



**THE INFLUENCE OF VISUAL TECHNOLOGICAL RESOURCES ON
GRADE 9 LEARNERS' CONCEPTUAL KNOWLEDGE OF
TRANSFORMATION GEOMETRY**

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A Research Report submitted in partial fulfilment of the requirements for the
degree of Master of Education by combination of coursework and research

Faculty of Humanities

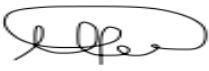
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Declaration

I, Nndileleni Nedambale, declare that this Research Report is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of references. It is being submitted in partial fulfilment of the requirements for the degree of Master of Education at the University of the Witwatersrand, Johannesburg. I have not previously submitted this work or part of it for any degree or examination at any other University.

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Date: 15 March 2024

Nndileleni Nedambale

Abstract

This study investigates the influence of visual technological resources (VTRs) on Grade 9 learners' conceptual knowledge of Transformation Geometry. This was done by giving two groups of learners the opportunity to learn with and without VTRs. The conceptual knowledge gains of the learners in both groups were compared and analysed after they wrote the same test. The experimental group was instructed with VTRs while the control group was instructed without VTRs. The data collected were qualitatively and quantitatively analysed. There were three main items that were studied, i.e., lesson observation schedule data, learners' actual responses to transformation geometry questions, and learners' test performance scores. The TPACK framework was used to analyse the use of VTRs in the classroom by a teacher. The two facets of conceptual knowledge were used to measure the conceptual gains of learners from the written test. It was found that 30 % of the learners in the experimental group performed above 40% in the test that was given to them. 16% of the learners in the control group performed above 40%. An analysis of the learners' scripts showed that the experimental group had more conceptual gains than those of the control group. The usage of VTRs improved the conceptual knowledge of Transformation Geometry for learners in the experimental group. It was also found that learners in both groups struggled to obtain the coordinates of transformed points from the questions presented. The results revealed that the learners could not adequately explain the meaning of reflection and translation. It was also found that a lack of accessibility to technological infrastructure and equipment presented challenges in the classroom to integrate VTRs. The study recommends that mathematics teachers integrate VTRs in the classroom instruction of Transformation Geometry and other topics.

Dedication

This study is dedicated to my wife Tshilidzi and son Khare Nedambale for their loving support. I dedicate this study to my mother Musalafhi and late father Thililelwi Nedambale who inspired me to always thirst for knowledge.

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CHAPTER 1: CONCEPTUALISATION OF THE STUDY

1.1. Introduction

The fourth wave of the industrial revolution has not spared the department of education. The use of various technological resources in teaching and learning is arguably at the highest level since the inception of formal educational institutions. Technology has brought many changes in schools. Teaching and learning have been transformed and improved in many aspects. In mathematics education, various technological resources and software have been developed for implementation in the classroom. These softwares include Geogebra, Desmos, Sketchpad, and Rocket Maths to list a few. The purpose of these applications is to improve teaching and learning of mathematics. These software and technological resources are used across various mathematical topics. Game-based learning is also being implemented across schools (Boonmoh, Jumpakate, & Karpklon, 2021). Although the availability of technological resources is quite conspicuous, the influence of such resources on teaching and learning requires a thorough investigation. This study seeks to investigate the influence of *visual technological resources* (VTRs) on Grade 9 learners' conceptual knowledge of transformation geometry. VTRs include videos and various interactive software such as Sketchpad and Geogebra. In this study, VTRs refer to videos. Chapter 1 sets out the foundation of the study by giving insights into Transformation Geometry as a topic in Grade 9 mathematics. The focus also shifts to how technology is currently being used in classrooms and what teacher attitudes are towards its usage. The chapter also explains the main objectives of the study. Chapter 2 provides the pertinent literature around the usage of technology in classrooms, challenges of using the technology, and conceptual knowledge of learners. Chapter 3 gives the two main frameworks which undergird the study. These are the two facets of conceptual knowledge framework and the Technological, Pedagogical, and Content Knowledge framework. Chapter 4 presents the research design and methodology required to investigate the influence of technology on the conceptual knowledge of learners. Chapter 5 provides a detailed presentation and analyses of the investigation results. Chapter 6 gives an interpretation of the findings and conclusions around the investigation.

1.1.1. The importance of transformation geometry

Transformation Geometry forms part of Space and Shape content area (DBE, 2011). This is in the Senior Phase (SP), grades 7-9. The curriculum and assessment policy statement (CAPS)

explains that this topic contributes 30% to the content required for Grade 9 mathematics (DBE, 2011). The 2023/24 Annual Teaching Plan (ATP) for Mathematics shows that Transformation Geometry takes up 14.3% of the total Geometry topic. Although the weight of Transformation Geometry in the senior phase may make the topic seem insignificant, it is foundational to Further Education and Training (FET) Analytical Geometry and Functions. The weight of Transformation Geometry can therefore be related to the weights of Analytical Geometry and functions in the FET phase. For instance, in Grade 10, Analytical Geometry and Functions take up 22.5% of the curriculum (DBE, 2011). In both Grade 11 and 12, Analytical Geometry and Functions take up 25% of the curriculum (DBE, 2011).

Transformation Geometry is important because it creates an environment for thinking about mathematical concepts and affords learners an opportunity to be part of activities that require higher cognitive skills (Hollerbrands, 2013; Febrian, & Perdana, 2017; Adiafidah & Qohar 2020). This is because the concepts involved in Transformation Geometry may appear abstract to learners. The concepts involve reflecting and translating points on the Cartesian plane. The abstract nature of these concepts allows learners to think about them deeply and consequently requires higher-order mathematical skills. The opportunities presented by Transformation Geometry to learners are, therefore, foundational to learner development in terms of their mathematical abilities.

According to Guven (2012), Transformation Geometry enhances learners' spatial abilities. This means Transformation Geometry allows learners to improve their skill of visualising and understanding how objects relate to the spaces they occupy. This is an important skill required in mathematics learning. The enhancement of spatial skills brought about by Transformation Geometry may also improve learners' mathematical skills. In their study Evidiasari, Subanji, and Irawati (2019) found that learners relied on their spatial abilities to solve Transformation Geometry questions, which corroborates the findings of Guven (2012). These findings therefore demonstrate the importance of Transformation Geometry in mathematics learning. The findings also call for an exploration into methods which can improve the way learners understand Transformation Geometry.

1.1.2. Technology in mathematics education

Technological advancements have impacted the classroom in various ways. This has resulted in more learning opportunities in the classroom. Olive, Makar, Hoyos, Kor, Kosheleva, and Strasser (2009) explain that technology has brought about an improved interaction between mathematical knowledge and mathematical practice. This means that technology allows learners to apply the concepts they learn in the classroom. Olive et al. (2009) also imply that technology allows for learning to take place in a rather balanced manner as concepts are put to practice in technologically resourced classrooms.

Arguably, technology has now allowed learners to learn in such a way that concepts are reinforced and represented in an understandable and relatable way. The key aspect of using technology in the classroom lies in representing concepts. The abstract nature of mathematics makes concepts difficult to understand for learners. Technology therefore allows the concepts to be represented in clear and concise ways, which enable learners to understand them.

Learners are afforded the opportunity to experiment, visualise, and test their mathematical understanding (Olive et al., 2009). In a classroom context, experimenting with mathematical concepts may mean trying different solution paths to problems or even checking to see the effects of different parameters on functions using different software and technological resources. Experimenting makes the learners feel connected to the concepts. Subsequently, the concepts become relatable.

Another aspect Olive et al. (2009) bring forward is that learning through technological resources allows learners to visualise concepts. In this sense, technology permits learners to have a clear mathematical idea about various concepts. Again, various software and technological resources may aid in achieving this aspect. For example, videos can be used to demonstrate to learners what a reflection of a shape looks like. This would be different from trying to sketch or explain a reflection to the learners. The authors further indicate that the aspect of being able to visualise concepts introduces a dynamic perspective to learning. This means that learning is not restricted to one form. Learners who may fail to understand an explanation of a reflection may be allowed to successfully visualise the transformation during the same classroom instruction.

According to Edwards (1990), dynamic representations of mathematical concepts are essential to improve learners' knowledge. By dynamic representations, Edwards (1990) refers to all methods that can aid in learners' visualisation and experimental abilities. These include technological resources used in the classroom. Wijaya, Ying, and Purnama (2020) put forward similar findings in that dynamic technological software improved the understanding of learners in their study. Mathematical models and digital resources are means of representations for mathematical concepts.

In their study, Attard and Holmes (2020) also found that the use of technology in learning widens the opportunities for mathematical participation by providing multiple pathways for learning.

This may very well be the link required to improve the conceptual knowledge of learners about different mathematical topics.

1.1.3. Attitudes towards using technology in the classroom

It is important to understand the attitudes that are prevalent when it comes to integrating technology in classrooms. The prevalent attitudes guide us in understanding the current terrain of technology integration between schools. In a study conducted by Bwalya (2019) in Zambia, it was found that technology helped improve the attitudes of learners in the classroom. The focus group consisted of mathematics learners. The findings help to understand that there is a positive reception of technology integration on the side of mathematics learners. In other words, learners would be more than willing to receive technology-infused mathematical instruction. The study findings also indicated that technology is an effective teaching tool in classrooms. This suggests that educators may also be willing to integrate technology into the classroom.

In Thailand, a study conducted revealed that educators were eager and willing to implement technological resources in their classrooms (Boonmoh et al., 2021). In fact, most educators were found to have been using computers and mobile devices in classrooms (Boonmoh et al., 2021). This finding shows that both learners and educators are willing to embrace the integration of technology into the classroom. Boonmoh et al. (2021) further indicated that despite the willingness of educators to integrate technology in teaching and learning, there were challenges restricting them from using it in classrooms.

In rural South Africa, where the success of technology integration may be least probable due to contextual issues, educators were found to be willing to integrate technology into their classrooms (Chisango, Marongwe, Mtsi & Matyedi, 2020). Furthermore, Chisango et al. (2020) indicated that educators lacked the skills to integrate technology. This means that although educators may express interest in technology integration, skills remain a necessity in the terrain of technological implementation. Therefore, it is clear that both educator and learner attitudes in integrating technology in classrooms are positive and desirable.

1.2. Rationale

Transformation Geometry in Grade 9 requires a different teaching approach since the performance of learners has shown that they have little gains from the instruction they receive in the classroom, as explained in the Annual National Assessment (ANA) diagnostic report released by the Department of Basic Education (DBE) (DBE ANA Diagnostic report, 2013). The diagnostic report showed that the performance of learners in Transformation Geometry was unsatisfactory.

