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Instructional Practices by Engineering Graphics and Design Teachers: A Focus on Teaching and Learning of Isometric Drawing

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ABSTRACT

This qualitative study was conducted to investigate the instructional practices employed by Engineering Graphics and Design (EGD) teachers to teach Isometric Drawing (ID). This enquiry was necessitated by the growing concern from subject advisors and teachers about the poor performance of learners in isometric drawing. In an attempt to meet the objectives, this study adopted an interpretivist position to understand the instructional practices employed by teachers in teaching isometric drawing. This study used seven (7) EGD teachers who were conveniently selected, it is worth noting that the sample was influenced by the fact that EGD is a subject that is not common hence not many schools offer it. Data was collected through semi-structured interviews and was analyzed using a thematic analysis. Pedagogical Content Knowledge (PCK) was used as a framework that underpinned this study. Findings from this study indicated that all EGD teachers have the common understanding that ID involves converting 2d orthographic view into a 3d figure. The findings further revealed that teachers rely heavily on models, YouTube videos and AutoCAD to develop learners' spatial ability which is a very important skill. The study recommended that there should be no teacher hired to teach EGD without being fully trained. The study further recommended that future research should be conducted on learners to get their insight on why they are performing poorly in ID.

KEYWORDS

Isometric drawing; Engineering Graphics and Design; PCK; teachers.

INTRODUCTION

In past years there has been an outcry from teachers, subject advisors, examiners, moderators, and lecturers in the institutions of higher learning about the poor performance in ID. The same outcry has been heard from the side of learners in schools and students in universities, more especially the pre-service teachers about the difficulties of understanding ID which subsequently results to poor performance in ID. Each year the technical subjects diagnostic report always reports how poor learners are performing in ID and this is the call for concern as ID is the second highest contributing chapter in P2 of EGD as it contributes over 20 percent of the entire P2. The same concern was alluded to by Sotsaka (2015), that many learners are performing poorly in P2 due to learners in ability to understand Assembly Drawing (AD) and ID of which are chapters that contributes to over 65 percent of P2 when combined. Many authors including the Department of Basic Education (DBE) have attributed the poor performance to lack of spatial visualization skill. It is said that if learners can develop the spatial visualization skill the poor performance in ID can be curbed. Yue and Chen (2001) concur as they argue that spatial ability has been observed to affect learners' performance in EGD. It has been further observed that ICT has the ability to improve spatial visualization skill. Consequently, this study is conducted with an aim to investigate the way EGD teachers are teaching ID.

Poor performance in teaching and learning of isometric drawing is a globe concern as some studies conducted outside the country also allude to the same concern of poor performance in teaching and learning of isometric drawing. For example, a literature has revealed that high failure rate in ID has been an issue across the globe. In support of the aforementioned statement, a study done in India by Khabia and Khabia (2012, p.:5) reported that students with less visualization ability find it difficult to pass ID. As a result, AutoCAD was used in a study to improve spatial visualization and the results indicated an improved performance in ID. Furthermore, the findings in a study done in Nigeria by Eteli and Eniekenemi (2016) revealed that AutoCAD was used as a tool to improve the performance in teaching and learning of ID. Another Nigerian study indicated that there are difficulties in both teachers and learners in understanding of drawing (Chedi, 2015). The study further revealed that the poor performance is due learners failing to visualize and teachers unable to teach it due to not being fully trained, lack pedagogical skills to teach. The difficulties in ID are also evident locally which influenced the researcher to conduct this study locally. A study done in University of Zululand by Bayaga and Kok (2019) indicated that poor spatial visualization was observed in both students and lecturers and the findings of the study through using AutoCAD showed an increase in spatial visualization in both students and lecturers. In the same study it was apparent that students were drawing ID poorly and lack of spatial visualization was cited as the main problem (Bayaga & Kok, 2019). The poor performance in ID is collaborated by 2021 EGD's diagnostic report which indicates that EGD pass rates dropped from the previous year's owing to poor performance in ID. According to Report (2022), most candidates drew the isometric drawing incorrectly as they demonstrated poor drawing skills. Similarly, Report (2021) reported that most candidates are

struggling to convert a 2D drawing to a 3D drawing of which is what ID is all about. Based on all the above cited studies it shows that there is a problem in isometric drawing. The above studies show that a lack of spatial visualization skill is the reason isometric drawing is performed poorly hence they recommended how it can be improved however the problem still persist. It is for that reason that this study will investigate teachers' instructional practices in teaching isometric drawing to change the narrative and look at the side of teachers as the above studies are only focusing on the side of learners.

