, to rotate objects mentally and to asseble parts of the object is explicit in the above excerpts. The mediation process with its multiple opportunities to learn, both in a community and individually, facilitated the development of first year EGD PSTs ability to measure, draw to scale, apply the SANS code, manipulate objects and assemble them.

10.2.3. Step-by-step support

Teaching and learning is construed to be step-by-step process as can be gathered from the excerpts below.

"the lecturer does not rush , because he is so familiar with the content, he breaks the content into small manageable tasks for us that become progressively difficult, we are suppoted by our peers and the lecturer if we cannot manage on our own – in this way EGD is doable and we are all improving our skills and knowledge" P7 (individual interview)

"*the support from peers and the lecturer is good, there are multiple chances for learning and mastering of EGD skills, the smaller and shorter tasks help me to grasp the concepts that were once so difficult and foreign to me, I'm enjoying this learning community*" P5 (individual interview)

"knowing that you are not alone in learning the difficult terms, being unable to differentiate the different view or lines is comforting, working closely with peers and the lecturer who help you to understand the parts that make up the sum of EGD is important. We all enjoy doing the smaller tasks set and are able to master the work tested in them." P3 (Focus group interview)

It can be discerned from the above excerpts that the lecturer teaches the first year EGD PSTs within their ZPD. The ZPD is part of Vygotsky's socio-cultural theory of learning, which explains how the development of conscious intellectual activity is the result of social and cultural influences. The core idea is that with more capable peer(s) or the lecturer assists first year EGD PSTs to operate at a higher level than they could on their own, by scaffolding their learning in a step-by-step manner. An advantage of collaborative peer-to-peer learning is that it gives first year EGD PSTs the opportunity to share their individual experiences, exchange ideas, learn the importance of teamwork and makes teaching and learning a shared experience. Examples of the scaffolds used include providing multiple smaller tasks; demystifying complex views; providing constructive timeous feedback so first year EGD PSTs can use it to better understand the task they face or suggestions about what they could try; peers that guide each other through the steps they need to follow, such as a manipulation of objects, seeing the relationship between parts, seeing how parts fit together and assembling all parts.

Scaffolding enables first year EGD PSTs to learn to operate independently at this level. In other words, the ZPD is used as a theory behind the tools for teaching. Through teaching and scaffolding the first year EGD PSTs' learning with smaller tasks that are progressively more difficult, first year EGD PSTs develop knowledge, skills, behaviours, conceptions and attitudes that expand the range of what they can do with assistance and tasks that they are not able to do on their own. (Wass, Harland & Mercer, 2011). This “scaffolding” refers to the guidance that allows first year EGD PSTs to more readily master a task that is beyond their existing skill set or knowledge base. Scaffolding includes both affective and cognitive elements. In addition to providing assistance and timely feedback, scaffolding involves communicating reassurance; helping students understand the habits of mind necessary to become proficient and helps them understand the task’s relevance and how their personal trajectory toward competence could unfold (Nasir et al., 2014).

10.5. Conclusion

This chapter provided answer to Research Question 4, which is: Does the reading and interpreting of AD, by first year EGD PSTs, change after mediation? If so how? If not, why? Data generated via think-aloud task two, semi-structured individual interviews, collages and post collage focus group interviews were used to respond to the question.

The data from think-aloud task two indicates that the reading and interpretation of AD by first year EGD PSTs improved after exposure to the teaching mediation program. The improvement noted was in respect of first year EGD PSTs ability to read and interpret information from the title block, their ability to differentiate between orthographic and isometric projections and visualize different views, their ability to see the relationship between objects and rotate objects mentally, and to measure correctly and recall the SANS code of practice as well as assemble parts and draw different lines types. This improvement made the third part of the research question redundant.

As to the “how” aspect in the second part of the research question, the aforementioned changes could be attributed to three key factors, as revealed in the collages and interviews; specifically, teaching strategies, tools of the trade (understanding the demystified terminology of measure, rotate, assemble) and step-by-step support. Key concepts that undergirded these three reasons are scaffolding and ZPD. In the next chapter in present recommendations that follow from these findings.

CHAPTER 11:

FINAL INTERPRETATION, SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

11.1 Introduction

This qualitative study sought to explore how first year engineering graphics and design (EGD) pre-service teachers (PSTs) read and interpret assembly drawing at the DS University of Technology (*a nomme de plume*). Multiple methods were used to generate data: the Purdue spatial visualization test (PSVT), think aloud tasks, individual interviews, collages, concept maps and focus group interviews. The task based activity was "marked" to identify areas of strengths and weaknesses in how first year EGD PSTs read and interpret AD. Content analysis was used to make sense of the data from the interviews, collages, concept maps and focus group interviews. The constructs from the theoretical framework, namely, Vygotsky's zone of proximal development (ZPD) and Gardner's multiple intelligences (MI), guided the data analysis. This concluding chapter serves to bring together the key findings that arose from the data generated in response to the four research questions that guided the study.

In the next section, a summary of the research findings corresponding to each research question is presented. This is followed by a discussion of teaching and learning in the ZDP. Next, some recommendations are suggested and this concludes the chapter.

11.2. Summary of key findings

11.2.1. Findings for Research Questions 1 to 4

A summary of the themes that emerged from the data, organized according to the four research questions, is given on the next page in Table 11.1.

Table 11. 1 Summary of key findings

Research question	Themes
1. What are first year EGD PSTs' levels of spatial visualization ability?	As the number of rotations increased first year EGD PSTs encountered greater difficult in visualizing and mentally manipulating the objects.
2. What challenges do first year EGD PSTs encounter when they read and interpret AD?	• Inability to read and interpret information in title block • Inability to differentiate orthographic and isometric projection and visualize the different views • Inability to visualize: see spatial relationships between objects and rotate objects • Inability to measure accurately and apply SANS code of practice • Inability to assemble and recognize lines
3. Why do first year EGD PSTs encounter challenges when the read and interpret AD?	• School challenges • Teacher challenges • Parent challenges • Learner challenges
4. Does the reading and interpreting of AD by first year EGD PSTs, change after mediation? If so how? If not, why	• Teaching strategies • Tools of the trade: Understand demystified terminology, measure, rotate , assemble • Step-by-step support

The overall finding for Research Question 1 sheds light on first year EGD PSTs' spatial ability. The findings reveal that as the object has to undergo more rotations the more difficult is becomes for first year EGD PSTs mentally visualize and manipulate the object. The majority of first year EGD PSTs were able to mentally manipulate the object even once. This means that the majority of first year EGD PSTs have poorly developed spatial ability. The challenges that first year EGD PSTs encounter when they read and interpret AD is interconnected with their spatial visualization ability.

The analysis of data generated by think-aloud task one, individual interviews, collages, concept maps and a post collage focus group interview reveal that first year EGD PSTs encountered five principal challenges when they attempt to read and interpret AD. These challenges were their inability to: read and interpret information in title block, to differentiate between orthographic and isometric projections and visualize the different views, to visualize, that is see spatial relationships between objects and rotate objects, and to measure accurately and apply the SANS code of practice along with an inability to assemble and recognize lines.

First year EGD PSTs encountered the above mentioned limitations when they read and interpret AD due to challenges arising from their school, teachers, and parents and within themselves. An intervention mediation programme was designed by the EGD lecturer at DS University of Technology to assist first year EGD PSTs overcome the challenges they had re-encountered when they read and interpreted AD. After the mediation, their participation in think-aloud task two revealed improvements in the first year EGD PSTs' task performance, indicating that their ability to read and interpret AD had improved. This particular finding confirms that spatial ability, is the ability to mentally rotate or manipulate objects, is not innate. Instead, it can be learned with appropriate teaching.

Three factors shaped the way in which first year EGD PSTs could read and interpret AD after mediation. These were teaching strategies, tools of the trade (that is, understanding the now demystified terminology, measure, rotate, assemble) and step-by-step support.