Technology maximises learning opportunities in the classroom (Attard & Holmes, 2020). In other words, technology aids in learning mathematical concepts. Technology may be of benefit to learners in improving their skills to respond correctly to questions on Transformation Geometry. It is therefore important that the influence of technology on learning transformation geometry is explored. Olive et al. (2009) highlight that technology may aid in combining procedural knowledge¹ and conceptual² knowledge. These are the two forms of knowledge that are critical to understanding mathematical concepts.

Although procedural knowledge is important, the content on which this study is based is conceptual in nature. For example, the study focuses on the meaning of the terms reflection and translation. Understanding these concepts requires conceptual knowledge, not procedural knowledge. This means that the focus of the study is on the conceptual development of learners.

South African classrooms experience limited use of computers, especially in rural areas (Julie, Leung, Thanh, Posadas, Sacristán, & Semenov, 2009; Padayachee, 2017; Munje & Jita, 2020). This seems to suggest that technology is not fully taken advantage of in rural areas (under-

¹ Procedural knowledge is the knowledge of procedures. (Star, 2000)

² Conceptual knowledge is the knowledge of concepts. (Star, 2000)

resourced schools). The failure of schools to take advantage of technology may be due to a lack of technological resources and even time constraints on the part of teachers.

Providing teachers with ready-made videos to facilitate teaching and learning of Transformation Geometry (reflection and translation) may be of benefit to learners in rural areas as well. The significance of this study stemmed from the unsatisfactory performance of learners in transformation geometry and their lack of understanding of concepts related to Transformation Geometry such as translation and reflection. The researcher believed that the study may provide a clear view of the influence of VTRs on mathematical concepts in the classroom. The significance of this study was also related to the small number of similar studies, particularly in rural or disadvantaged areas.

1.3. Problem statement

Transformation Geometry is foundational in senior phase mathematics. Learners struggle to grasp this topic, and their performance in the topic shows there is a deep lack of comprehension in terms of performing transformations. The 2021 Grade 12 (NSC) Diagnostic Report recommended that mathematics teachers should show learners how to visualise and make rough drawings of all extra information given in Analytical Geometry questions (DBE Diagnostic Report, 2021). The report also stated that creating visual representations is an important skill in geometry. This is important to note, as similar findings were presented in the 2013 Annual National Assessment Diagnostic Report, which explained that Grade 8 learners lacked important skills to correctly respond to questions on transformation geometry. It was also highlighted in the 2013 ANA Diagnostic Report that learners were unable to perform reflections and translations of various shapes.

These findings show that learners struggle with Geometry concepts and suggest that learners may need different approaches to the teaching of Transformation Geometry. These approaches are required as early as Grade 8 since it is foundational to Grade 9 Transformation Geometry and Further Education and Training (FET) mathematics, especially Analytical Geometry and Functions. It is also of importance to note that one of the proposed interventions was to 'emphasise' Transformation Geometry skills such as 'reflecting a point in the x -axis' (DBE ANA Diagnostic report, 2013). This implies that more should be done on the side of the teacher for learners to conceptually understand Transformation Geometry and the related concepts.

This study therefore investigated the influence of VTRs on Grade 9 learners' conceptual knowledge of Transformation Geometry.

1.4. Aim, objectives, and research questions

1.4.1. Aim

The main aim of this study was to investigate the influence of VTRs on Grade 9 learners' conceptual knowledge of Transformation Geometry.

1.4.2. Objectives

The main objectives of this study were the following.

- To evaluate the influence of VTRs on the conceptual knowledge of learners of Transformation Geometry
- To investigate the challenges (if any) of using VTRs during classroom instruction of Transformation Geometry
- To explore the challenges (if any) learners have in understanding Transformation Geometry

1.4.3. Research questions

1.4.3.1. Main research question

- What is the influence of VTRs on the conceptual knowledge of transformation geometry of learners?

1.4.3.2. Sub-questions

- What are the factors that may affect the use of VTRs in classroom instruction of Transformation Geometry?
- What are the challenges (if any) that learners have in understanding Transformation Geometry?

1.5. Significance of the study

The findings of this study can inform teachers of the potential challenges that learners have when learning Transformation Geometry. This is important because it may influence how

teachers plan their lessons and classroom instruction. The findings can also influence how teachers organise learners' assessments. This means that teachers can design tasks that help clarify the potential challenges of learners. More importantly, the findings of this study can also aid the Department of Basic Education in reorganising and improving the structure and sequence of Grade 9 Transformation Geometry concepts. A reorganised structure of the topic may afford learners an opportunity to improve their understanding of Transformation Geometry.

Factors that affect the use of technology during instruction were also investigated. This will help to understand the implementation of technology in rural school classrooms.

The findings of this study can also aid in understanding the influence of technology in learning Transformation Geometry. This means that a clear conclusion can be drawn about the influence of technology on learning. Teachers may then realign their classroom instruction so that technology is incorporated into teaching Transformation Geometry, should the findings be positive. The results of this study can consequently inform teachers on how to organise their lessons in a way that improves the conceptual understanding of transformation geometry by learners.

1.6. Summary and conclusion

This chapter highlighted the importance of technology in the current education setting. Transformation Geometry was also discussed as a challenging topic for learners, especially those in Grade 9. There is an undeniable link between Transformation Geometry in the Senior phase and Geometry in the FET phase. Learners struggle with Transformation Geometry and consequently struggle with Functions and Analytical Geometry. The use of VTRs during classroom instruction can positively influence the conceptual understanding of learners and should therefore be investigated.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

This chapter focuses on existing literature that is pertinent to the study. The literature is linked to the study research questions and is presented systematically. Section 2.2 focuses on the existing challenges of using digital resources in the classroom (First sub-question). This is followed by exploring literature on the challenges learners have in understanding Transformation Geometry, Section 2.3, (Second sub-question). The last section, Section 2.4, focuses on the influence of VTRs on learners' conceptual knowledge.

2.2. Factors that may affect the use of VTRs in classroom instruction of Transformation Geometry

Olive et al. (2009) have proposed that technology usage in the classroom may present an improved learning environment. Arguably, all stakeholders within education departments would find improved learning environments desirable. This particularly means that the suggested benefits of using technology should in part motivate teachers to use it in the classroom.

The question then becomes, why do South African classrooms experience a limited usage of computers, especially in rural areas? (Julie, Leung, Thanh, Posadas, Sacristán & Semenov, 2009; Padayachee, 2017; Munje & Jita, 2020). Perhaps there are challenges that inhibit teachers from using technology in the classroom?

Julie et al. (2009) stated that technology usage in South Africa was restricted in most schools. A few schools were optimally using computers in their classrooms. This was further supported by Padayachee (2017) who explained that not enough schools were embracing technological integration in the classroom. Years later, after the findings of Julie et al. (2009), Padayachee (2017) still reported unsatisfactory computer usage in schools across South Africa. Munje and Jita (2020) also acknowledged the absence of the desired acceleration in computer usage in schools. In fact, Munje and Jita (2020) even claimed that not using technology in the classroom can frustrate learners and prevent them from obtaining the associated potential benefits. Munje and Jita (2020) therefore explicitly put forward the reality that technology usage in these times has almost become mandatory. This means that learners should not be deprived of learning with technology.

2.2.1. Ways in which technology can be used

Technology can be used in the classroom in different ways. As discussed by Grugeon, Lagrange, Jarvis, Alagic, Das, and Hunscheidt (2009, p. 330), Musley, Lamndin, and Koc (2003) explain that there are mainly three ways in which technology can be used in the classroom. The three ways are discussed separately.

- *Technology as videos and other multimedia resources (Grugeon et al., 2009, p. 330)*

This involves using screens to show videos to learners in a classroom. The videos may contain audios for clear communication. This means that the teacher should decide on the kind of video to be used and how long it will take to run. The multimedia resources include animations that communicate concepts to learners. This is technology used primarily for visualisation of concepts and explanation of concepts.

- *Technology as software packages and the Internet (Grugeon et al., 2009, p. 330)*

This involves using technology in the form of computer-installed software which are interactive in nature. The software is educational and allows learners to learn concepts by testing inputs on the software platform. These include Geogebra, Sketchpad etc. Other software is available online and may be used directly from websites.

- *Technology as calculators, computers, and other electronic resources (Grugeon et al., 2009, p. 330)*

Here technology is used as a tool to solve problems. Technology is used as an aid to problem solving in this case. Calculators aid during complicated calculations and minimise errors during problem solving. Software is designed to take inputs from users and produce desired outputs from the given data.

2.2.2. Aspects affecting the incorporation of technology within educational settings

There are various factors that affect the use of technology in the classroom. These are important to unpack should one need to implement technology in the classroom. The factors also help to understand the limitations that are unavoidable in the use of technology in the classroom. Some of the factors are teacher dependent. These are factors that are directly affected by the ability

of the teacher to use technology and their attitude towards using it. Goos et al. (2009, p. 322) outline eight factors that may inhibit technology usage in the classroom.

- Pedagogical beliefs of teachers (Goos et al., 2009, p. 322)

This is an important aspect of whether teachers will use technology in the classroom or not. This factor is deeply rooted in what teachers believe is meaningful learning. This includes how teachers believe learning takes place. If teachers believe that they can achieve the stipulated results of the curriculum without using technology, then they may be less motivated to use technology in the classroom. The beliefs teachers have about teaching are also grounded in what has worked for them in previous years. Teachers who have not used technology in their classrooms but still perceive themselves as attaining the desired objectives of the curriculum may not be easily persuaded about the benefits of using technology in the classroom. The other side of this coin points out that teachers who believe that technology may, to a reasonable extent, enhance learning may be willing to integrate it into their classrooms. Pedagogical beliefs teachers have about how learning should take place directly affect the probability of technology being used in the classroom.

- Teacher skills / experience working with technology (Goos et al., 2009, p. 322)

As part of the central factors that affect the use of technology in the classroom, the skills that teachers possess to operate the technology may affect their willingness to integrate it into the classroom. This is an issue of ability and expertise.

Padayachee (2017) found that teachers lack the skills to use technology resources in the classroom. Muhazir and Retnawati (2020) also put forward that there exists a low level of teacher skills in using technology for mathematics teaching and learning. This means that teachers who do not possess the know-how in technology integration may not be willing to integrate it into their classrooms. The lack of skills to operate the technology in front of learners may be enough to discourage teachers from integrating it into their lessons. Teachers who have the skills to operate technological devices may be more willing to integrate technology into their classrooms. The experiences teachers have had with technology also shape their perceptions toward using technology in the classroom, according to Goos et al. (2009).

Teachers who have experienced challenges in the classroom while aiming to successfully integrate technology may not be optimistic about its benefits. This means that their perceptions on using technology are primarily based on their negative experience. Teachers with positive experiences related to the integration of technology may be more willing to implement the use of technology in their classrooms.