Statement of the Problem

Learners doing EGD in secondary schooling sector and those in higher institutions of higher learning have always been encountering problems with Isometric Drawing. These concerns have also been put forth by Department of Basic Education (DBE) in their yearly diagnostic report that learners are performing poorly in isometric drawing which contributes to 20 percent of their final examination paper two (DBE 2021). The same concern was alluded to by Sotsaka (2015), that many learners are performing poorly in P2 due to learners in ability to understand Assembly Drawing and Isometric Drawing of which are chapters that contributes to 65 percent of P2 when combined. As a result, this study seeks to investigate EGD teachers understanding of isometric drawing and how they are teaching it. This is done to establish where the problem lies in teaching and learning of isometric drawing. This line of thinking is influenced by the findings in a study by (Mlambo & Mkhwanazi, 2024; Sotsaka, 2015) that learners are performing poorly in assembly drawing because teachers are ill qualified hence they are unable to teach it. In light of the above, this study is aimed at investigating how are EGD teachers teaching ID.

Aim and Research Questions

The aim of this study was to investigate the instructional practices employed by EGD teachers when teaching ID. This was necessitated by the concerns from DBE that learners are performing poorly in ID. Findings that will be obtained from this study will shed light on how EGD teachers can best teach isometric drawing so that learners can perform better.

The objective of this study was to explore the instructional practices of Engineering Graphics and Design teachers in teaching and learning of isometric drawing. This was necessitated by the growing concern of learners continuously under performing in isometric drawing. This study was guided by the following main research question:

Main research question: What are Engineering Graphics and Design teachers' Instructional Practice in Teaching of Isometric Drawing?

The above main research question was supported by the following sub research questions:

- What are Engineering Graphics and Design teacher's understanding of Isometric Drawing?
- How do Engineering Graphics and Design teachers teach Isometric Drawing?
- What are the challenges do EGD teachers observe when teaching isometric drawing?

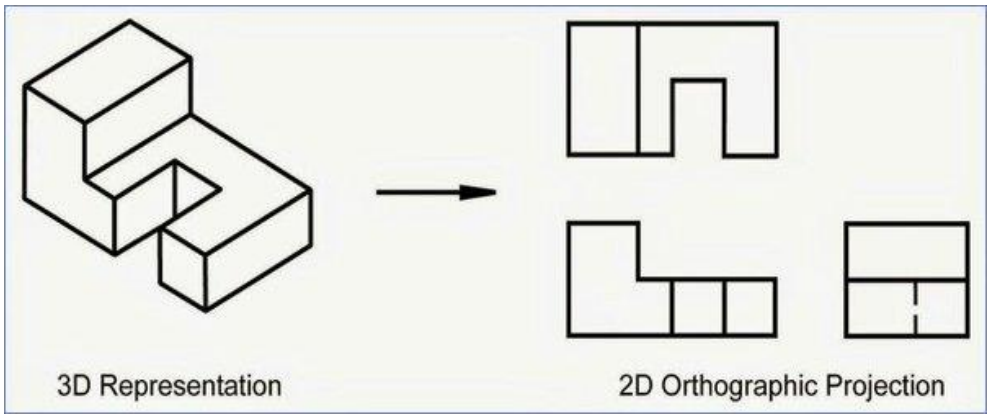
LITERATURE REVIEW

Isometric Drawing in the Context of EGD

Isometric Drawing is a topic in EGD that is introduced from Grade 10 and being taught all the way up to Grade 12. According to Education (2020a), isometric drawing includes drawing the width and depth axes inclined at 30 degrees to the horizontal, placing the lowest point of the drawing on a designated point indicated on the drawing sheet or orientating the drawing correctly. This topic is usually given in 2-dimensional views and learners are expected to convert the given 2-dimensional drawing to a 3-dimensional drawing. These views are to be drawn on axis that are elevated by the angle of 30 degrees in between x,y and z axes which forms a total of 120 degrees. When translating a 2d figure to 3d, students must encode information from 2D views by searching for relationships between the objects different parts, integrating the information retrieved from existing knowledge and combining the information to create a 3-D image (Gagnier et al., 2017).

Figure 1.