11. 3 Towards the ZPD: linking Teaching of EGD and learning how to read and interpret AD (new contribution)

The data generated in response to Research Questions 2, 3 and 4 reveal that first year EGD PSTs had experienced teaching and learning as separate processes when they were in high school (*school you could not ask questions, the teacher just taught and left , he was not bothered if we understood).* In other words, there was a lack of concern on how learning had occurred in high school. This lack of concern of how learning had occurred shaped the prior EGD knowledge and spatial ability that first year EGD PSTs carried with them to DS University of Technology. The data from Research Question 4 illustrates how, at DS University of Technology, the lecturer's concern for how learning occurs, the lecturer's content knowledge, and use of different teaching strategies, the lecturer's knowledge of learners' learning styles enabled first year EGD PSTs' spatial ability to grow and their ability to read and interpret AD to improve (*now my confidence is improving, the classroom atmosphere is relaxed, the lecturer encourages us, he used different teaching methods to help us undertand the work, different types of assessment to help us learn, I look forward to EGD lectures*).

The data from this study indicates that, in EGD, all too often ineffective teaching or instruction is not acknowledged to be the major factor contributing to ineffective learning in the subject. The assumption made is that if something has been taught then it should be automatically learnt, and if it is not learnt then the problem lies with the learners (in)ability or (lack of) motivation to learn. The bigger question that then arises is how to mediate the teaching and learning of AD by first year EGD PSTs in order to facilitate their reading and interpretation of AD. The findings from this study are used to propose a model for linking the teaching and learning of AD in EGD. Figure 11.1 depicts the model for linking teaching and learning of AD in EGD.

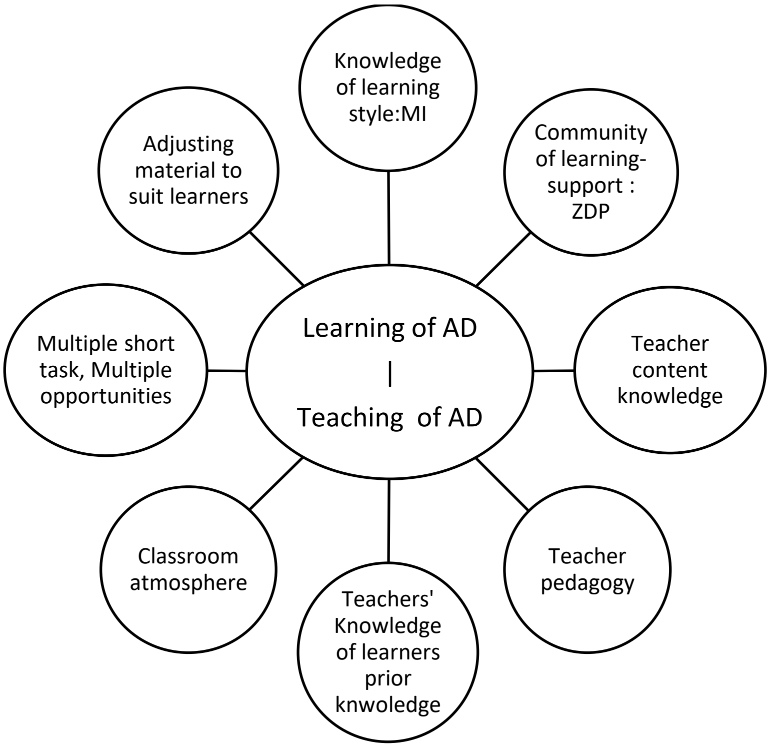


Figure11.1 Linking the teaching and learning of AD

The role of the teacher is both that of planner and mediator of learning and not a mere transmitter of content. It is important for the teacher to know which information or skills learners will require in order to master specific content. This means that the teacher should be a strategist who makes decisions, by reflecting on practice and in practice, about the underlying procedures and processes that need to be acquired for learning to be effective.

Applying the above model to the teaching the reading and interpretation of AD

Some possible ways are given below to improve the current status quo of learners entering engineering related fields with poor spatial ability, and poor understanding of the nomenclature of EGD, and inability to differentiate between different views, draw to scale or apply SANS code of practice.

- Motivate students to learn the basics by approaching engineering graphics as a language of visualization and communication with rules and standards, like any other language. This means teaching the nomenclature of EGD and getting students to use the nomenclature appropriately. I base the notion of teaching the nomenclature of EGD on the work of Metraglia et al. (2011), who argue that when you know the meaning and the pronunciation of words, you are able to make sense of language. Similarly, when you are understand the terms that are used in a problem or question, you can respond appropriately.
- Train students to use mental imagery, and engage in exercises involving modelling and sketching, and exercises that link three dimensional models to different views used in multi-view sketching and drawing.
- Teach the SANS code of practice explicitly. A few lessons should be dedicated to unpacking the SANS code of practice for students to become familiar with the code, thereafter demonstrate the applications of each code in AD problem. The code become the rules for drawing. When you know the drawing rules and you know how to design drawings for specific goals, then you can use engineering graphics to solve design problems. By focusing on engineering graphics as a language through which information is communicated, students may be more interested in learning the code of communication, i.e. rules and fundamentals (Canty & Seery, 2012).
- Assess students' prior knowledge in EGD to gauge their real level of spatial ability and ability to read and interpret AD in order to design introductory tasks focused on the development of a solid basic grounding. Assessment tools should be aimed at evaluating both comprehension of the fundamental knowledge and skills in producing ADs. Have multiple short tasks to encourage many opportunities to practice and apply knowledge and skills.
- Assess students' prior knowledge of scale and dimensions in order to develop tasks to scaffold learning of scales and dimensions.

11.4. Implications

The findings of this study have the following implications.

- Spatial ability and ability to mentally rotate and manipulate objects are not innate. Instead, they can be improved with appropriate teaching involving multiple opportunities to practice these skills.
- An interaction-enabled relaxed teaching and learning environment is needed to scaffold learning of spatial ability, visualization, measuring and dimensioning.
- Female students are just as capable as male students when it comes to spatial ability and mentally rotating or manipulating objects.

11.5. Recommendations

The following recommendations stem from the findings of this study.

- There needs to be cooperation between Universities of technology and high schools, especially non-technical high schools, by proposing introductory engineering graphics courses tailored to high school learners interested in pursuing engineering related courses at tertiary institutions, so as to teach them some of the basics before they enter university.
- Additional introductory courses should be provided for engineering students at universities and colleges, where students who feel they are weak in the basics can attend integrative lessons to better understand the key concepts of engineering graphics.
- Practicing teachers of EGD need in-service training to help them keep abreast of content knowledge and pedagogy.
- Working partnerships need to be forged between schools with poor resources for EGD, and tertiary institutions, for learners to make use of the EGD workshops at universities.
- Further research is needed on first year female EGD PST students' spatial ability and ability to read and interpret AD. There are more female PSTs enrolled for the module than males at AD University of Technology and they performed better than their male counterparts in the PSVT. Research is also need for all EGD students entering all engineering related fields.

11.6 Conclusion

An intervention model is now available to improve the teaching of AD at teacher training institutions. The teaching intervention programme designed in response to first year EGD PSTs' poor spatial ability, and poor ability to read and interpret AD was appreciated by the first year EGD PSTs, as it assisted them in improving their spatial ability and their ability to read and interpret AD. It is envisaged that these first year EGD PSTs will have honed their content knowledge and pedagogy so that when they graduate to teach AD at a school, they will be able to produce learners with the necessary spatial ability for pursuit of engineering careers, thereby making an essential contribution to the skills needed to develop the country.

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APPENDICES

APPENDIX A1

ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

28 November 2017

Mr Douglas TS Sotsaka 210555976
School of Education
Edgewood Campus

Dear Mr Sotsaka

Protocol reference number: HSS/2204/017D
Project title: Unmasking how First year Pre-service Engineering Graphics and Design teachers read and interpret Assembly drawing at a particular university of technology: A mixed method approach.

Expedited Approval

In response to your application dated 21 November 2017, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

Please note: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

……………………………………
Dr Shamila Naidoo (Deputy Chair)

/px

cc Supervisor: Dr A Singh-Pillay
cc Academic Leader Research: Dr SB Khoza
cc School Administrator: Ms T Khumalo and Ms P Ncayiyana

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
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APPENDIX A2

EDITING CERTIFICATE

Sheelagh Halstead

BSc (Natal) HED (UNISA) MSc (UKZN)

Independent Education Consultant

13 Denbigh Road tel: 010 203 9019

Parkwood, Johannesburg cell: 082 3717650

2193 email: halstead@nitrosoft.co.za

EDITING CERTIFICATE

NAME: Douglas Thembinkosi Sibusiso Sotsaka

AFFILIATION: Science, Mathematics, and Technology Education Cluster, Faculty of Education, University of KwaZulu-Natal.