- Teachers' access to hardware, software, and teaching materials (Goos et al., 2009, p. 322)

This is an important factor in underresourced schools. A teacher may be willing to integrate technology within their classroom, but the absence or lack of technological hardware and software required restricts the implementation of technology. On the other hand, the presence of technological hardware and software may motivate teachers to integrate technology into their classrooms. It is important to note that the availability of technological hardware and software does not guarantee technology integration during teaching and learning. However, the presence of technological hardware and software creates a favourable environment for integrating technology.

Padayachee (2017) found that schools lack the infrastructure required to integrate technology into classrooms. Muhazir and Retnawati (2020) also corroborated these findings and indicated that the facilities and infrastructure provided by schools were inadequate for the use of technology in teaching and learning. This is a significant inhibitor of technology integration, as it reduces the willingness of teachers to use technology in the classroom. Even if teachers had a desire to integrate technology into the classroom, the unavailability of resources significantly restricts their efforts. Munje and Jita (2020) claim that the main cause of inadequate facilities and infrastructure is a lack of financial support for schools. This means that schools lack technological resources because they lack the financial resources to purchase them. Providing schools with financial support or even facilities and infrastructure would significantly help in integrating technology into the classroom.

- Teacher support from colleagues (including technical support) (Goos et al., 2009, p. 322)

A collaboration of teachers exists in schools. The nature of the network can affect whether teachers integrate technology in the classroom or not. This is not about the skills of the teachers,

but about teachers working together and motivating each other to take part in various programmes. In schools where teachers support each other to integrate technology into their classrooms, there may be a successful integration of technology during instruction. Teachers who do not support each other in integrating technology within lessons may not include technological resources in their classrooms, and this may affect new teachers negatively in schools. The old saying may prevail, ‘when in Rome, do as the Romans do’. This means that teachers may create an environment where technology integration is supported. Teachers may also create an environment that does not promote technology integration. Goos et al. (2009) further explain that it is not only about teachers supporting and promoting the usage of the technology in classrooms within the schools, but also about teachers receiving technical support when using the technological resources. The availability of technical support is critical to integrating technology in the classroom for teachers. This is because teachers may have technical challenges that need to be addressed while using the technological resources. The presence of technical support allows teachers to receive assistance faster, whereas the absence of technical support may cause frustrations resulting in a less or slower integration of technology in schools. Unfortunately, the support provided by schools to teachers has been found to be inadequate for the use of technology in teaching and learning (Muhazir & Retnawati, 2020). Munje and Jita (2020) also point out that there is a lack of technical support for teachers. Although this may not be the reality in all schools, it provides much needed information on what really goes on in schools. There are schools that do not provide teachers with the essential support structures required to implement technology in classrooms. This greatly minimises the possibilities of successfully integrating technology.

- Curriculum and assessment requirements (Goos et al., 2009, p. 322)

In the South African school terrain, the mathematics curriculum encourages the use of technological resources (DBE, 2011). The forms of assessments are handwritten tests and examinations in both the Senior and the FET phases. However, learners are not restricted from using technological devices, especially in well-resourced schools. This means that learners do not require technological devices for any forms of assessment since this may discriminate against under-resourced schools. One of the implications of this curriculum set-up is that integrating technology is not mandatory for teachers. Second, the forms of assessment also do not make the integration of technology urgent in schools since learners still rely on pen and paper exams.

As explained by Brodie (2017), teachers need to cover a wide curriculum and primarily follow what has been termed a ‘curriculum of compliance’. This means that teachers may opt to do the bare minimum in and outside the classroom. This is because the teaching demands are too high and, more importantly, complex (Brodie, 2017). The complexities of teaching may cause teachers to be less interested in integrating technology into the classroom. It may be noteworthy that teachers who understand the impact of technology during instruction may embrace its integration into teaching and learning.

Muhazir and Retnawati (2020) also corroborated these findings in their study. According to their findings, digital resources were not used in classrooms due to the mathematics learning material being less suitable for the use of technology. This means that the mathematics curriculum may not be designed in ways that allow for technology integration easily. For example, a topic like finance in mathematics may not warrant the integration of technology, especially when learners are able to master it without many difficulties. This implies that teachers may not be easily persuaded to integrate technology for topics that are not entirely suitable for technology integration.

- Learners’ perceived abilities, motivation, and behaviour (Goos et al., 2009, p. 322)

A hidden driving force among the factors that affect the integration of technology in classrooms is the behaviour and attitudes of learners in schools. The learners present in schools may affect teacher attitudes towards integrating technology. According to Goos et al. (2009), the academic abilities learners possess affect whether teachers will implement technology in the classroom. This means that learners who possess exceptional academic ability can steer teachers toward the integration of technology. However, it may be argued that learners with lesser academic abilities would, in fact, benefit more from the use of technological resources during classroom instruction (Munje & Jita, 2020). This is because there are associated benefits that learners miss out on if technological resources are not used in classrooms (Munje & Jita, 2020). The main idea is that learners may have a positive impact on the integration of technology in classrooms if their attitudes and behaviours persuade teachers to want to go the extra mile in their teaching and learning.

These factors determine whether technology could be used in the classroom in a way that improves learning. To summarise these factors, Das (2020) stated that a lack of Internet access,

technology, and teacher trainers all contribute to the challenges teachers experience with using digital resources in the classroom.

Teaching is already a complex process, and integrating technology in the classroom escalates this complexity (Fuglestad, Healy, Kynigos, & Monaghan, 2009; Sua´rez-Rodríguez, Almerich, Orellana, Dı´az-Garcı´a, 2018). This means that some teachers are facing apparent challenges in using digital resources.

Perhaps the conceptual gains of learners that may come with using technological resources in the classroom could address the challenges.

2.3. Challenges that learners may have in understanding Transformation Geometry

Transformation Geometry is a topic covered in the fourth term of the Grade 9 academic year (DBE, 2011). According to the ATP 2023/2024, it is allocated 7 hours which are spread over 2 teaching weeks. It is within the Shape and Space (Geometry) content area. One of the Specific Aims of Senior Phase mathematics is to ‘establish deep conceptual understanding to make sense of mathematics’ (DBE, 2011, p. 8). This means that learners should be instructed in such a way that they grasp the concepts thoroughly. The learners should also be able to relate the concepts to their real-life experiences. The emphasis on this specific aim of learning mathematics is to make mathematics less abstract and more understandable or relatable.

The following are listed as the scope and depth of what is to be covered in Grade 9 Transformation Geometry:

- ‘Recognise, describe and perform transformations with points on a coordinate plane’ (DBE, 2011, p. 115)

This is foundational to understanding Transformation Geometry. Transformations include translations, reflections, and rotations (DBE, 2011). Although the CAPS document lists rotations as part of the transformations to be covered, the 2023/2024 ATP excludes rotations from the grade 9 curriculum. Consequently, rotations are left out of the discussion of this study to avoid instructing learners on content that is not part of their assessments. Learners are expected to be able to point out the kind of transformation made on a point on the Cartesian plane. This is also important to understand functions. The learners should not only be able to recognise the kind of transformation performed on a point in the Cartesian plane, but they should also be able to describe the transformations that have been made on the points. This requires a clear understanding of the underlying principles involved in Transformation

Geometry. More importantly, learners should be able to perform transformations on points given on the Cartesian plane. Figure 1 shows a point on the Cartesian plane. Learners should be able to translate and reflect point A on the Cartesian plane.

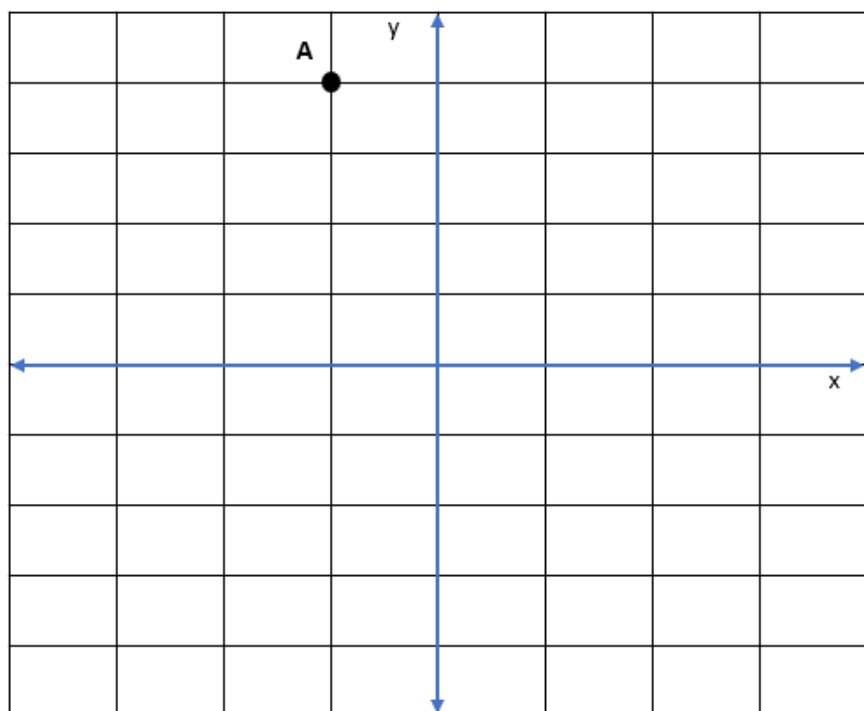


Figure 1: A point A on the cartesian plane

- ‘Recognise, describe and perform transformations with triangles on a coordinate plane’ (DBE, 2011, p. 115)

Learners are expected to perform transformations on triangles and not only on points lying on the cartesian plane. The transformations still include reflection and translation. The same methods used in transforming points are used when triangles are transformed. The main issue when dealing with triangles is that three points should be taken into consideration when transformations are performed. This will be the focus of this study.

- ‘Use proportion to describe the effect of enlargement or reduction on area and perimeter of geometric figures’ (DBE, 2011, p. 115)

Different shapes may be enlarged or reduced on the cartesian plane. This affects their perimeter and area. Learners are expected to represent an enlargement as well as a reduction on the cartesian plane for different shapes. The scope of this study will exclude this aspect of transformation. This is because the 2023/2024 ATP does not include these transformations in

the concepts to be covered in grade 9. Enlargements are therefore not part of the grade 9 Transformation Geometry curriculum.

There is evidently a wide scope of content to be covered in Transformation Geometry. Figure 2 is followed by the kinds of questions learners are expected to answer in Transformation Geometry, as guided by the 2023/2024 ATP CAPS document. The questions may require learners to apply conceptual or procedural knowledge.