2D and 3D representation of isometric drawing



The above figure 1 shows 2d which is normally given to learners to manipulate and get the final product which is a 3d. The above figure is exactly in the way Sullivan (1964, p. 3) explains isometric drawing which is a conventionalized method of representing an object pictorially

Isometric Drawing and associated concerns

According to DBE (2021), ID is a chapter in EGD that deals with converting 2D views to 3D. Eteli and Eniekenemi (2016), sees ID as a 3D chapter that uses 30 degrees and 90 degrees to convert 2D to 3D. DBE (2021) further mentions that ID requires a high level of spatial ability so that one can be able to understand it. With isometric drawing being the second most weighing topic of P2 it means that learners performing well in this chapter will ensure that they pass the paper very well. However, performing poorly in ID will have dire effect in overall results of EGD as a subject. Unfortunately, there has been a concern about ID performance over the past years as it has been reported that learners are performing poorly in ID. Converting 2D to 3D has been the most challenging part of EGD (DBE 2021). Isometric Drawing is a topic introduced in Grade

10 and goes all the way up to Grade 12 however, most candidates are still struggling to get the basis of ID right (Education, 2020b). Eteli and Eniekenemi (2016), argues that some students are shying away from EGD citing difficulties in understanding. This is a serious concern as learners engage in ID for three years and still most of them cannot understand it. In the same vein, DBE (2022) reported that most candidates could not draw the ID correctly and in many instances, line work was untidy and of poor quality. DBE (2022) further mentioned that candidates drew the entire drawing using a construction line instead of a mandatory A-type line (solid line).

Teaching Engineering Graphics and Design

Engineering Graphics and Design (EGD) is a practical subject that relies heavily on spatial visualization skill. Spatial visualization skill is defined as the cornerstone of EGD that a learner must have in order to understand EGD concepts. Spatial visualization is the ability to form pictures in the minds of what is expected of you to draw before you can draw it. In simpler terms it is an ability to see things that are not physically visible assembly Drawing and Isometric drawing are sections that are taught in a similar way. Singh-Pillay and Sotsaka (2016, p.1217), teachers rely heavily on models to teach these sections since EGD is an abstract subject so engaging with physical materials does assist in bringing meaning to abstract concepts. On the other hand, Khoza (2013), technology such as AutoCAD has been used by many teachers when teaching EGD. This is collaborated by Mlambo (2023, p.165), who put forth that AutoCAD has been observed to assist learners in understanding 2D and 3D sections in EGD. If teaching assembly drawing using technology infused pedagogies it means that isometric drawing needs to be taught via technology infused pedagogies so that learners will improve their performance. Based on the above literature is clear that adopting different teaching methods will result in learners improved performance in difficult sections like assembly drawing and solids geometry. As a result, this is the reason why this study sought to investigate the way teachers teach isometric drawing and their understanding of what isometric drawing is.

Importance of relevant teaching qualifications

Engineering Graphics and Design is a subject that deals with high quality precision from linework, measurements and geometrical constructions used in the subject, and it requires a high level of knowledge for the subject. This basically means that even the teachers offering the subject should be highly knowledgeable about the content taught in this subject which will ensure that learners are benefiting from a well knowledgeable teacher. In support of the above, a study by Sotsaka (2015) indicated that most teachers he interviewed did not have qualifications in EGD which was seen as the factor why learners perform poorly in Assembly Drawing. This was of concern to Khoza (2013) who cited that to teach EGD you must have the basic knowledge and skills of EGD. This basically means that there is no way an underqualified teacher can be able to teach EGD to learners. The same notion is echoed by Mlambo and Mkhwanazi (2024) , that one of the factors contributing to students poor performance in assembly drawing are ill qualified teachers. This is the same concern that influenced the researcher to investigate the way teachers teach EGD. The importance of knowing the content

is further echoed by (Koehler & Mishra, 2009; Koehler et al., 2013; Shulman, 1987) who came up with the notion of Pedagogical Content knowledge (PCK) and Content knowledge (CK) as the core elements that shapes the way teaching and learning should occur. Shulman (1987) argues that on top of subject knowledge and general pedagogical skills, teachers must know how to teach topics in ways that learners can understand. On the other hand, (Koehler & Mishra, 2009; Koehler et al., 2013) see CK as the knowledge of the subject matter to be taught to learners which is a very crucial aspect of teaching and learning. Based on the above, it is very clear that a teacher needs to understand the subject content to ensure that learners will perform better. For this to happen teachers must be professionally trained to teach the content they are teaching and in the context of this study EGD teachers must be professionally trained to teach EGD so that learners will understand and perform better in isometric drawing.