Draft PhD thesis: *Unmasking how Pre-service Engineering Graphics and Design teachers read and interpret Assembly drawing at a particular University of technology: A case study in Umgungundlovu, KwaZulu-Natal*

I confirm that I have edited this draft thesis for grammar and appropriate use of academic language. I have made some recommendations regarding the structure of his argument. In the preliminary pages I edited the abstract and list of acronyms. For the reference list, I have indicted those that were superfluous and made some minor corrections and inserted notes where I thought more information was needed. I have addressed the issue of the list being in alphabetical order.

As an independent educational consultant, one of my specialisations is editing academic documents. I am a native English speaker. I obtained a BSc at the University of Natal, with chemistry and applied mathematics majors. After graduation, I was a Research Officer in the Ministry of Roads and Road Traffic in, as was then, Rhodesia. My duties included writing reports and editing those of my colleagues. Some years later I entered the teaching profession and studied with UNISA for a postgraduate Higher Education Diploma, achieving a distinction for the English language module. After 20 years teaching at high school, I took up an academic position at the University of KwaZulu-Natal, where I completed an MSc. in chemistry education and wrote several research articles. Since retirement about eight years ago, I have edited many academic papers, theses and dissertations, several of which were judged to be *cum laude*, and some of which required no alterations from the examiners.

Sheelagh Edith Halstead 11th November 2019

Halstead

APPENDIX B1

Application letter to conduct research

Edgewood Campus
Private Bag X03
Ashwood
3605
18 April 2017

Dear: Head of Department: School of Education
Faculty of Art and Design
Durban University of Technology
15 FJ Sithole Road, Imbali,
Pietermaritzburg, 3201

RE: Request for permission to conduct research

My name is Douglas T.S. Sotsaka, I am a PhD candidate studying at the University of KwaZulu-Natal, Edgewood campus, South Africa. I am currently engaged in a research project entitled "An exploration of how Pre -service EDG teachers engage with Assembly Drawing: A gendered gaze: A case study of the pre-service teachers at Durban university of Technology, KwaZulu-Natal". I hereby seek permission to conduct this project at level 1 year EGD students the within the DUT campus. This study is purely for academic purposes and there will be no financial gain involved. It is expected that through this study that EGD lecturers will teach AD in a more nuanced manner and this will improve students' performance in the AD question in the examination module as a whole. You are assured that the findings of the research will not be used for any purpose other than the PhD dissertation. In this regard, no harm will be caused to the DUT, School of Education, and the student/s participating in this study. Furthermore, students' anonymity is assured. Pseudonyms will be used to protect their identity as well as their schools identity. All information disclosed will be kept in confidence. The participation in this research is voluntary and should you find that you wish to withdraw or terminate your permission for the research, you may do so without any negative consequences.

Thank you.
Yours faithfully

Douglas T.S. Sotsaka

Should you have any queries you can contact my supervisor

Dr. A. Singh –Pillay
Telephone no: 031- 260 3672 102
Email: pillaya5@ukzn.ac.za

The following personnel from the research office may be contacted:
Ms Phumelele Ximba Tel. No. 031 60 3587 Email: HssrecHumanities@ukzn.ac.za
Mr Premlall Mohun Tel. No. 031 260 4557 Email: HssrecHumanities@ukzn.ac.za

APPENDIX B2

Permission to conduct research

DUT DURBAN UNIVERSITY OF TECHNOLOGY

FACULTY OF ARTS & DESIGN

SCHOOL OF EDUCATION

School of Education
Faculty of Arts and Design
Durban University of Technology
15 FJ Sithole Road, Imbali,
Pietermaritzburg, 3201

P O Box 101112,
Scottsville, 3209, South Africa
Tel: 033 845 8927
Fax: 033 845 8936
Email: upasnar@dut.ac.za
Contact Secretary: Upasna Rampersadh

www.dut.ac.za

Edgewood Campus
Private Bag X03
Ashwood
3605
18 April 2017

Dear: Head of Department: School of Education
Faculty of Art and Design
Durban University of Technology
15 FJ Sithole Road, Imbali,
Pietermaritzburg, 3201

RE: Request for permission to conduct research

My name is Douglas T.S. Sotsaka, I am a PhD candidate studying at the University of KwaZulu-Natal, Edgewood campus, South Africa. I am currently engaged in a research project entitled "An exploration of how Pre -service EDG teachers engage with Assembly Drawing: A gendered gaze: A case study of the pre-service teachers at Durban university of Technology, KwaZulu-Natal". I hereby seek permission to conduct this project at level 1 year EGD students within the DUT campus. This study is purely for academic purposes and there will be no financial gain involved. It is expected that through this study that EGD lecturers will teach AD in a more nuanced manner and this will improve students' performance in the AD question in the examination module as a whole. You are assured that the findings of the research will not be used for any purpose other than the PhD dissertation. In this regard, no harm will be caused to the DUT, School of Education, and the student/s participating in this study. Furthermore, students' anonymity is assured. Pseudonyms will be used to protect their identity as well as their schools identity. All information disclosed will be kept confidential.

Thank you.
Yours faithfully

Douglas T.S. Sotsaka

----------------------------------Date 18/04/2017

Permission Granted

HOD ----------------------------- Date 19/04/17.

Should you have any queries you can contact my supervisor

Dr. A. Singh –Pillay
Telephone no: 031- 260 3672 102
Email: pillaya5@ukzn.ac.za

The following personnel from the research office may be contacted:
Ms Phumelele Ximba Tel. No. 031 60 3587 Email: HssrecHumanities@ukzn.ac.za
Mr Premlall Mohun Tel. No. 031 260 4557 Email: HssrecHumanities@ukzn.ac.za

APPENDIX B3

Informed consent letter

School of Education
College of Humanities
University of KwaZulu-Natal
Edgewood Campus
17 August 2018

Dear Participant

INFORMED CONSENT LETTER

My name is Douglas T.S. Sotsaka, I am a PhD candidate studying at the University of Zulu-Natal, Edgewood campus, South Africa. I am interested in learning about Unmasking how Pre -service Engineering Graphics and Design teachers read and interpret Assembly drawing at a particular university of technology. To gather the information, I will ask you to complete a Purdue Spatial Visualization test, two think aloud tasks based on AD, individual interviews, collage making, concept mapping and I will conduct focus group interviews. In addition I also require permission to video record the think aloud tasks and interviews.

Please note that:

- Your confidentiality is guaranteed as your inputs will not be attributed to you in person, but reported only as a population member opinion.
- The Purdue Spatial Visualization test.
- The think aloud task based activities will take 1 hour each.
- The individual interview may last for about 10 to 15 minutes and may be split depending on your preference.
- The collage and concept mapping will take 1hour each.
- The focus group interview will take 1 hour
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- Data will be stored in secure storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- The research aims at understanding how Pre -service Engineering Graphics and Design teachers read and interpret Assembly drawing at a particular university of technology.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.