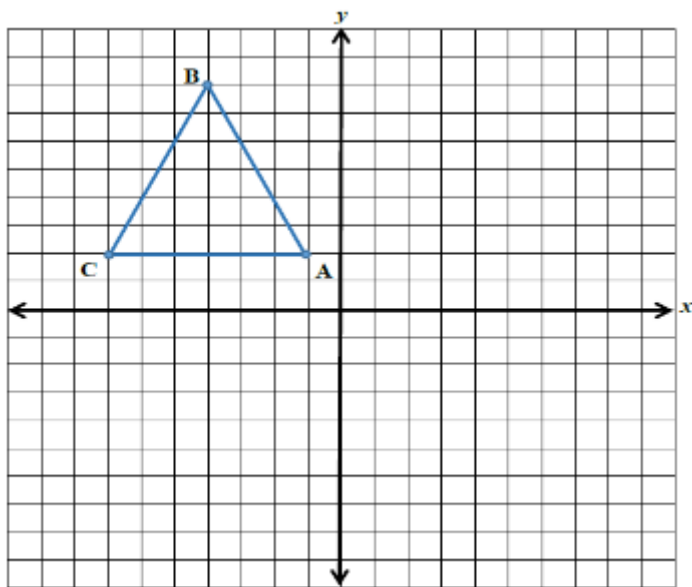


Figure 2: A triangle BAC on the Cartesian plane

Questions

1. Reflect triangle BAC along the y-axis and draw it on the same diagram.
2. Write down the coordinates of A', B' and C'.
3. Triangle BAC is shifted 5 units downwards and 3 units to the right. What are the coordinates of A', B' and C'? Draw the shifted triangle.
4. Reflect triangle BAC along the line $y = x$. What are the coordinates of A', B' and C'?

The responses that learners give to the provided questions may reveal potential challenges they have in the classroom to conceptualise the translations and reflections of different geometric shapes, especially when it is only shown on a chalkboard (in the case of this study). The chalkboard may restrict the explanation of the teacher since transformations cannot be shown in motion, and this may limit the conceptual gains of learners on reflection, and translation. This may partly highlight the need to visualise during classroom instruction. It may be

insufficient to explain only the processes involved in transformation geometry without demonstrating them in the classroom.

According to Guven (2012), learners have difficulties in understanding transformations (translation and reflection). This has far-reaching consequences since Transformation Geometry hinges on those concepts. This resonates with the findings of ANA 2013 Diagnostic report. In that report, learners showed limited knowledge and understanding of points of intersection and transformations. In other words, the learners were not able to reflect images, write the coordinates of reflected images, and draw rotated images (DBE ANA Diagnostic report, 2013).

Learners also struggled to determine the length of a line joining two points when their coordinates are known. These difficulties stem from the reality that while most learners gain procedural knowledge, most learners do not develop conceptual knowledge of Transformation Geometry (Guyen, 2012). The argument put forward by Guven (2012) is that the majority of learners in schools understand Transformation Geometry procedurally and not conceptually. This means that learners may only know how to perform a transformation without understanding the underlying principles involved. More importantly, learners may not even be able to distinguish between the kinds of transformation in question. The evidence of this understanding lies in the reality that learners struggle with questions that require an application of knowledge gained during the instruction of Transformation Geometry.

Aktaş and Ünlü (2017) found that learners had difficulties in understanding transformations. There are two pertinent findings from that study that need to be analysed to understand some of the challenges learners have in learning Transformation Geometry. First, learners struggle to obtain the correct direction when translating a point (Aktaş & Ünlü, 2017). This means that a translation to the right by a certain number of units may be performed in the opposite direction, but with the correct number of units required for the transformation. For example, a learner may correctly apply a translation of five units but may perform the transformation in the incorrect direction. Second, the learners could not differentiate between reflecting and translating. This would mean that the fundamental principles of reflecting and translating points had not been mastered by the learners. It is as though the learners understood transformations as having movements of points and shapes without knowing when to apply either kind of movement.

In a similar study, learners showed difficulties in being able to understand and apply Transformation Geometry concepts (Noto, Priatna & Dahlan, 2019). This means that the learners just couldn't understand the concepts involved in Transformation Geometry. This is in line with the findings of Aktaş and Ünlü (2017) that learners confuse translation with reflection. Consequently, learners will not be able to perform transformations correctly if they do not understand the underlying concepts.

Another finding put forward by Noto et al. (2019) is that learners struggle to understand questions in Transformation Geometry. Noto et al. (2019) explain that part of the difficulties of learners in responding correctly to Transformation Geometry questions lies in their inability to understand what is expected of them. Perhaps if the question was simplified, learners would be able to correctly apply the concepts and demonstrate conceptual and procedural fluency. An example of a Transformation Geometry question is shown below to expand on the difficulty in the discussion. The diagram of the question is given in Figure 2.

Example:

Triangle BAC is shifted 5 units downward and 3 units to the right. What are the coordinates of A', B' and C'? Draw the shifted triangle.

The way the question is structured may make learners unable to comprehend the procedure and underlying conceptual principles required to solve the problem. The example given shows that the learners should perform four actions. First, they should shift the shape downward. Second, they should move the shape to the right. After performing those actions, they should write down the new coordinates of the shifted figure. The fourth action is to draw the transformed shape. These required actions may be overwhelming to learners. As discussed by Noto et al. (2019), learners who do not understand the problem may not be able to finish solving the problem.

An important contributor to the difficulties that learners have in understanding Transformation Geometry is their challenge to visualise geometric objects (Noto et al., 2019). This also includes their challenge to visualise reflections and translations. Learners who struggle to visualise reflection and translation transformations will not be able to master the underlying concepts. Learners who struggle with visualising geometric objects will in turn fail to respond to questions on transformations correctly.

In this study, the researcher seeks to investigate the influence of carefully selected VTRs in the development of conceptual knowledge of learners during the instruction of Transformation Geometry. This may aid learners in visualising geometric objects and responding correctly to questions.

2.4. The influence of VTRs on learners' conceptual knowledge of Transformation Geometry as related to the main research question

The mathematics classroom requires learners to have skills and knowledge about different concepts. Learners should be able to apply concepts across a wide spectrum and they should be able to solve problems systematically.

The two types of mathematical knowledge required in the classroom are conceptual knowledge and procedural knowledge (Haapasalo & Kadijevich, 2000). The relationship between conceptual knowledge and procedural knowledge is convoluted (Star, 2000). This is because it may be difficult to determine whether a learner has mastered a topic conceptually or procedurally.

These two types of knowledge are essential in the mathematics classroom. Debates have been ongoing about which of these two knowledge types develops first and the findings have been inconclusive (Star, 2000; Rittle-Jonson, Schneider & Star, 2015). In the following section, the two types of knowledge are discussed.

2.4.1. Conceptual knowledge

Conceptual knowledge can be described as what one knows about a concept (Star, 2000). This includes the facts and information related to that concept. For example, when a learner is asked to define a 'reflection' transformation, they are required to apply conceptual knowledge. The learner may explain that a reflection is a transformation that flips an object or a shape. This shows that the learner understands the facts and information about the concept of reflection in Transformation Geometry.

Haapasalo and Kadijevich (2000) further explained that this kind of knowledge requires conscious thinking. The learner should be applying their higher-order thinking skills to show this kind of knowledge. In the case of the example given above, Section 2.2 (Figure 2), the learner needs to think about what the reflection transformation does to an object or shape. The response the learner provides should be correct and should clearly express what a reflection transformation does to a shape or object.

Star and Stylianides (2013) define conceptual knowledge as a web of knowledge. This implies that conceptual knowledge requires linking different facts and information to provide sufficient responses to questions in the classroom or in an examination. This also means that it is not enough to simply have facts and information on concepts. Facts and information should be correctly linked and appropriated accordingly, depending on the needs of a question or a required explanation. In the case of Transformation Geometry, instead of asking learners to perform a transformation, learners may be asked to explain the kind of transformation a given object or shape on the cartesian plane has undergone. This would require the learner to go through a selection process of Transformation Geometry concepts. To select the correct transformation, the learner would have linked facts and information related to Transformation Geometry.

Conceptual knowledge may also be an understanding of the links between pieces of knowledge in a particular field (Star & Stylianides, 2013). The main idea is that conceptual knowledge involves connecting pieces of facts or information together and generating an understanding of a concept. Learners who have gained sufficient conceptual knowledge show understanding by interpreting and applying mathematical concepts (Engelbrecht, Bergsten, & Kågesten, 2009). This is because they have a deeper grasp of concepts and can translate it to different scenarios through careful analysis of given problems.

Conceptual knowledge can also be understood by explaining what procedural knowledge is. Although this study is not rooted in procedural knowledge, it is helpful to unpack what it is like to separate it from procedural knowledge. This will also aid in understanding what conceptual knowledge is not.

Haapasalo and Kadijevich (2000) explain procedural knowledge as knowledge that involves the use of specific rules and procedures in problem solving. This may be more appropriate for routine types of question. This means that procedural knowledge focuses on what a learner can do or 'perform'. This may be displayed in the action of performing a calculation. In Transformation Geometry, a learner may be asked to translate a given object by 3 units to the right on the Cartesian plane. This means that the learner should apply a procedure or an acquired method to perform the transformation. In fact, the learner is 'triggered' to perform a known action as soon as the question is posed.

Procedural knowledge involves action sequences for solving problems (Star and Stylianides, 2013). The question itself does not require critical thinking skills. However, the learner is

required to exercise precision while following the method of performing the required transformation since there are steps in carrying out a calculation.

Procedural knowledge does not rely on higher-order thinking skills since it is the knowledge of procedures (Rittle-Johnson et al., 2005). This contrasts with conceptual knowledge, which is more concerned with applying concepts in different situations. According to Rittle-Johnson et al. (2015), procedures are linked steps and actions that lead to a solution of a given problem. This is a type of knowledge that a learner can acquire by working across similar problems. This means that when a new problem is posed, the learner may struggle to solve it since it is not packaged in the same way as the practised problems.

Procedural knowledge involves the use and manipulation of mathematical skills (Engelbrecht et al., 2009). This means that procedural knowledge is, in fact, valuable for learning. Procedural knowledge may appear easier to master, but it is important for learners to acquire. The main difference between procedural knowledge and conceptual knowledge lies in the ability of learners to apply concepts across a wider spectrum as far as mathematical problems are concerned.

Teaching mathematics in schools emphasises procedural skills more than conceptual thinking (Engelbrecht et al., 2009). This is because assessments focus only on whether a learner got the method right. This means that the assessments do not directly test for conceptual knowledge, but mostly test for understanding, which is only necessary to solve given problems. Consequently, most maths assessments in schools focus on evaluating whether learners can correctly apply a sequence of steps.

Conventional school textbooks also primarily focus and are based on procedural tasks that promote skills more than understanding (Haapasalo & Kadijevich, 2000). The goal of the textbooks is to develop the skills of solving various problems and not understanding the concepts involved. This may lead to learners who can perform calculations for problems correctly without understanding the material or the topics (Star & Stylianides, 2013). Learners become proficient in following steps and solving routine problems or problems they have encountered before. This means that when learners are required to solve problems they have not previously encountered, their procedural fluency restricts them from analysing the questions conceptually. In simple terms, learners perform dismally on questions that are not

familiar or questions they have not previously encountered when learning is based on procedural fluency.