Technology integration to teaching and learning of EGD

EGD is based on abstract concepts which are sometimes difficult for students to comprehend due its complexity and lack of relevant skills. As a result, many scholars such as Khoza (2013) put forth that some topics in EGD requires students to imagine parts of the drawing that are not there which requires a high level of spatial visualization. EGD being an abstract based subject has compelled many scholars to recommend the use of technologies to teach EGD. According to (Khoza, 2013; Mlambo et al., 2023) the use of technology in EGD lessons assist in transforming abstract concepts into concrete concepts which will be easy for students to understand and resonate with it. These technologies are YouTube, AutoCAD and Simulations (Mlambo, 2023; Mlambo et al., 2023). AutoCAD, drawing set squares (30, 45 and 60 degrees set squares), pencils are some of the materials that have been recommended by the Education (2011) as one of the requirements an EGD class should have. The importance of using technology in teaching and learning of EGD can never be over emphasized. This is attested by Gambari et al. (2014) who advanced that Interactive White Board (IWB) is a technology that was seen to have a positive impact in teaching and learning of isometric drawing. This further shows that integration of technology in EGD lessons does play a huge role.

Learner's difficulties with spatial visualization

In order for the learner to be proficient on the aspect of orthographic projection, it would only be possibly when the learner is capable of visualizing the object in his or her mind (Mendoza, 2020). However, in a study conducted by Pillay & Sotsaka (2020) they argue that students with well-developed spatial visualization ability can mentally transform or rotate 2D or 3D objects to whatever direction indicated through spatial visualization. The above statement means that the problem could be not that learners are unable to visualize, but because learners are not well trained or that the teacher lacks pedagogical knowledge to help learners improve their visualization ability. According (Bayaga & Kok, 2019; Mlambo, 2023), spatial visualization can be developed through using technology such as AutoCAD and Sketch up. However, this can be achieved and realized in well-resourced schools, not in a school where you find that learners lack even the basic instruments for EGD.

Singh-Pillay and Sotsaka (2016), alternate that when an EGD teacher does not understand or have a shallow understanding of a particular content, they are most likely to teach it in a way that will help learners understand. This is a strong point that if the teacher lacks an understanding of how to see and imagine the drawing or to rotate it mentally, it would be impossible for learners to learn in a way that will help them understand. Spatial visualization skill is a crucial skill in EGD so teachers should be warry about that and try by all means to assist learners in improving their spatial visualization skills. (Lehtinen et al., 2021). The outcomes of spatial visualization tests conducted in the study by Makgato (2016), also indicate that visualizing an object that has been rotated from different forms is a monumental task for learners. Most learners go to EGD classes with little or no content knowledge, as a result teachers must pay much attention to line work and task that improve spatial visualization that can be achieved through adopting Piaget's perception and imagery theory.

Training of teachers while still in the university on visual skills is important and needed as literature reveals that visualization can be taught and learned. Recent studies are showing that researchers in the field of science, technology, engineering and mathematics (STEM) are experimenting with different methods and programs in trying to find ways in that can help stimulate or improve spatial visualization for learners and students who are in the field of engineering as it plays a big role in problem solving. Amongst these researchers Power and Sorby (2021), encourages that in addition to the variety of resources used by teachers to facilitate, physical modelling material are also recommended for use in teaching curriculum. This would bring interest to the learners. It also challenges leaners' experience in interpreting the orthographic views as it used in castings.

THEORETICAL FRAMEWORK

Isometric drawing and assembly drawing are chapters that are similar in nature and learners are performing poorly in both sections. These sections combined they contribute to 60 percent of the final examination paper two hence failing these chapters has dire consequences such as not getting admission to engineering courses in universities. Additionally, many studies have been conducted on assembly drawing such that of (Singh-Pillay & Sotsaka, 2020; Singh-Pillay & Sotsaka, 2016; Sotsaka & Singh-Pillay, 2020; Sotsaka, 2015, 2019) and solid geometry by (Khoza, 2018; Khoza, 2004, 2013) but none have been done on isometric which is why this study is necessary to get to the bottom of poor performance in teaching of isometric drawing. Since this study will investigate the instructional practices by EGD teachers a Pedagogical Content Knowledge (PCK) by Shulman (1987) will be adopted to underpin this study. This framework revolves around two major constructs which are PCK and pedagogical knowledge (PK) and these two will used in this study. According to Shulman (1987), PCK concerns the overlap of information on subject knowledge. Pedagogical knowledge (PK), on the other hand, is the knowledge of how to teach. A teacher may deeply understand a subject area but must also be able to facilitate the understanding of the subject or concepts for students. The rationale behind

the adoption of PCK as the framework stems from studies such as that of Blayi et al. (2022, p. 26), which looked at the way technical teachers teach technical subjects by investigating their PCK. Another studies done by (Kekana et al., 2024; Mtshali & Singh-Pillay, 2023) which allude to the PCK as the essential element in teaching and learning. As a result, PCK was seen as a tool to assist in investigating how teachers are teaching and further investigate their understanding of isometric drawing.