- If you are willing to be interviewed and have the interview video recorded please indicate (by ticking as applicable) whether or not you are willing to allow the recording by the following equipment:

	Willing	Not willing
Audio equipment		
Video equipment		

I can be contacted at: Tel. No.: 033 845 9064
Cell. No.: 081 577 1203
Email: douglassibusiso@gmail.com

My supervisor is Dr. A Singh- Pillay who is located at the School of Education, Science and Technology cluster, Edgewood campus of the University of KwaZulu-Natal.
Contact details: email: pillaya5@ukzn.ac.za Phone number: 031 26053672

The following personal from the research office may be contacted:
Ms Phumelele Ximba Tel No. 031 260 3587 Email: HssrecHumanities@ukzn.ac.za
Mr Premlall Mohun Tel: No. 031 260 4557 Email: HssrecHumanities@ukzn.ac.za

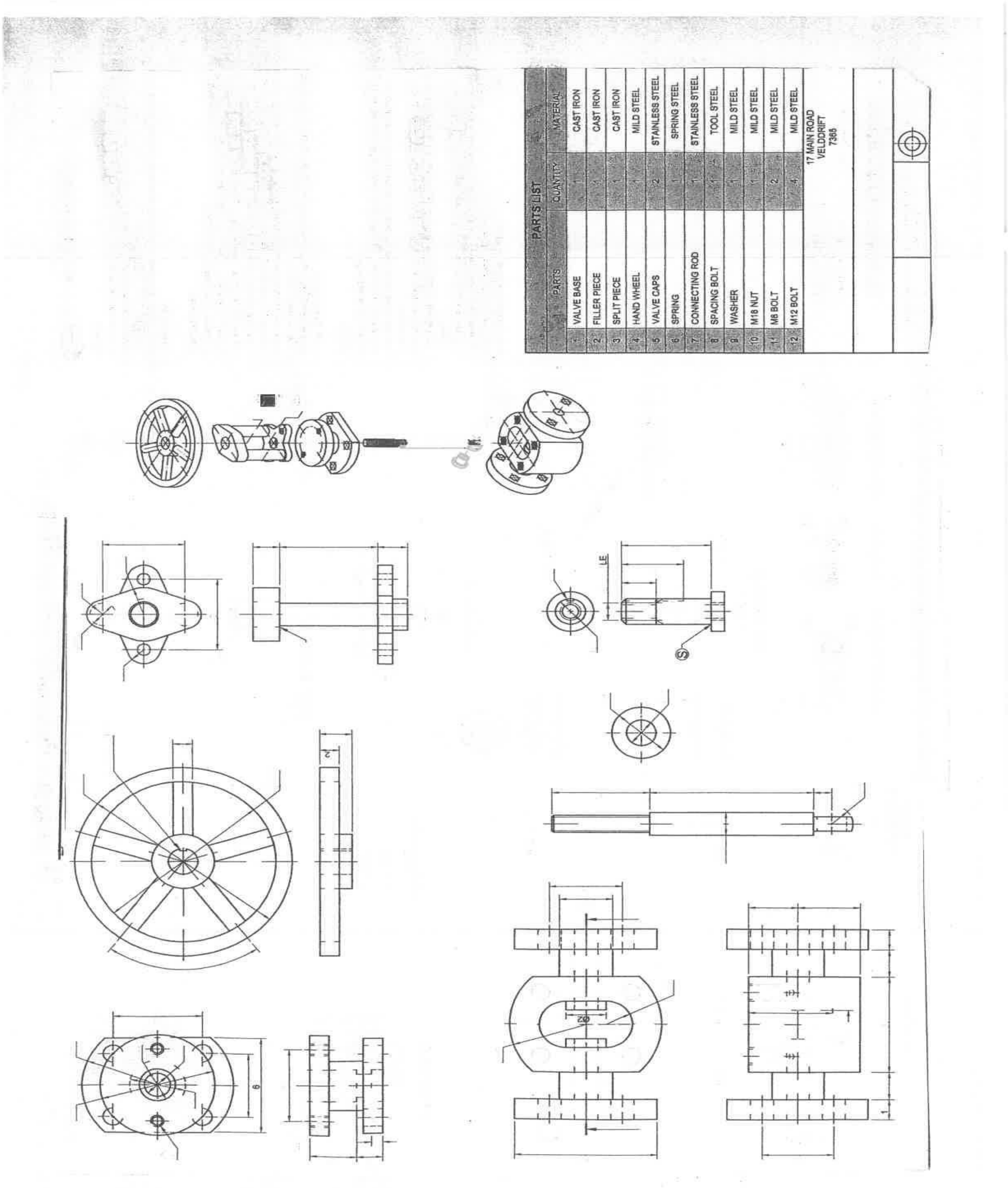
Thank you for your contribution to this research.

DECLARATION

I……………………………………………………………………………………… (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participate in the research project.

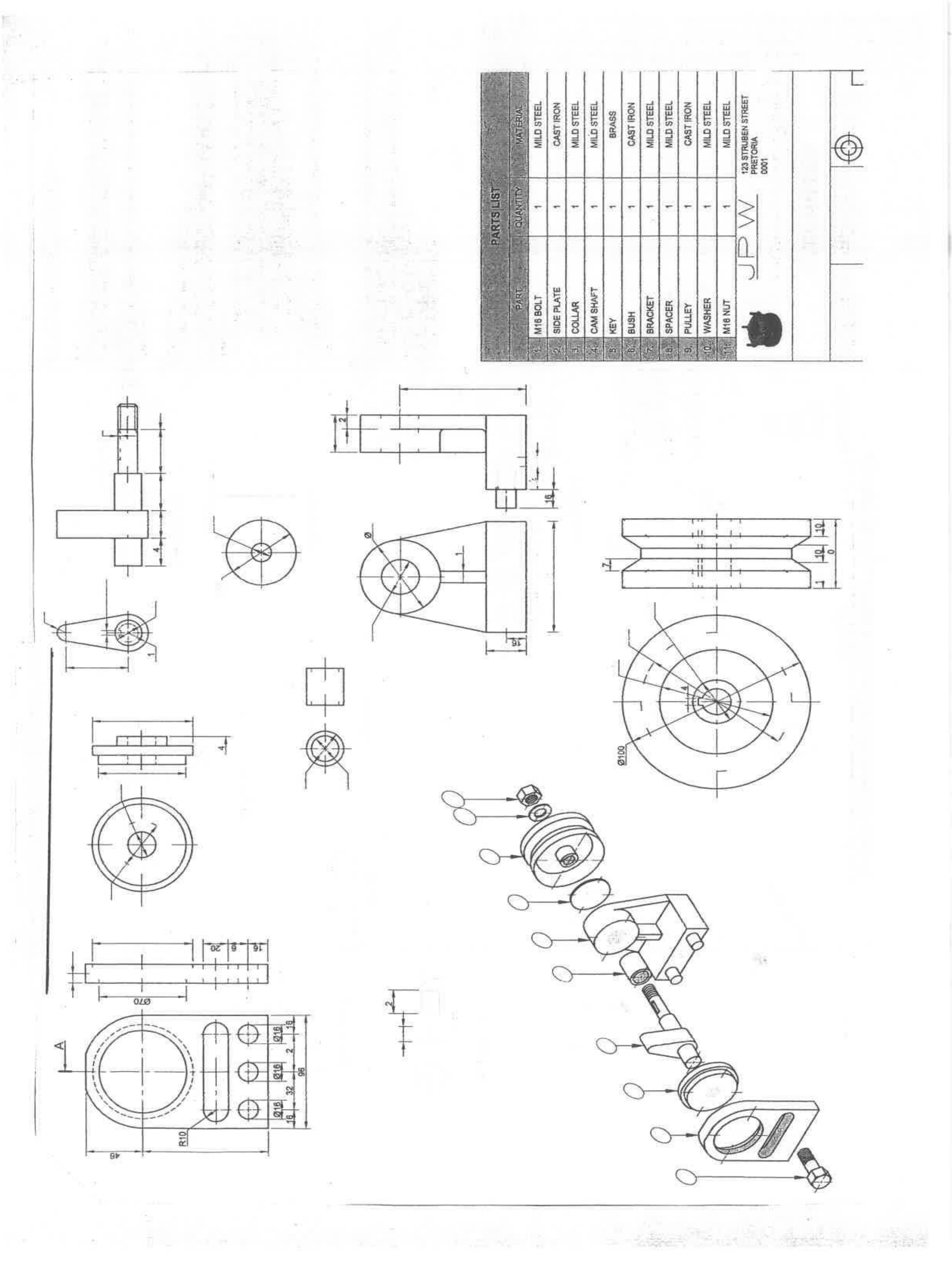
APPENDIX C 1

THINK ALOUD TASK ONE



APPENDIX C2

THINK ALOUD TASK TWO



APPENDIX C3

INDIVIDUAL INTERVIEW QUESTIONS

Post think aloud Task One interview questions

1. How did you feel about the task?
2. What were your first thoughts when you were given the task to complete?
3. Was the task simple/difficult- please explain
4. Out of the 12 parts given in the task, which one did you like/understand? Please explain why?
5. Out of the 12 parts given in the task, which ones did you not like/understand/ manage? Please explain why?
6. Take me through how you solved part … of the task (here you refer to the ones they got wrong, you know this from marking their tasks and providing detailed feedback)
7. How did you interpret this part of the problem. And why do you interpret it like you do
8. Do you think sufficient information was provided to solve the task?
9. What do you find challenging in AD /or easy in AD why is that
10. Did you apply the SANS code? how
11. Is applying the code easy for you
12. How do you prepare for AD tasks
13. Where you able to mentally rotate the diagram? Why … how did you do it
14. What makes you respond to the question the way you do
15. How did you know that this was the dimensions you have to use?
16. Did you know how to identify the views referred to in the task?
17. Why do you think students perform poorly in AD
18. Do girls perform better that boy in AD tasks or is it vice versa- please explain
19. How can you rate your visualization skill to interpret that task from scale of 1 as poor to 5 as excellent?