The goal in a classroom is to fuse the two types of knowledge (procedural and conceptual) so that learners are proficient in both (Star & Stylianides, 2013). This allows learners to be able to analyse the questions and work out a correct solution path. Learners are also equipped to handle routine problems when procedural knowledge is fused with conceptual knowledge. Engelbrecht et al. (2009) explain that being competent in mathematics is a combination of knowing concepts and knowing procedures.

In the context of Transformation Geometry, learners should be able to perform a sequence of steps to demonstrate the effects of various transformations and they should also understand why each action is performed in solving the problem. The two processes cannot be separated from each other. The interdependence of the two knowledge types is quite complex (Engelbrecht et al., 2009). For instance, learners are expected to understand and follow a procedure set out to solve problems. On the other hand, learners are expected to apply their understanding of concepts across different problems, which may in fact be unpacked and arranged as procedural problems. Procedural knowledge relies on conceptual knowledge, while conceptual knowledge relies on procedural knowledge. This interdependence should draw us to realise that understanding mathematics is indeed the synthesis of knowing the concepts and carrying out procedures (doing). Understanding mathematics cannot be the achievement of conceptual fluency in the absence of procedural fluency (Star, 2000).

The prevalent belief is that in terms of sequence, the conceptual-to-procedural is expedient in the classroom (Rittle-Johnson et al., 2009). The implication is that learners should understand the depth of concepts before acquiring procedural skills. For example, in transformation geometry, learners should understand the definitions and effects of different transformations (reflection and translation) on objects or shapes on the Cartesian plane. However, it is important to note that this is only a belief and thus still requires thorough testing.

The complexity of the interdependence of conceptual knowledge on procedural knowledge and vice versa may perhaps make it difficult to measure both forms of knowledge. There are, however, distinct and reliable ways of measuring both knowledge forms to a reasonable degree. Conceptual knowledge can be tested by providing learners with tasks that are relatively unfamiliar to them (Rittle-Johnson et al., 2009). The responses of the learners would allow the teacher to determine the depth of the learners' understanding of the topics. Unfamiliar tasks

also allow learners to link concepts and demonstrate their grasp of concepts. The learners will connect the knowledge pieces they have to generate solutions. An example of a question that can be used to measure the conceptual knowledge of learners is given below.

Example:

Explain the differences between 'reflection' and 'translation'.

The provided question requires the learners to think deeply about reflection and translation. The learners should connect the two concepts and describe how they differ. A learner who does not understand either of the concepts will not be able to respond correctly to this kind of question.

Procedural knowledge is measured according to the accuracy of learners' answers to given problems (Rittle-Johnson et al., 2009). This includes providing tasks that are relatively familiar to the learners. The main objective when measuring procedural knowledge is to evaluate whether learners can follow a sequence of steps to determine a solution to a problem. Learners may need to make small changes to solution steps from a previous problem to solve new problems presented to them. An example of how procedural knowledge may be measured is given below.

Example:

Task 1: A triangle with points A (-5; 5), B (-1; 5) and C (-3; 1) is shifted 2 units to the right. Determine coordinates of A', B' and C'.

Task 2: A triangle with points A (-5; 5), B (-1; 5) and C (-3; 1) is shifted 5 units to the right. Determine coordinates of A', B' and C'.

The solution paths of the learners are similar for both tasks in the given example. This means that the teacher seeks to evaluate whether the learners can follow the steps to determine the new coordinates of points on a shifted triangle. After working on Task 1, it becomes easier for learners to work on Task 2 because they only need to shift the shape by 3 units to the right.

2.4.2. Conceptual knowledge and technology in the classroom

It is important to explain that effective teaching and learning are based on many factors. The conceptual gains of learners in the classroom, according to Olive et al. (2009), may be a product of the tasks that learners are given. The design of the classroom tasks might enable learners to grasp the concept. The way in which the teacher supports learners and facilitates teaching also affects conceptual development of learners (Olive et al., 2009). Furthermore, the social culture in the classroom and the mathematical content being taught may also affect the way conceptualisation of topics develops during instruction. All these factors involved in effective teaching and learning indicate that enhancements in conceptual gains of learners cannot be solely attributed to the use of technology in the classroom (Olive et al., 2009). This is important to understand, as the contribution of the teacher in the classroom can be undermined or left unnoticed, while stakeholders perceive technology as the main instrument of enhancing the learning environment.

Padayachee (2017) echoed the same idea in stating that technology does not just transform education. Therefore, the main issue in introducing technology into the classroom is to support teaching and learning. The job of the teacher still lies with the teacher. The difference is that technology introduces much-needed aids into the classroom which may be essential for enhancement of concepts. The idea is that technology is an added accessory in the classroom to maximise the work of teachers.

According to Olive et al. (2009), visualising concepts using technology introduces a dynamic aspect to teaching and learning. Therefore, alternative learning opportunities are created in the classroom. Learners are provided opportunities to visualise concepts as they are being taught in the classroom. The implication is that whatever the teacher may be unable to explain clearly to learners, the technology used makes up for through visualisation of concepts. This is important if learners are to generate conceptual knowledge.

In another study, Mofolo-Mbokane, Engelbrecht, and Harding (2013) indicated that some difficulties of learners in understanding geometry were related to a lack of visualisation and imagining rotations of different solids. The study required the learners to calculate volumes of solids and the learners needed to have a clear picture of the solid and the volume required to be calculated. This means that learners who were unable to visualise the solids and required

volumes had a lower probability of obtaining the correct solutions. A classroom set-up which does not bring dynamic aspects to teaching may therefore disadvantage learners from mastering concepts and linking them through learning. Perhaps digital resources that demonstrate rotations could have aided learning in that study.

Mofolo-Mbokane et al. (2013) further suggest that technology (digital resources) may bring some aspects of various abstract concepts to life. The concepts with which learners struggle can be made clearer to learners through technology. The visualisation aspect of learning can also be enhanced through technology.

Technology can, therefore, also aid in deepening and extending mathematical learning (Olive et al., 2009). This speaks to the conceptualisation of topics during classroom instruction. Learners are afforded an environment where technological aids can deepen their understanding of abstract topics. In the case of transformation geometry, learners may require transformations to be displayed through technological resources.

Ocal (2017) studied the impact of digital software (Geogebra) on conceptual and procedural knowledge. The study's findings showed an improvement in the conceptual gains of the learners. This suggests that the usage of technology in the classroom may enhance the learning process and, more importantly, may support the development of conceptual knowledge. In that study, it was also established that the procedural gains of the experimental group were not so different from those of the control group. This may imply that the use of technology in the classroom has more influence on conceptual knowledge than on procedural knowledge. Olive et al. (2009) had explained that some technologies used in the classroom may enhance the development of a combination of conceptual and procedural knowledge which is termed 'proceptual knowledge'. This means that learners' development of conceptual and procedural knowledge takes place simultaneously in such environments.

Mlotshwa, Tunjera, and Chigona (2020) also found that the use of technological resources in teaching mathematical functions improved learners' conceptual knowledge. The software used in this study was Moodle and the learners were allowed to explore the properties of the functions through it. As an interactive software, Moodle allowed learners to deepen their conceptual understanding of functions. This study provides another link between the conceptual knowledge of learners and the use of technology in classrooms.

According to Goos, Soury-Lavergne, Assude, Brown, Kong, Glover, and Sinclair (2009), technology usage in the classroom can be considered effective when teachers are able to design learner tasks that increase the relationship between the abilities of the learners and their mathematical knowledge. Goos et al. (2009) are very direct about the nature of the objectives of using technology in the classroom. Technology should not be introduced into the classroom if it is not meant to increase the conceptual knowledge of the learners about topics and their ability to solve problems. Technology should be included in the development of classroom tasks and assessment forms. Technology should be central to the development of lessons and explanations of topics and keywords. Technology should be used to create a confluence of the mathematical knowledge of learners and their independent conceptualisation of that knowledge. Technology, therefore, needs to be effectively integrated into the learning curriculum if learners are to benefit from it (Padayachee, 2017).

The literature clearly shows a relationship between the use of technology in the classroom and the development of learners' conceptual knowledge.

This means that using digital resources may have a positive influence in improving the conceptual knowledge of learners, especially concepts that learners find challenging.

2.5. Summary and conclusion

This chapter was intentionally sequenced to firstly highlight some of the aspects that inhibit teachers from using digital technological resources in classrooms. This was followed by some of the challenges learners face in understanding Transformation Geometry. Lastly, a landscape of existing literature on the influence of VTRs on learners' conceptual knowledge was discussed.

It was also clear that there are various challenges in using technology, particularly in under-resourced schools. The main challenges were directly related to resource shortages and a lack of training in the use of technology in schools.

The literature unpacked in this chapter indicates that learners have challenges understanding transformations (reflection and translation), regardless of the method of instruction in classrooms.

This chapter also showed that the use of VTRs in teaching and learning produces significant gains in the understanding of concepts by learners, including transformation geometry.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1. Introduction

This study was conceptualised within two theoretical frameworks. The first framework is conceptual knowledge and its two facets (Crooks & Alibali, 2014). The second framework was the technological, pedagogical, and content knowledge (TPACK), as explained by Koehler and Mishra (2009).

3.2. The two facets of conceptual knowledge

The Framework of Conceptual knowledge (discussed in Section 2.4.1) was used to measure learners' conceptual knowledge since the study investigates their gains when VTRs were used. According to Star (2000), conceptual knowledge is difficult to measure. This means that it is hard to test and would rely on multiple ways to assess learners on. Star (2000) further explains that conceptual knowledge may be assessed verbally or through carefully designed tasks. These tasks should seek to ask learners questions that would prompt responses that demonstrate sufficient quality of their conceptual knowledge.

Crooks and Alibali (2014) put forward a framework which divides conceptual knowledge into two facets. These are 'knowledge of general principles' and 'knowledge of the principles underlying procedures' (Crooks & Alibali, 2014). The framework presents a plausible way to measure learners' conceptual knowledge and will aid in responding to the main research question.

The first facet, the knowledge of general principles, refers to learners' understanding of important principles that are foundational to a topic (Crooks & Alibali, 2014). This includes knowing and providing explanations of terms verbally. This is useful during classroom instruction to gauge the learners' conceptual knowledge gains. The teacher may ask questions to the learners and gauge the gains from the learners' verbal explanations. The depth and quality of a learner's response would aid the teacher in measuring their conceptual knowledge. This facet may also be used in a test, where a learner is asked to explain a concept in words. The learner's attempt to explain the concept would also be measured in terms of depth and quality. As an example, a learner may be asked to explain the idea of 'reflection' in their own words. This question requires the learner to understand the general principles of transformations.