METHODOLOGY

Research approach

This study adopted a qualitative research approach. According to Bhandari (2020), qualitative research involves collecting and analyzing of non-numerical data. This approach is mainly used because of its ability to gather in-depth insights into a problem. The aims of this study were to get EGD teachers understanding of Isometric Drawing and how they are teaching it and qualitative was best suited to gather such data through engaging verbally with the participants to gauge how they teach isometric drawing.

Research paradigm

According to Kivunja and Kuyini (2017, p. 28), there are three main research paradigms that can used in educational research which are positivism, interpretivism and critical theory. Positivism is usually used in a quantitative study where data can be obtained through questionnaires and experiments and on the other hand, interpretivism is used in a qualitative study where interviews and observations are used to collect data. Since this study adopted a qualitative approach, an interpretivism paradigm was used. This paradigm tries to get into the participants head to understand what the participants are thinking about the matter presented in front of them (Kivunja & Kuyini, 2017, p.33). Based on the above it for that reason the researcher employed interpretivist paradigm to gather EGD teachers view about the pedagogical practices they follow when teaching isometric drawing.

Data collection

Since interpretivist strives on verbal engagement with the participants this study used semi-structured interviews to exploit the advantages of using an interpretivist paradigm. Bhat (2020) mentions that interviews are used to gather first-hand information through one-on-one discussion with the participants and invites the opportunity to draw in depth information from the participants. This data collection method is seen as the perfect tool to get the teachers understanding of what isometric drawing is and how do they teach it to the learners. Raman and Yamat (2014, p. 14), further put forth that semi structured interviews are favored because of its ability to it elicit insights towards understanding a phenomenon. The interviews were conducted in EGD labs during their free periods so as to not interfere with teaching and learning, English was used as the language of communication. Furthermore, a tape recorder was used to record the interview sessions so to be able to do transcription at a later stage. The interview schedule included ten (10) interview questions designed to answer the research

questions of this study, and an additional three (3) questions dedicated to participant biographies. Interviews with teachers lasted 12-15 minutes.

Data analysis

Data gathered from the interviews can be analyzed following a narrative, descriptive and thematic analysis. In the context of this study data from the participants was analyzed using thematic analysis in conformity with Braun and Clarke (2006, p.80) six (6) steps of analyzing using themes. When creating themes, a researcher examines the data to identify common trends and patterns (Braun & Clarke, 2006; Caulfield, 2019; Clarke et al., 2015). As mentioned above this will be following Braun and Clarke's steps of thematic analysis which are data familiarization, coding, generating themes, reviewing themes, defining and naming themes and writing up. The researcher used thematic analyses to gather patterns in the way EGD teachers teach isometric drawing.

Sampling and participants

This study used a sample of seven (7) EGD teachers, the small sample was influenced by the fact that EGD is not a popular subject hence not many schools offer it. As a result, this study used convenience sampling to select seven (7) teachers to participate in this study. Convenience sampling involves using participants that are readily available which saves time and avoid many limitations a researcher could face (Taherdoost, 2016). A researcher used convenience sampling because EGD is a very scarce subject that not many schools have, hence a researcher used only those teachers that were readily available and nearby the researcher. Table 1 below shows the participants of this study.

Table 1.

Participants biographic information

Name of teacher	School	Gender	Qualification	Experience
Teacher A	School A	Male	B. Ed (EGD)	11 years
Teacher B	School B	Female	B. Ed (EGD)	2 years
Teacher C	School C	Male	B. Ed (EGD)	6 months
Teacher D	School D	Female	B. Ed (EGD)	2 years
Teacher E	School E	Male	B. Ed (EGD)	10 years
Teacher F	School F	Male	B. Ed (EGD)	2 years
Teacher G	School G	Male	B. Ed Honours (EGD)	6 years

Table 1 above shows the biographical information of teachers that made up a sample for this study. Based on the table above there are more male (4) EGD teachers as compared to female (2) EGD teachers, the table above further depict that all teachers that are teaching EGD are professionally trained to teach EGD as in their qualifications they majored with EGD. Their experiences in teaching EGD ranges from 11 years to 6 months which shows that the sample contained novice and well experienced teachers.