APPENDIX C 4

INDIVIDUAL INTERVIEW QUESTIONS

Post think aloud Task Two interview questions

Individual interview questions

20. How did you feel about the task?
21. What were your first thoughts when you were given the task to complete?
22. Was the task simple/difficult- please explain?
23. What made it simply / difficult?
24. Out of the 11 parts given in the task, which one did you like/understand? Please explain why?
25. Out of the 11 parts given in the task, which ones did you not like/understand/ manage? Please explain why?
26. Take me through how you solved part … of the task (here you refer to the ones they got wrong, you know this from marking their tasks and providing detailed feedback)?
27. How did you interpret this part of the problem …. And why do you interpret it like you do?
28. How long did you take to be able to visualize the possibilities of assembling the parts?
29. Do you think sufficient information was provided to solve the task?
30. What do you find challenging in AD /or easy in AD why is that?
31. Did you apply the SANS code, how?
32. Is applying the SANS code easy for you?
33. What is your interpretation of terminology used in that task?
34. How do you prepare for AD tasks?
35. Where you able to mentally rotate the diagram? Why … how did you do it?
36. What makes you respond to the question the way you do?
37. How did you know that this was the dimensions you have to use?
38. Did you know how to identify the views referred to in the task?
39. Why do you think students perform poorly in AD
40. Do girls perform better that boy in AD tasks or is it vice versa- please explain
41. How can you rate your visualization skill to interpret that task from scale of 1 as poor to 5 as excellent?
42. What you think should be added or removed in this activity to be more interesting?
43. In one or two words what can you call Assembly Drawing that you were asked to draw?

APPENDIX C 5

Post collage focus group interview

1. What does each picture depict- explain why you chose it to tell your story /experiences of AD?
2. What promotes your engagements with AD?
3. What inhibits your engagement with AD?
4. Do boys/girls do better at AD tasks?
5. Do your family think you should excel at AD or other things?

APPENDIX C 6

PURDUE SPATIAL TEST

Purdue
Spatial Visualization
Tests

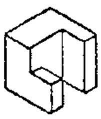
Roland B. Guay

VISUALIZATION OF ROTATIONS

Do NOT open this booklet until you are instructed to do so.

Answers A, B, C, and E are wrong. Only drawing D looks like the object rotated according to the given rotation. Remember that each question has only one correct answer.

Now look at the next example shown below and try to select the drawing that looks like the object in the correct position when the given rotation is applied.



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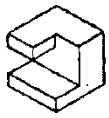

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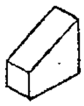

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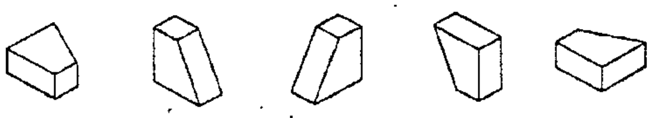


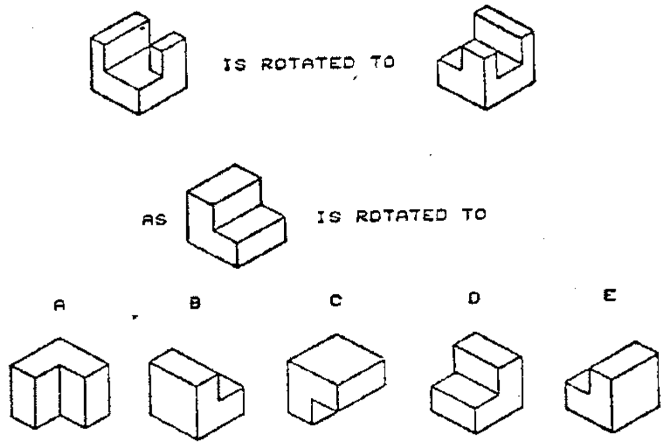
Notice that the given rotation in this example is more complex. The correct answer for this example is B.

Do NOT make any marks in this booklet.
Mark your answers on the separate answer card.
You will be told when to begin.

Do NOT make any marks in this booklet.
Mark your answers on the separate answer card.

Directions

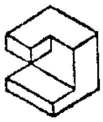
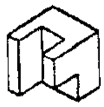
This test consists of 30 questions designed to see how well you can visualize the rotation of three-dimensional objects. Shown below is an example of the type of question included in the second section.

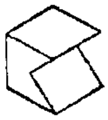


You are to:

1. study how the object in the top line of the question is rotated;
2. picture in your mind what the object shown in the middle line of the question looks like when rotated in exactly the same manner;
3. select from among the five drawings (A, B, C, D, or E) given in the bottom line of the question the one that looks like the object rotated in the correct position.

What is the correct answer to the example shown above?

1  IS ROTATED TO 

AS  IS ROTATED TO

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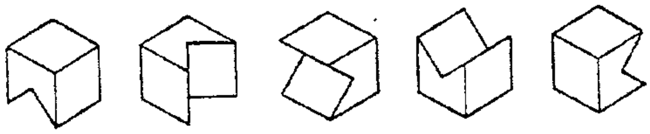
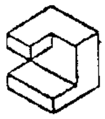
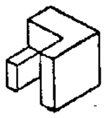


2  IS ROTATED TO 

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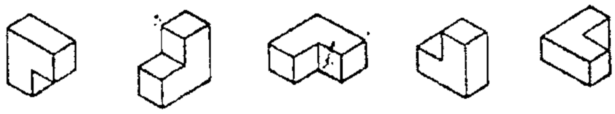