Explaining the concept in the learner's own words also requires the learner to have a thorough knowledge of reflections and to link ideas carefully.

The second facet, knowledge of principles underlying procedures, is more connected to understanding the reasons for performing certain procedures when solving problems (Crooks & Alibali, 2014). This implies that the learner needs to be able to explain why each step is performed at any point in their method to determine an answer. Crooks and Alibali (2014) further explain that learners should also be able to understand why some procedures work for specific problems. This means a learner should meaningfully and intentionally perform procedures. This would provide, to a reasonable degree, a thorough measurement of the learner's conceptual knowledge. This includes asking learners to solve a problem in a specific way (Crooks & Alibali, 2014). This facet may be applied in the form of test questions primarily. A learner may be told that a translation has been performed on a shape and, after that, asked to write the coordinates of the transformed shape. The learner may further be asked to sketch the transformed shape. These kinds of questions allow the learner to demonstrate their knowledge of underlying procedures.

This framework will be used to analyse learners' conceptual knowledge gains when VTRs are used and when they are not used through a written test. Learners will be required to provide explanations of concepts (first facet).

The second facet will aid in measuring learners' conceptual knowledge through their written responses to test questions requiring conceptual knowledge application.

The two facets of the conceptual knowledge framework will aid in responding to the main research question.

3.3. TPACK Framework

The TPACK framework was also a guiding framework of this study since technological resources were selected and used as part of classroom instruction.

This is the knowledge that a teacher should possess to effectively use technology (Koehler & Mishra, 2009). Implementing technology in the classroom will not be successful if components of this framework are missing. This framework is built on the interaction of content and the teacher's pedagogical and technological knowledge (Koehler & Mishra, 2009).

The TPACK framework rests on different knowledge types as shown in Figure 3.

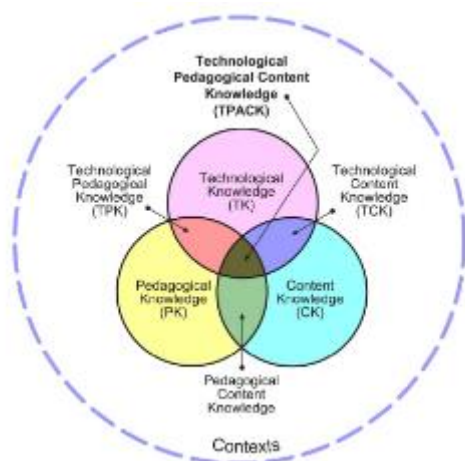


Figure 3: The TPACK framework (Koehler & Mishra, 2009, p. 63)

Koehler and Mishra (2009) explain six different knowledge types required for the TPACK framework.

- Content knowledge (CK)

This is the teacher's knowledge about the subject matter. It includes concepts, theories, and ideas about the subject content. (Koehler & Mishra, 2009). A lack of content knowledge hampers the teaching and learning objectives and outcomes. In this study, the teacher requires knowledge of Transformation Geometry. This includes the teacher's knowledge about points on the Cartesian plane and reflections and translations of geometric shapes.

- Pedagogical knowledge (PK)

This is the teacher's knowledge regarding processes and practices regarding teaching and learning (Koehler & Mishra, 2009). It is the knowledge of teaching and learning methods. It includes the application of learning theories. The teacher should understand how learners construct knowledge and acquire skills. The teacher should know how learners acquire knowledge in Mathematics.

- Pedagogical content knowledge (PCK)

This is the teacher's knowledge of pedagogy pertinent to the teaching of specific content (Koehler & Mishra, 2009). This includes deciding how to teach a topic and identifying the misconceptions involved in that topic beforehand so that how they can be avoided is incorporated into lesson planning. This specialised knowledge allows the teacher to take advantage of the learner's prior knowledge. PCK is an interaction

between pedagogical knowledge and content knowledge as shown in Figure 3. It involves learning how to introduce learners to the Cartesian plane, reflections, and translations. The teacher may use models in the classroom. This is important since the teacher should know how best to introduce and instruct on Transformation Geometry.

- Technological knowledge (TK)

This is the knowledge of information technology for problem-solving (Koehler & Mishra, 2009). Technological knowledge involves the teacher's ability to operate technological resources in the classroom. It may include knowing how to use a computer, projector, tablet, smartphone, and smart board in the classroom. The teacher should be proficient in using the different technologies.

- Technological pedagogical knowledge (TPK)

This is the teacher's knowledge of how teaching and learning can change when technologies are used in certain ways (Koehler & Mishra, 2009). This includes knowing the limitations of certain technological tools in the classroom. This is an interaction between technological knowledge and pedagogical knowledge as shown in Figure 3. The teacher should know the impact of using a smart board in the classroom on some learners. The teacher should weigh the gains of using technological resources in the classroom against the potential loss in learner concentration. The teacher should know whether learners will understand better when using a video in the classroom or if they would be captivated by the presence of a technological device, which defeats the whole idea of using the technological device.

- Technological content knowledge (TCK)

This is the teacher's knowledge about how technology and content influence each other (Koehler & Mishra, 2009). This includes knowing the tools which are best for different topics. This is an interaction between technological knowledge and content knowledge as shown in Figure 3. This will be important for this study since it relies on using technological resources in the classroom. The teacher should know which technological resources can be used for different topics. For example, should they use suitable software designed for learners to engage with or a mere video to explain what translation is? Should the teacher use both the designed software and carefully selected videos?

A successful integration of technology requires an interaction of all the listed specialised knowledge types which is the central region identified in Figure 3. A teacher can make efficacious lesson decisions about using technology in this overlap region.

The main research question seeks to explore the influence of VTRs on learners' conceptual knowledge. This study used the teacher's technological, content, and pedagogical knowledge to explore the influence of technological resources on learners' conceptual knowledge. Technological knowledge helps in deciding how technology will be expediently introduced in the classroom. Videos were used in this study to explore the influence of VTRs on learners' understanding of reflections, and translations. The content knowledge of the teacher should allow for the selection of the videos that best describe the concepts of reflection, and translation. Pedagogical knowledge aided in knowing how to give instruction in the classroom with and without technological resources to determine the actual influence of digital resources on conceptual knowledge of transformation geometry.

The influence of VTRs in the classroom also relates to the study's first sub-question, which seeks to investigate the existing challenges in using VTRs during instruction. This sub-question partly seeks to explore how well a teacher may be able to use VTRs effectively if they are to bring positive influence on the conceptual knowledge of learners. This sub-question also hinges on whether there are challenges a teacher would face using VTRs in the classroom. This question aids in understanding why VTRs are not used in the classroom to the benefit of learners in some schools. Technological knowledge is important in exploring these challenges. Pedagogical knowledge also aids in understanding the challenges since it affects the instructional approaches in the classroom. Some challenges may stem from how a teacher believes Transformation Geometry should be taught and how learners should learn it. Content knowledge aids in understanding whether some challenges are owing to how the teacher understands Transformation Geometry as a topic. If the teacher's content knowledge is limited, then they may not be willing to explore other instructional techniques, especially using technological resources in the classroom.

The second sub-question in this study seeks to explore the difficulties (if any) learners may have in understanding Transformation Geometry. The teacher's content knowledge is central in identifying the learners' knowledge gaps. The teacher should know Transformation Geometry well enough to anticipate difficulties for the learners. This includes understanding

what a reflection is on the Cartesian plane. The teacher should also be able to pick on learner errors and misconceptions. This study will rely heavily on content knowledge to understand the difficulties learners have in Transformation Geometry. The teacher's pedagogical knowledge is also central to understanding learner difficulties. The teacher should know how learners acquire knowledge and skills in Transformation Geometry. This includes knowing how instruction should build up to introduce reflection and translation. In this study, the instruction design should allow the teacher to pick on the difficulties learners have in understanding Transformation Geometry.

3.4. Summary and conclusion

In this chapter, two theoretical frameworks were discussed. Teaching and learning are two processes that are interconnected in the classroom. Since the study focuses on the influence of VTRs on learners' conceptual knowledge, the two theoretical frameworks used catered for both the teacher and learners. The framework of the two facets of conceptual knowledge was chosen to aid in measuring the conceptual gains of learners during the investigation. The TPACK framework was selected to ensure that there is maximum proficiency, on the side of the teacher, in carrying out the classroom instruction of transformation geometry using VTRs.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1. Introduction

This chapter focuses on the research method used in the study. It also explains the research design. The emphasis is on data collection and analysis.

4.2. Research design

In this study, a mixed method design was applied. A mixed-method approach combines both quantitative and qualitative research (Abdulai & Owusu-Ansah, 2014). This means that the data was collected and analysed both qualitatively and quantitatively.

The first objective states that the influence of using VTRs in the classroom will be investigated. The third objective states that the challenges (if any) of learners in understanding Transformation Geometry should be investigated. These two objectives were explored in two Grade 9 classes in the same school. Grade 9B and Grade 9C were randomly chosen and they had 73 and 70 learners respectively. Grade 9B was the Experimental group while Grade 9C was the Control group. The experimental group was instructed using VTRs while the control group was instructed without VTRs. The two classes were given instruction on Transformation Geometry by the same teacher. Facilitation of lessons by the same teacher in both classes was intentionally done to improve the reliability of the study findings. Since the same teacher taught both classes, though differently, it makes the teacher a constant variable in the study. This leaves the main variable as the use of VTRs during classroom instruction. The conceptual gains of learners from either class can therefore not be attributed to the facilitator of the instruction, but rather to the method of instruction. The teacher was the regular Grade 9 mathematics teacher at the chosen school. Preference was given to a mathematics teacher who was technologically proficient as the TPACK framework is one of the two frameworks which ground this study (Section 3.3). This made the use of VTRs in the classroom easier and more effective since the teacher was fluent in technology usage. A teacher who was not technologically proficient would have required training prior to lessons.

In this study, the selection of a teacher who was technologically proficient helped reduce the potential challenges of using VTRs in the classroom. The VTRs were two videos explaining reflection and translation. The VTRs were offered to the teacher as aids to enhance learning. The first video was used from the Youtube channel ‘Turtlediary’ (3 Types of Transformations

*Translations Reflections & Rotations *Math for kids*). This video was nine minutes and twelve seconds long. The second video was used from the Youtube channel 'Praveen Nair' (Reflection, Translation & Rotation – Transformations | Geometry). This video was two minutes and twenty-three seconds long. Both videos were selected due to their clarity in explaining and demonstrating different transformations. The length of both combined videos was 11 minutes and 35 seconds. This made it possible to view and interact with both videos within one lesson. Each lesson was 35 minutes long.