Ethical considerations

How you handle participants in research plays is very crucial hence a term ethics in research was established to ensure that participant's private information is not divulged in any manner. To ensure that integrity and privacy was caried out, the researcher requested a gatekeeper's letter from KZN department of basic education to conduct the study in schools, after it was received a researcher drafted letters requesting permission to all principals of the study sites to allow this research to take part in their schools. After permission was granted, teachers were given informed consents forms, and they were notified that only teachers signed the consent will partake and they are free to revoke their participation anytime. Since the study used semi-structured interviews, a researcher requested to record the interview and notified the teachers that pseudonyms will be used to protect their identity and that of their schools. Participants were also notified that the interview recordings will be kept safe and be destroyed after five (5) years. Pilot study, which is defined as the small-scale study was done to ensure validity and reliability of the findings. To further ensure that validity was maintained the researcher subjected participants to the process called member checking/participant validation. In this process data or results are returned to participants to check for accuracy and resonance with their experiences. Data collected from the interviews was transcribed using NVivo software to ensure reliability of the transcription.

FINDINGS

As mentioned above, the participants were subjected to semi-structured interviews to gather their in-depth views about the instructional practices they adopt when teaching isometric drawing. The interviews were used to respond to the research questions that guided this study which are as follow: What are Engineering Graphics and Design teachers' Instructional Practices in Teaching of Isometric Drawing?

The above main research question was supported by the following sub research questions:

- What are Engineering Graphics and Design teacher's understanding of Isometric Drawing?
- How do Engineering Graphics and Design teachers teach Isometric Drawing?
- What are the challenges do EGD teachers observe when teaching isometric drawing?

To respond to these questions, a thematic analysis was employed. As a result, seven (7) themes emerged from the transcription of data. Below are the responses of the participants based on the posed question presented under themes that emerged. The transcription was done using the NVivo software to ensure that reliability is maintained, and the participants are captured correctly. The transcription below was from the seven (7) teachers who were interviewed.

THEME 1: Common Understanding of Isometric Drawing

When teachers were asked the following question: What is your understanding of Isometric Drawing? Please explain. Below is how they responded:

Teacher F said the following:

"An isometric drawing is a 3D drawing that is draw taken from a 2D explaining how that 2D would look like if it were to be built"

Teacher E went on to say:

"Isometric drawing shows objects in three dimensions on a 2D surface, using lines at 30-degree angles"

In the same vein, Teacher D:

"Isometric drawing is a drawing that displays the three sides of an object. Drawn using an angle of 30°. It contains isometric lines, circles, and non-isometric lines"

Teacher B went along the lines of the other teachers and said:

"Isometric drawing deals with 2d drawing to be converted into 3d drawing using elevated angles of 30 degrees apart from the starting position"

THEME 2: A Box Principle

The second posed to teachers was: Can you explain the principles behind creating an isometric drawing? Below is how they responded:

Teacher A said the following:

"The basic principle of isometric drawing is to understand the box technique which I always encourage my learners to use"

Teacher C narrated and said:

"It must be drawn using an angle of 30°. Identify the starting point. It requires the first three lines from the point. The first line is drawn using an angle of 30° on the left, a perpendicular line and a 30° line to the right. Mark the: Height, Length, and width. Complete by projecting and completing the box"

Teacher E went on to say:

"The principles involve drawing lines parallel to the three axes (x, y, z) and maintaining equal measurements"

Teacher F shared the same sentiment of an isometric box:

"Basic principle is to start by drawing an isometric box"

THEME 3: Teachers must be qualified to teach Isometric Drawing

Another question that was asked to teachers was: Do you think a teacher who is not qualified to teach EGD can be able to teach Isometric Drawing? Please explain. Below is how teachers responded:

Teacher F said:

"No. he/she will lack special drawing virtualizing, the line work won't be as good as expected from a teacher, non-isometric shapes will give he/her hard times"

In the same vein, Teacher A said:

"A teacher who is not qualified to teach EGD cannot teach Isometric drawings, this topic is one of the challenging topics in EGD it requires high level of knowledge and practice in order to teach it correctly"

Teacher E went on to say:

> *"A teacher not qualified in EGD may struggle to teach isometric drawing effectively due to lack of knowledge"*

Teacher shared the same sentiment as the other teachers:

> *"I don't think they can. ID is a very complicated topic that needs a fully qualified teacher to be able to teach this topic"*

THEME 4: Visual Aids

During the interview, teachers were also asked the following question: How do you introduce the concept of isometric drawing to students who may be unfamiliar with it? Below is how they responded to the question:

Teacher B said the following:

> *"I rely on models so that learners can make a relationship with the views and the actual 3d figure"*

Teacher C said:

> *"By playing videos using a projector, and models"*

Teacher A went on to say:

> *"I use Videos on YouTube as an introductory lesson in conjunction with the models"*

THEME 5: Visualisation as a Challenge

Another question asked was: Have you encountered any common challenges or misconceptions that students face when learning isometric drawing, and how do you address them? Below is how they responded:

Teacher B said:

> *"Most learners are struggling to visualize how the final product will look like so models assist a lot in that aspect"*

Teacher A said:

> *"Most learners are struggling to actual imagine how it will look like once converted to 3d, as a result I normally advise them to start by making a free hand drawing of the final drawing which makes it easy to move from there to the final 3d figure using instruments and dimensions"*

In the same vein, Teacher D said the following:

> *"The challenge my learners often encounter is that they lack a visualization skill to actual see the drawing before they start engaging with it"*

THEME 6: Different Kinds of Materials

Another question that was posed to the participants was: What types of resources or materials do you use to support the teaching of isometric drawing? Below are how teachers responded:

Teacher E said the following:

> *"I use drawing tools such as the set squares (30, 60 and 45), graph paper, instructional videos, and examples of isometric drawings in a form of models"*

Teacher C went on to say:

"I only use sets squares (45 degrees and 30 x 60 degrees), protractor as well as a compass"

Teacher A had the following to say:

"Play simulation videos that stimulate spatial visualization ability"

Teacher B said the following:

"I mostly rely on Models that we have in class in conjunction with the drawing instruments"

THEME 7: Technology an Aid to Visualization

The last question the teachers were asked is: How do you integrate technology or digital tools into your instruction when teaching isometric drawing? Below is how they responded.

Teacher B said the following:

"There are videos on YouTube, so I download those videos and use them in class through an overhead projector to explain certain concepts"

Teacher D went on to say:

"By projecting a step-by-step PowerPoint process of completing an isometric drawing"

Teacher E said the following when asked the above question:

"I integrate digital tools such as CAD software and online tutorials to enhance instruction and practice"

Discussion of the results from the interviews

Based on the responses above, all teachers had a common understanding of what isometric drawing is. As they all mentioned that isometric drawing has to do with converting a 2d orthographic views into a 3d figure. This is an indication that the EGD teachers know what isometric drawing is and that will go a long way in teaching it better to students. Teachers understanding of isometric drawing are aligned with the way defined by many scholars. Report (2021) defines isometric drawing as simple converting a 2d figure to 3d. The assertion of the teachers also aligns with Eteli and Eniekenemi (2016) who put forth that isometric drawing involves a topic that deals with converting a 2d to 3d using 30 degrees and 90 degrees angles.

From the teachers' responses it was also evident that they instructional practice when teaching isometric drawing rely heavily on using a box method. Teachers' responses are in line with (Education, 2011, 2020a; Report, 2021) that a box method is very important is when teaching isometric drawing as it allows students to be confined within that box when drawing. This method of using a box allow students to keep to measurements as their drawing will be confined with a box. This shows that most teachers are teaching the way prescribed by the department. From the teachers' responses, it was evident that they were all of the view that teachers who are not trained to teach EGD they will never be able to teach it as EGD is a subject that deals with high precision of linework and constructions which requires one to be professionally trained to teach it. Teachers' views are aligned with what transpired in literature in chapter 2. For example, (Koehler & Mishra, 2009; Koehler et al., 2013; Shulman, 1987) argue that teachers must know how to teach a content in a manner that learners will understand. Mlambo and Mkhwanazi (2024) further mentioned that one of the factors that contribute to

learners' poor performance are teachers who are not fully qualified to teach a subject. Furthermore, to teach isometric drawing you must have the relevant knowledge and skills which can be acquired through being professionally trained to teach EGD (Khoza, 2013).