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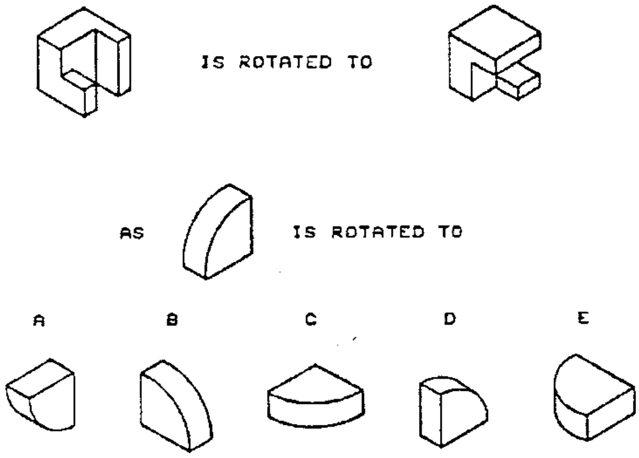
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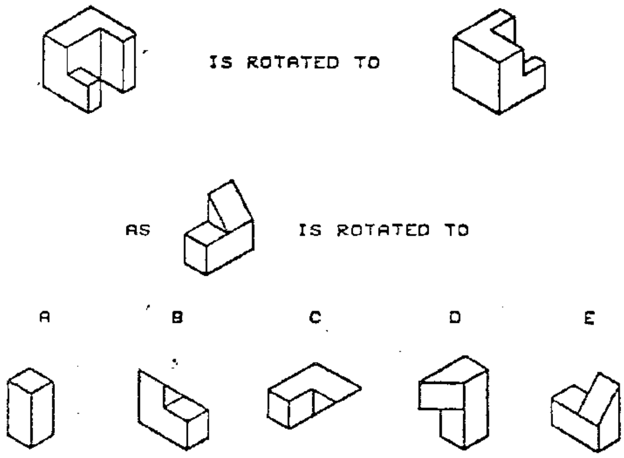
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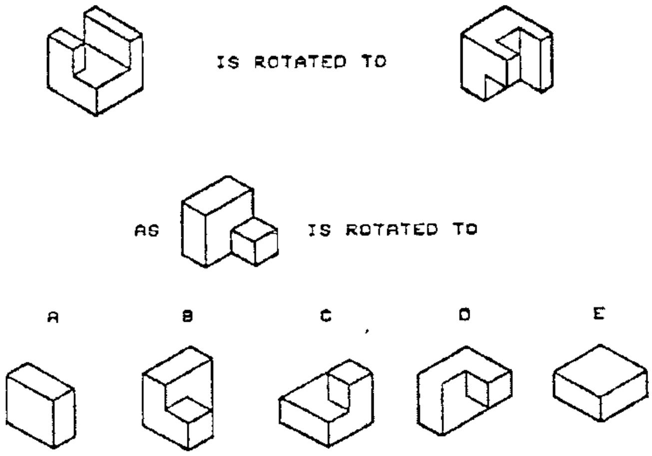
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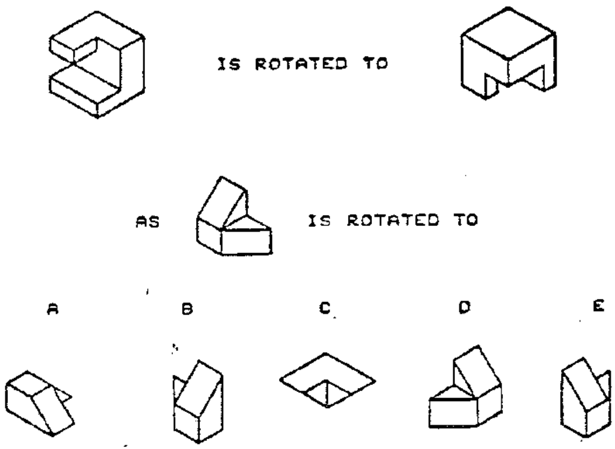
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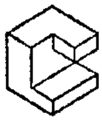
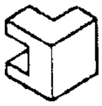
7  IS ROTATED TO 

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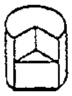
A 

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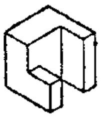
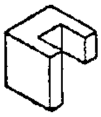
8  IS ROTATED TO 

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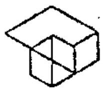
E 

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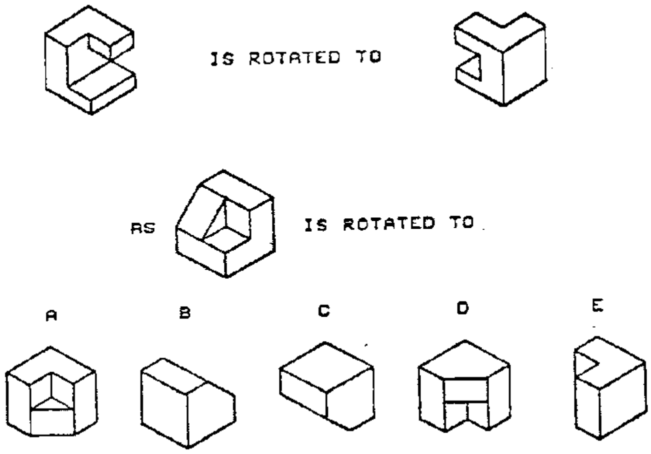
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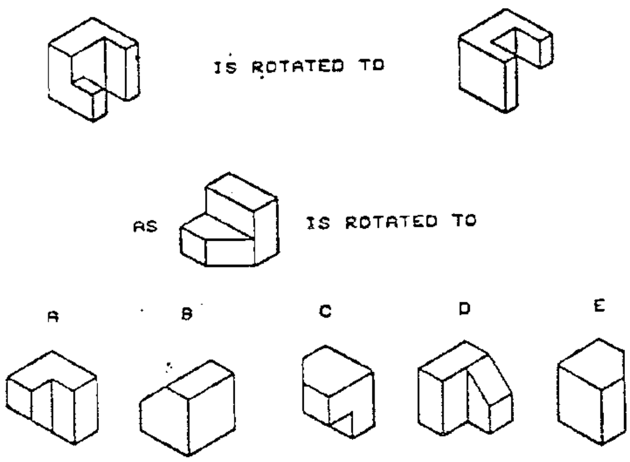
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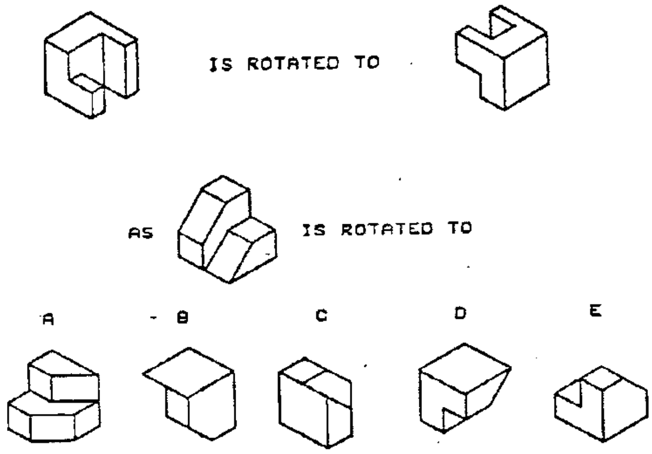
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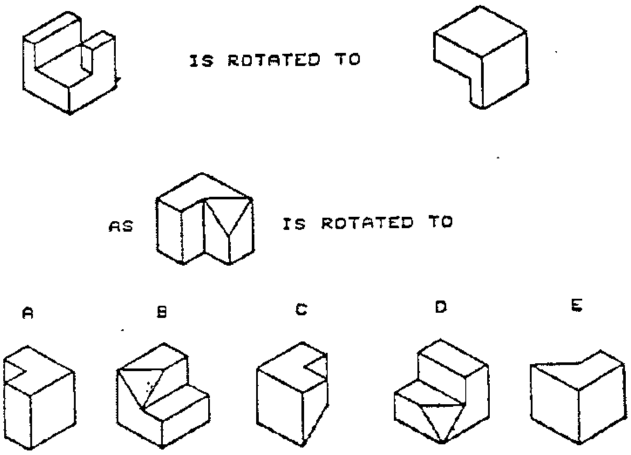
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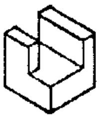
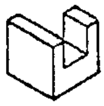
13  IS ROTATED TO 

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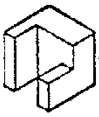
14  IS ROTATED TO 

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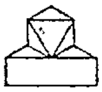
B 
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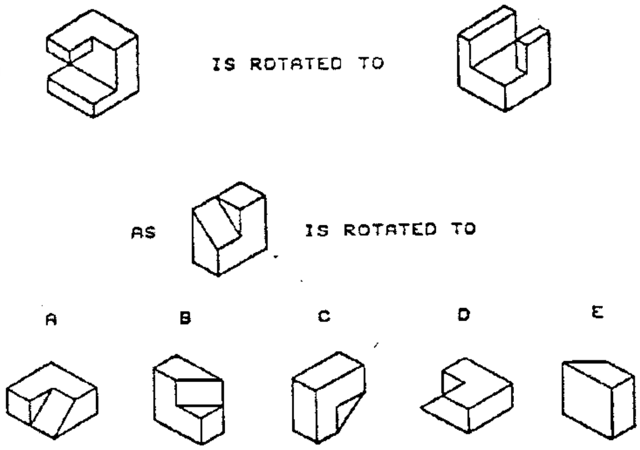
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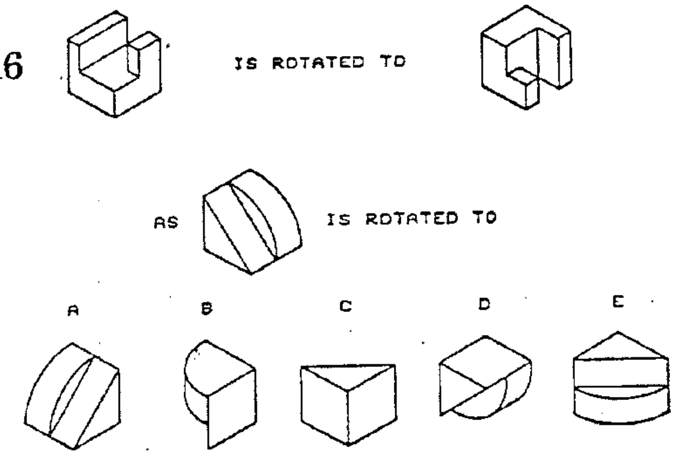
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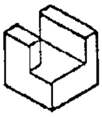
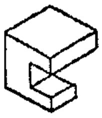
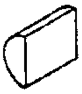
17  IS ROTATED TO 