In Grade 9C, instruction was given without the aid of VTRs (Control group) whereas in Grade 9B instruction was given with the aid of VTRs (Experimental group). The learners were allowed to randomly select their class at the beginning of the academic year by the school. Both classes had a similar spread of learners in terms of academic performance, i.e., high achievers are not grouped in one classroom.

Upon completion of the instruction in both classes, a test was given to the learners. The results of the test were used to measure the influence of VTRs on the conceptual knowledge of the learners. The test scores and performance of learners in both classes were compared to determine the nature of the influence of using VTRs. This was a quantitative analysis. The test also helped to identify the challenges that learners faced in understanding transformation geometry by analysing their solutions to the given problems. This was part of the qualitative analysis. The class that initially received instruction without VTRs was given the opportunity to be taught with VTRs after data collection.

Qualitative data was collected through an observation schedule to determine the challenges that learners face in transformation. According to Sani (2013), the observation data collection method can be used to determine the number of times an event takes place during an investigation. A mixed-method approach combines both quantitative and qualitative research (Abdulai & Owusu-Ansah, 2014). The researcher observed the classroom environment during the instruction of both classes. Classroom interactions between teacher and learners were recorded in the observation schedule, and this was used primarily to respond to the second objective. Observations also included taking note of the availability of technological equipment in the school, how long it takes the digital equipment to be set up, and any other observable conceptual knowledge development differences from both classes. The research design is summarised in Table 1.

Table 1: A summary of the research design

Group	Class	Instruction and Observation	Assessment
Experimental	9B	VTRs integrated	Test
Control	9C	No VTRs	Test

4.3. Sampling

Two Grade 9 (Grade 9B and 9C) classrooms were selected from the school chosen for this study. The school had a total of 1079 learners. There were 235 Grade 9 learners distributed across three classes. Each class has between 70 and 80 learners. Grade 9B and 9C were chosen for this study and they had 73 and 70 learners respectively. Grade 9B was the Experimental group while Grade 9C was the Control group. The third class (Grade 9A) was also given an opportunity to learn using VTRs although it was not selected for the study.

47 learners from Grade 9B consented to take part in the study while 45 learners from Grade 9C consented to take part. This brought the sample size to 92 participants instead of 143. The learners who did not consent to participate in the study were allowed to participate in all lessons. Only data from learners who presented completed consent forms and affirming participation were considered.

4.4. Data collection

Data collection was carried out in the third term of the 2023 academic year. It ran from September 18 to September 21. Data collection was carried out for a total of four days. This required permission from the school to introduce a Term 4 topic toward the end of the third term. The lessons were conducted during normal mathematics periods according to the school's schedule. This happened after the school's recommendation to use the periods since the learners had already completed their term tests and were available.

4.4.1. Data collection instruments

The main data collection instruments in this study were a written test and an observation schedule. The test written by the learners is given in Figure 4.

ACTIVITY 1 GRADE 09..... TRANSFORMATION GEOMETRY DATE:
Learner Code: Total Marks: 28

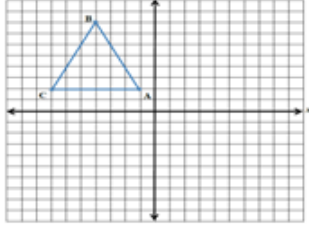
1. Complete the following statements.

1.1. Translation a shape. (2)

1.2. Reflection a shape. (2)

2. Triangle BAC is given with A (-1;2), B (-4;8) and C (-7;2). Write down the coordinates of points A', B' and C' if triangle BAC is shifted three units downwards. Sketch the transformation on the diagram.

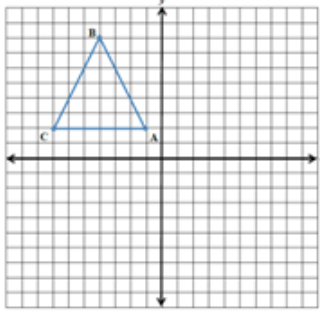
A' (.....) B' (.....) C' (.....)



(6)

3. Write down the coordinates of points A', B' and C' if triangle BAC is shifted two units downwards and then four units to the right. Sketch the transformation on the diagram.

A' (.....) B' (.....) C' (.....)

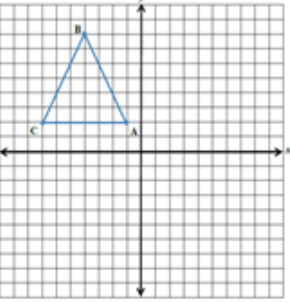


(6)

4. Triangle BAC is reflected in the y-axis. Write down the coordinates of A', B' and C'.

A' (.....) B' (.....) C' (.....)

Sketch the transformation on the diagram.

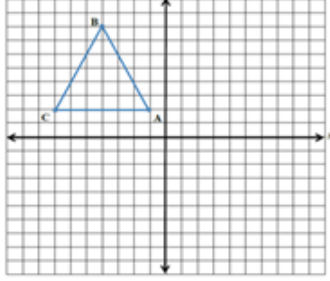


(6)

5. Triangle BAC is reflected across the line $y = x$. Write down the coordinates of A', B', C'.

A' (.....) B' (.....) C' (.....)

Sketch the transformation on the diagram.



(6)

TOTAL: 28

Figure 4: Written test activity for learners

The test provided was used to analyse the responses of the learners to questions that were conceptual in nature, and they were analysed according to the two facets of conceptual knowledge. The influence of VTRs on the conceptual knowledge of the learners was investigated by comparing the performance of the learners in both classes and the quality of the responses the learners provided for each question. The test consisted of five questions, which are analysed in the subsequent section.

The researcher conducted a classroom observation to investigate the challenges of using VTRs during classroom instruction. The potential challenges teachers may experience when implementing VTRs in the classroom were investigated through observed elements and researcher notes on the observation schedule. It is important to note that in this study, classroom observations were recorded primarily on the researcher's observation schedule. The researcher's notes were made on the observation schedule during the observation to capture important interactions during classroom instruction. The observation schedule is shown in Figure 5.

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (A or B)
Name of Observer: Mr. N

VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson					
2	Teacher is confident in executing the lesson					
3	Teacher confidently uses VTR's					
4	Learners follow the teacher's explanations using the digital resource					
5	Teacher experiences 'hiccups' during lesson presentation					
6	Teacher provides activities to learners that are connected to digital demonstrations					
7	Learners ask/answer questions based on digital resource					
8	Learners ask/answer about concepts presented without digital resource					

Figure 5: Observation schedule used during classroom instruction

The elements observed included indicating whether VTRs were used during instruction. This helped to differentiate between the experimental and control groups. The teacher's confidence in executing the lessons and using VTRs during instruction was also observed. The observation schedule also maps out the instances during instruction in which the teacher experienced 'hiccups' and challenges in implementing VTRs. Hiccups refer to moments during instruction when the teacher struggles to explain a concept or to use a technological device (Clark-Wilson & Noss, 2015).

All other relevant documents such as participant information sheet, consent forms, and learner assent forms are attached in the Appendices.

Data collection was carried out in two phases.

4.4.1.1. Phase 1

The first three days focused on giving instruction to both classes on translation and reflection. The lessons were carried out by the Grade 9 mathematics teacher. Each lesson was 70 minutes long (two 35-minute lessons). The researcher was present in each lesson for observations. The learners received a partial explanation for the presence of an observer in the classroom. This is one of the dimensions of the observation method according to Sani (2013).

The lesson observations aided in responding to the challenges teachers experience while using VTRs during classroom instruction of Transformation Geometry (First sub-question). The way the teacher demonstrated transformations with and without VTRs was important in this study. The way the learners engaged with the teacher when the lesson included VTRs and when VTRs were absent was also observed. This phase of the study also partly responded to the main research question on how VTRs influence the development of conceptual knowledge of learners during classroom instruction.

4.4.1.2. Phase 2

The fourth day of the study focused on giving a test to both groups of learners (as discussed in the research design). Both classes were given the same test to write at the same time. This required two periods to be requested for one of the classes from non-mathematics teachers. The test was written under supervision. The No VTRs class was invigilated by the mathematics teacher while the VTRs class was invigilated by the researcher. This was decided on at random by the researcher.

The learners' scripts of both classes were collected after the test by the invigilators and handed over to the researcher for marking purposes. Copies of the marked scripts were made and kept by the researcher while the original scripts were returned to the mathematics teacher for their own analyses. This aided the teacher in preparation of Term 4 since Transformation Geometry should be covered then according to the teaching plan.

The scripts were then analysed for the purpose of the study by the researcher. The Grade 9 maths teacher continued to provide feedback on the test to the learners after the study was completed. The responses the learners gave to the test questions helped to identify whether the learners had challenges or not in understanding Transformation Geometry. The responses of learners from the class taught with VTRs aided in responding to the main research question.

The test performances of both classes were also analysed to investigate the nature of the influence of using VTRs during classroom instruction of Transformation Geometry.

On the fifth day, the control group was given an opportunity to be instructed in Transformation Geometry using VTRs.

4.5. Data analysis

4.5.1. Data collected in Phase 1

The data obtained from Phase 1 was obtained mainly during classroom instruction. Data were captured from observations made by the researcher. The data collected in this phase allowed the investigation to respond to possible challenges that teachers may face in using VTRs in the classroom. The possible challenges learners may have in understanding Transformation Geometry were recorded in the researcher's observation schedule as part of the researcher's notes and analysed further to draw conclusions. The data collected also, in part, responded to the influence of using VTRs in the instruction of Transformation geometry. The data were qualitative in nature.

4.5.2. Data collected in Phase 2

The learners' marked scripts were analysed both qualitatively and quantitatively. The questions provided were designed to investigate the learners' conceptual gains after instruction. The solution paths of the learners from both groups were analysed for understanding through the two facets of conceptual knowledge.

Quantitative analysis was carried out using actual test scores of the learners and mean scores per question. The analysis involved descriptive statistics (measures of central tendencies). Descriptive statistics focus on the properties of the given data set (Sutanapong & Louangrath, 2015). In descriptive statistics, the data set is obtained from a sample of an entire population. Therefore, it is important to qualify the findings based on descriptive statistics. This is done using inferential statistics. Inferential statistics allow for a more generalised prediction of findings (Schumacher & McMillan, 1993). Since the sample population is related to the entire population, inferential statistics also take into account sampling and measurement error. Measurement error, in particular, is unavoidable in research since variables are never truly measured perfectly (Schumacher & McMillan, 1993). In this study, data collected from Phase 2 were first analysed using descriptive statistics. This is because descriptive statistics form the basis of inferential statistics. The descriptive statistics analysis was followed by an inferential

statistics analysis. An independent samples t-test was used since the study tested the difference between the mean of an experimental group and a control group.

Learners were presented with the following questions in a test.