From the teachers' responses, it was evident that most teachers outlined that upon teaching isometric drawing they have observed that most learners are struggling with the ability to visualize what the final 3d figure will look like just by looking at the given 2d views. This visualization skill is very crucial in isometric drawing. This assertion is attested to by Mendoza (2020) who posits that in order for the learner to be proficient on the aspect of orthographic projection, it would only be possible when the learner is capable of visualizing the object in his or her mind. This shows that the concern with visualization in learners is a universal concern. Teachers also mentioned that to try and bridge the gap and assist developing learners' spatial visualization they use materials such as models and technological based such as YouTube videos, AutoCAD and simulation-based teaching. The above views of teachers align with the views of (Khoza, 2013; Mlambo, 2023; Mlambo & Mkhwanazi, 2024) who are all of the view that technologies such as YouTube videos, AutoCAD and simulation based learning are useful in developing learners spatial visualization ability as they have the ability to translate abstract concepts into concrete concepts with ease.

Teachers' responses above also indicated that they use materials such as set squares (30 by 60 and 45 degrees set squares), whiteboard, overhead projector and AutoCAD drawing to teach isometric drawing. These materials they have in their classes align with those prescribed by DBE (2011) that it is a requirement that an EGD classroom have an overhead projector, whiteboard, and access to AutoCAD.

CONCLUSION

This study has shed light on the instructional practices followed by EGD teachers, their understanding of isometric drawing and the challenges they have observed when teaching isometric drawing. The findings above showed that all EGD teachers have a common understanding of what isometric drawing is, as they all indicated that ID deals with converting 2d orthographic views to a 3d figure. Which is in line with the way most scholars such as (Education, 2011; Eteli & Eniekenemi, 2016; Gagnier et al., 2017). This is an indication that these teachers are not just teaching ID, but they also have deeper understanding of what it is. The findings further showed that EGD teachers are of the view that a teacher who is not professionally trained will never be able to teach ID as EGD is a very complex subject that deals with high level of accuracy and precision. These views of the teachers aligns with (Khoza, 2013; Mlambo & Mkhwanazi, 2024) who argues that a teacher must have the basic knowledge and skills for the subject they are teaching. It is worth noting that all teachers who took part in this study had qualifications to teach EGD. Which put them at a better place to teach learners ID which is by nature a very complex topic. From the findings teachers also mentioned that their instructional practices rely heavily on using a box method which assist learners to keep their

drawing within the expected size and further aid in ensuring that each view is located where it is supposed to be. This method that is adopted by teachers is prescribed in DBE (2011) and in many EGD books used in high school such as the Mind Action Series. This basically means that these EGD teachers are applying the prescribed methods of teaching isometric drawing.

The findings further revealed that the most common challenge they encounter when teaching ID is the learner's inability to visualise, which is the most crucial skill in EGD. These views are in agreement with the literature, for example (Bayaga & Kok, 2019; Mendoza, 2020; Mlambo, 2023; Mlambo & Mkhwanazi, 2024; Power & Sorby, 2021) argue that spatial visualisation is the most important skill in EGD and most learners are lacking. However, they also indicated that they rely heavily on models, technology-based teaching such as AutoCAD, YouTube, and simulations in addition to the normal drawing instruments like the 30 by 60- and 45-degree setsquares. The importance of using these technologies for the improvement of spatial visualisation is echoed by (Mlambo, 2023; Mlambo et al., 2023; Mlambo & Mkhwanazi, 2024) that AutoCAD, models and simulations are useful in EGD to assist with the transition from abstract concepts to concrete concepts. Using these materials have been alluded to by many scholars to assist in improving the spatial ability of learners. The Department of Basic Education has also prescribed the use of technologies in an EGD classrooms. Based on the findings from EGD teachers it is clear that they are teaching the way it is prescribed by the Department of Basic Education, they are also putting into practice the recommendations made by scholars who are engaged with EGD, however the learners are still struggling in ID.

Recommendation and future research

In light of the findings above, the study recommends that studies of this nature should be conducted on a different sample so that problems can be discovered as to why learners are still performing poorly in ID even though teachers are teaching using the prescribed methods and using relevant tools. The study further recommends the usage of technologies such as AutoCAD, YouTube and simulations as they have been proven to improve learners' spatial visualization skills which has been alluded to by teachers as a challenge to learners.

This study was conducted on EGD teachers only. For future research, studies should be conducted on learners to gauge the challenges they are faced with when being taught isometric drawing and gather their views on methods of teaching they prefer. Future studies should also be conducted on how learner's spatial visualisation skill can be improved.

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