AS  IS ROTATED TO

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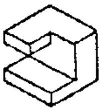
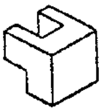
18  IS ROTATED TO 

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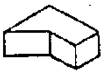
D 

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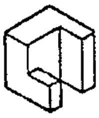
19  IS ROTATED TO 

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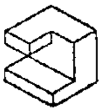
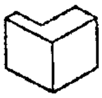
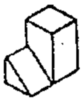
20  IS ROTATED TO 

AS  IS ROTATED TO

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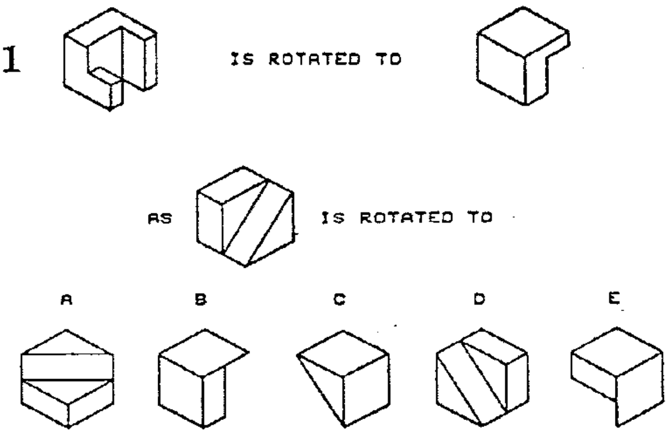
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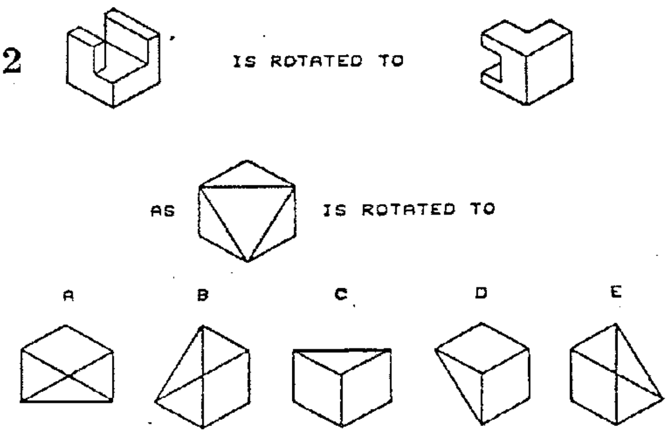
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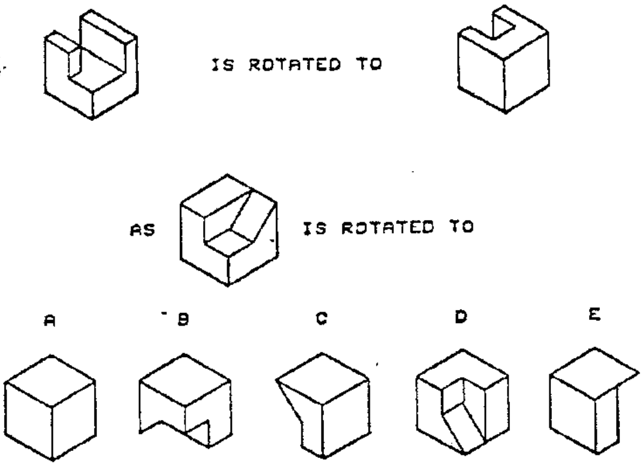
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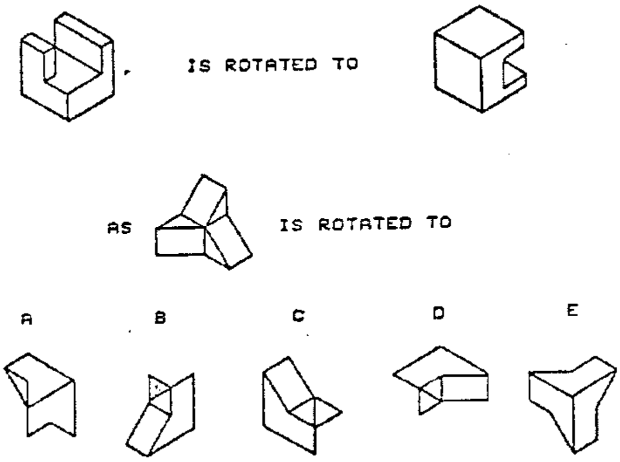
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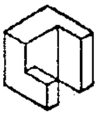
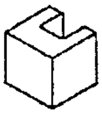
25  IS ROTATED TO 

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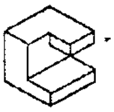
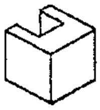
26  IS ROTATED TO 

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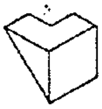
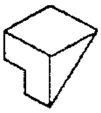
B 

C 

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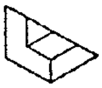
E 

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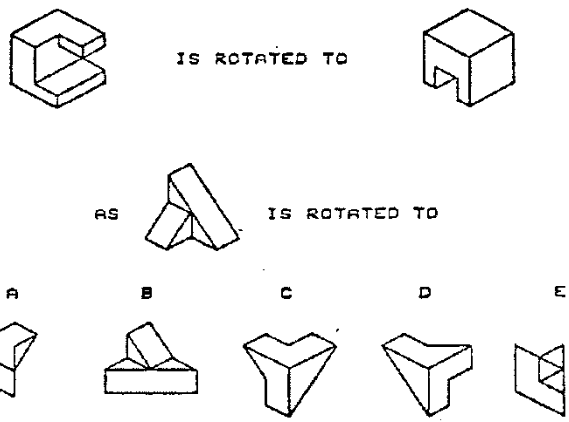
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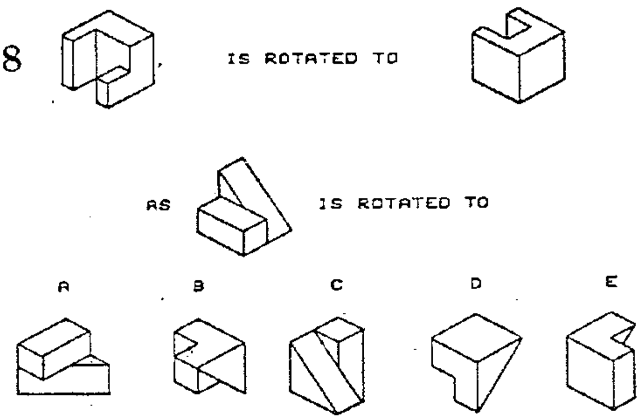
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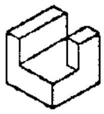
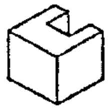
29  IS ROTATED TO 

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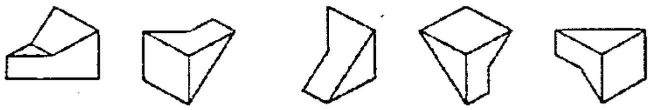
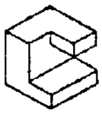
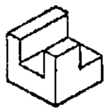
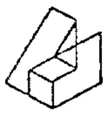


30  IS ROTATED TO 

AS  IS ROTATED TO

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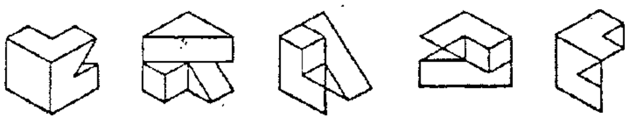

APPENDIX D 1

Table Think aloud task one individual interview response

Participant	**Excerpt**
P1	*"It is given that the isometric exploded drawing of the parts can be assembled, scale is 1: 1, it is in the third angle, but sometime, when you read these thing you just read them, the words remain foreign, you don't get any clue of how or where or when to use this information, these terms are so hard to understand and remember"*
P2	*"It would have been easier, if you were to just draw as you see it on the exploded drawing, but now the problem, is that you have to construct the bolt, you need to know how to construct the nu measurements must be accurate, so it becomes a bit complicated when it comes to that"*
P3	*"I find it very difficult to imagine drawings in 3D, I try so hard, if someone could train me how to do this I will learn, what must I do first, I will go with my gut feeling, I don't have a strategy to solve this"*
P4	"*I have forgotten, how to make sense of the given information, I remember my high school teacher saying that this is the starting point, but I don't know how or why, I tried looking around to see what other students were doing but it did not help, it is easier to read words rather diagrams*"
P5	*"This task is bit difficult and I am not able to remember the. I can see here I am required to do construction of bolt and nut. Eish I cannot remember how to do calculations in order to do the construction of bolt. Don't know where to start now"*
P5	"*We had 10 textbook to share among 45 students, it was hard to read and study- the terms in EGD are confusing, there were no models to see what the teachers was talking about, so you could then imagine the views of it*"
P7	*"There was one toilet for over 400 girls, can you imagine how hard it was for girls, it was always dirty, girls always left school when they needed to use the loo"*

P9	*"how can learner learn if the teacher does not know the content, does not come to class of time, does not care if learners come to class, his famous line was i will still get paid even if you fail"*
P10	*"I prefer task with words rather than diagrams, I have no visual skills, I learn by reading"*
P11	"*I can see the one view that is drawn, but I battle to imagine the sides that are not drawn, I also cannot see the relationship between some objects, I am hopeless, I want to quit this course before we get any further and it becomes more difficult, this 2D /3D stresses me* "
P12	*"We are poor, I walk to school to save money, after school I cook and clean, take care of my siblings, My mother works as a machinist at a clothing factor. She wants me to become an engineer so we can life a better life"*
P13	"*there was a discipline policy in paper- it was not followed at all, it's like it never existed, late coming, absconding, fights, disruptions were normal at the school I attended- lessons were often cancelled and teacher would sit in the staffroom, or he would get an ex-student to teach us".*
P14	*"I lack imagination, I can't see things mentally, I need to see an object physically to understand its structure in different views, I will try and see what works, its frustrating not knowing for sure*"
P15	*"Yes, I swear a lot, fighting, swearing, guns this is normal and acceptable where I come from, we used to swear at school during lessons to protect ourselves, Swearing makes you look tough and hard, I was caught up with this image of thug life, I spent more time out of class than in class"*
P15	*"The fights, smoking of drugs prevented many of us from focusing on learning we were always trying to survive the school day to go home to our family responsibilities"*
P17	"*I can physically flip an object that is in physically front of me, I cannot mentally flip an object nor can I image the hidden sides of an object or imagine how they fit together, with large objects I can try but the smaller object that is almost impossible, I can't imagine who to assemble the small part, its easier to do it physically*"
P18	*"When I got home I had to clean, cook, wash, take care of my siblings, there*

	was no time to study. I used to get up early, get my siblings ready for school then walk 5 km to school. I was always tired, my mum died and left me to bring up 4 children"
P20	*"The terms are so confusing, I really find EGD hard as I don't know how to visualise and move objects mentally"*

APPENDIX D 2

Table Think aloud task one focus group discussion.

Participant	**Except**
P9	"*there were no resource to teach, the teacher made no effort to explain or get models for us to see what he is talking about, when we used to mark our work, he will go over the easy example and leave out the ones we could not do, so in the exams I attempted the easy question on AD- I passed EGD because of PAT"* Group C -FGI
P13	*"Our principal was hardly in school, he was running his taxi business and tavern which was 500m from the school, he was not interested in rules or discipline, the learners used to hang around the tavern and only come to school for girls or to fight" Group B FGI*
P15	*"There were gangs coming to school and fights would occur daily, the lessons will stop, teachers will run to the staffroom, learners will run home" Group A FGI*
P18	*"We are poor, my mums is sick, after school I worked at the scrap yard to help put food on the table, that's physical work, I just never had time to study, sometime in our culture you are a child with adult responsibilities*" Group D FGI
P20	*"I prefer languages, and written text, the owner of the scrap yard encouraged me to do EGD, and my ward counsellor promised me a teaching post at my school once I qualify but I'm struggling, I also struggled at school the terms are difficult, the lesson is in English, EGD has its own language and I speak isiZulu- how confusing this is"* Group D, FGI

APPENDIX D 3

Table Think aloud Task Two individual interview

Participant	Excerpt
P1	*" I never experience EGD like this in high school, the lecrturer is easy going, he knows his content and the curriculum, you can ask as many quesations pertaining to the lesson and he take the time to explain, I' m starting to enjoy, he gives feedback to show where you are wrong EGD, In school you could not ask questions, the teacher just taught and left , he was not bothered if we understood"*
P1	"*I can now understand the jargon terms that were so difficult to understand in highschool, the leacture went all out to explain the terms in terms he breaks it down, he gave us short task on these difficult terms,we get mutliple opportunities to engage in different types of task, he provides feedback so you know what is wrong and can correct it, once this happens then you can understand the questions posed and respond to it*"
P5	"*the support from peers and the lecturer is good, the are multiple chances for learning and mastering of EGD skills, the smaller and shorter tasks help me to grasp the concepts that were once so difficult and foreign to me, I'm enjoying this learning cooomunity*"
P7	*"the lecturer does not rush , because he is so familiar with the content , he breaks the content into small manageable tasks for us that become progressively difficult, we are suppoted by our peers and the lectuere if we cannot manage on our own- in this way EGD is doable and we are all improving our skills and knowledge"*
P13	*"He has spent a lot of time equpining us with the basic terms in EGD which we did not understand in high school, gave us many chances to work with the different views individually and in group he has even provided us with pencils and equipment that we need for EGD*"
P16	" *I always foud it difficult to deal with diagrams, I am just strating to get to grips with it, this lecturer realizes that we are all not the the same and we have dfifferent learning styles and methods of learning,*

	he has different types of tasks to cater for us for example demonstrations, practical hands on activites, join the dot acrtivities, it has helped me, and he does not redicule us when we get things wrong, he encourages and motivates us"
P21	*" I am unashamed to state I battled with scales and dimensioning in EGD, but now I have mastered how to use a ruler properly, I can draw to scale, can read drawing, identify part, flip them in my mind and put or assemble them together, I seek this information when I draw*"

APPENDIX D 4

Table Think aloud Task Two focus group interview

Participant	**Excerpt**
P3	*"with all the support provided in the mediation and the learning commmunity formed I have improved my visualisation skills, I can figure the relationship between parts of an assembly"*
P3	*"knowing that you are not alone in learning the difficult terms,being unable to differentiate the different view or lines is comforting, working closely with peers and the lecturer who help you to understand the parts that make up the sum of EGD is important. We all enjoy doing the smaller tasks set and are able to master the work tested in them. "* P3 Focus group interview
P5	"*I always struggled with mental rotation, but with all the excerises and assessments we did on these aspects I have gained enough experience to master it.* P5 focus group interview"
P9	"*I was always afraid to try in EGD at school my teacher was a terror, but now my confidence is improving, the classroom atmosphere is relaxed, the lecturer encourages us, he used different teaching methods to help us undertand the work, different types of assessment to help us learn, I look forward to EGD lectures*"
P21	*"I learnt how to make sense of the information in the title block and use the information to address the questions posed, the leacture has gone the extra mile in making us understand the jargon terms , different views, line types so that we can at draw and visualise what is required in the questions posed. We work individually and in pairs in this way more PSTs are developing the spatial visual reasoning skills needed in EGD"*

APPENDIX E1

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