1. Complete the following statements.

1.1. Translation a shape. (2)

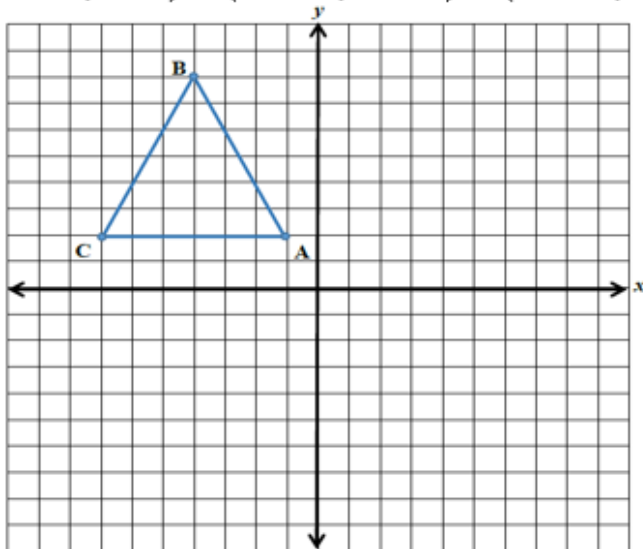
1.2. Reflection a shape. (2)

Figure 6: Question 1 of the written test

Question 1 required a brief explanation of translation and reflection in words, as shown in Figure 6. This is in line with the first facet as discussed by Crooks and Alibali (2014). The depth of the explanation of the learners should demonstrate their conceptual knowledge.

2. Triangle BAC is given with A (-1;2), B (-4;8) and C (-7;2).
Write down the coordinates of points A', B' and C' if triangle BAC is shifted three units downwards. Sketch the transformation on the diagram.

A' (.....;) B' (.....;) C' (.....;)



(6)

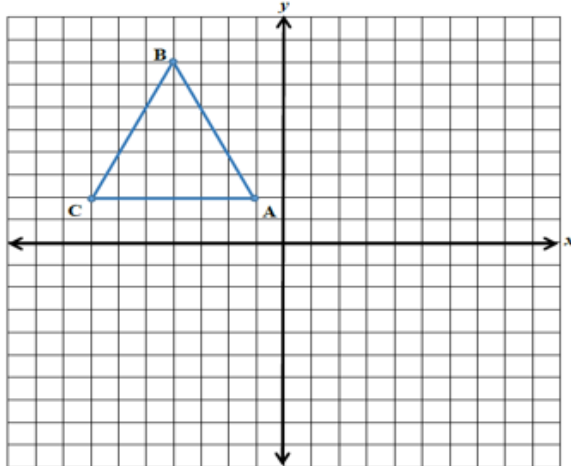
Figure 7: Question 2 of the written test

Question 2 required a single translation to be performed, as shown in Figure 7. The first part of the question required the coordinates of the translated points to be written down first. This required the learner to understand the effect of the transformation. A sketch of the transformed

triangle was required for the second part of the question. This question was based on the second facet of conceptual knowledge, as detailed by Crooks and Alibali (2014).

3. Write down the coordinates of points A' , B' and C' if triangle BAC is shifted two units downwards and then four units to the right. Sketch the transformation on the diagram.

A' (.....;) B' (.....;) C' (.....;)



(6)

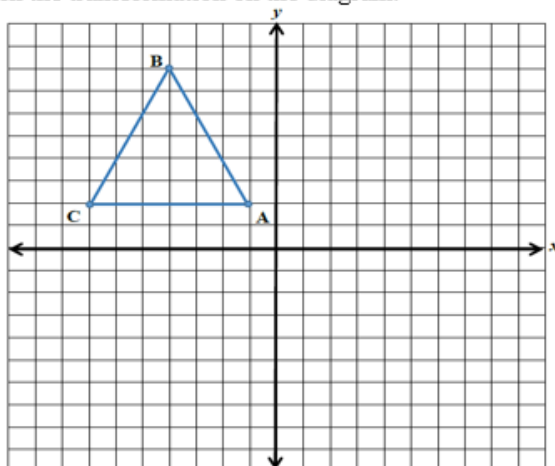
Figure 8: Question 3 of the written test

Question 3 was also based on translation. The main difference was that the learners needed to perform two translations, one downwards and the other to the right. The question is shown in Figure 8. The learners needed to demonstrate a deep and rich knowledge of the principles underlying procedures to correctly provide the translated coordinates of the transformed triangle.

4. Triangle BAC is reflected in the y-axis. Write down the coordinates of A' , B' and C' .

A' (.....;) B' (.....;) C' (.....;)

Sketch the transformation on the diagram.



(6)

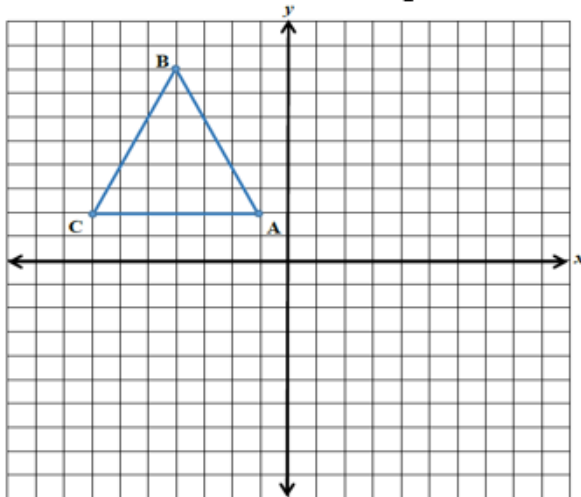
Figure 9: Question 4 of the written test

Question 4 was based on reflection. This was a straightforward reflection across the y -axis. The question required an understanding of the changes that reflection across the y -axis brings to the coordinates of the original points, as shown in Figure 9.

5. Triangle BAC is reflected across the line $y = x$. Write down the coordinates of A' , B' , C' .

A' (.....;) B' (.....;) C' (.....;)

Sketch the transformation on the diagram.



(6)

Figure 10: Question 5 of the written test

Question 5 was also based on reflection, as shown in Figure 10. In this question, learners needed to perform a reflection across the line $y = x$. This question was important because both groups were taught this reflection in the traditional method. This was done to further analyse whether there were conceptual gains in using VTRs during instruction.

The data collected in this phase aided in responding to the second sub-question and the main research question.

4.6. Coding

To ensure anonymity of the learners during the study, each learner was given a random number which they used on their scripts. The code started with the letter of the class in which the learner was, followed by numbers, to specify the group they were representing. This protected the privacy of the learners, but also allowed a way to compare the performance of the learners in both classes. After marking the test scripts of each group of learners, 70% to 100% were coded as high achievers, 40% to 69% were middle achievers, and 0% to 39% were low achievers.

4.7. Research questions, Theoretical framework, instruments, and methodology

Table 2 shows the connection between the research questions, theoretical framework, data collection instruments, and the methodology followed in the study.

Table 2: Research questions, Theoretical framework, Instruments, and Methodology

Research questions	Instruments and methodology
Main research question	
What is the influence of VTRs on learners' conceptual knowledge of Transformation Geometry?	The main data collection instrument used is the test. This question will be evaluated through the learners' responses to the test questions. The learners' responses to each question will aid in measuring their level of conceptual gains. The observation schedule will also be used to record any conceptual gains learners demonstrate during classroom instruction before the test is given. This will include all noted interactions that evidence conceptual gains.
Theoretical Framework	The framework of the two facets of conceptual understanding is applied for this question.
Sub-questions	
1. What are the factors that may affect the use of VTRs in classroom instruction of Transformation Geometry?	The observation schedule is the main data collection instrument for this question. The researcher will observe the classroom interactions between the teacher and learners. The observations will be recorded, and additional notes added for clarity on the observation schedule. The process of setting up the VTRs will also be noted in the observation schedule.
Theoretical framework	The TPACK framework is central to this question.
2. What are the challenges (if any) that learners face in understanding Transformation Geometry?	The observation schedule will be used to record the challenges that learners face in learning transformation geometry during classroom instruction. The test will also help highlight the challenges that learners face through the solutions they provide.
Theoretical framework	The framework of the two facets of conceptual understanding is applied for this question.

4.8. Ethical considerations

This study was subject to the decision of the University of the Witwatersrand to issue ethical clearance after an application to conduct research is made. After the university issued an ethics clearance, permission was requested from the provincial Department of Basic Education (DBE). After permission was obtained from the province, the next step was to seek permission

from the concerned circuit. Permission was also requested from the principal of the selected school to conduct research. All required school resources were made known to the principal. Upon receiving permission from the school principal, letters of consent and participant information sheets were sent to the teacher, parents, and learners. The participants were made aware of the objectives of the research. All learner participants remained anonymous to the researcher during data analysis. Participants were treated fairly and equally. Coding the learners' scripts ensured that their privacy was protected. The reporting of the findings was honest and unbiased. The teacher, principal, and school also remained anonymous in the research. All participants voluntarily participated in the investigation. During classroom instruction, the learner's anonymity to the researcher could not be maintained during observation, but the identity of the learners and the teacher was not revealed in the observation schedule. This ensured that the privacy of the participants was still protected.

4.9. Validity

Validity measures the success of the investigation against its objective (Abdulai & Owusu-Ansah, 2014). This includes evaluating whether an acceptable methodology was followed in the study. Abdulai and Owusu-Ansah (2014) add that validity encompasses how well the findings can be applied in a new setting. In this study, the lessons were planned according to the CAPS and Annual Teaching Plan documents. The Spot On learner's book was used during class instructions. The test was based on content the 2023/2024 ATP prescribed for learners to know in Transformation Geometry. The test was moderated by the Grade 9 mathematics teacher in the school. The lesson preparation and planning documents were made available to the mathematics teacher for instruction. The teacher was not forced to achieve the desired results from the classroom. The influence of VTRs in the classroom was, consequently, measured accurately given the methodology followed.

4.10. Reliability

Reliability is the extent to which an investigation (including tests) produces similar results when repeated many times (Kumar, 2011). This means that there should be consistency in the findings of a study, regardless of who the researcher is. The test offered to learners was an important part of this research. The main findings were the result of the given test. It was important that the test be reliable. Abdulai and Owusu-Ansah (2014) highlighted that reliability is important in academic research. In this study, the same test was written by learners from

both classes. This was done after instruction was offered to both classes for the same number of hours, by the same teacher and under similar circumstances.

4.11. Limitations of study

The given time frame allowed for the opportunity to probe the conceptual knowledge of both groups of learners in a limited way since there were time constraints. The sample size is sufficient for this study (92 learners). Although only one teacher participated in the study, the influence of VTRs on the conceptual knowledge of learners was successfully investigated.

4.12. Summary and conclusion

This chapter discusses the research design and methodology followed in this study. This included the data collection instruments used and how the data would be analysed. A link between the research questions, theoretical frameworks, data collection instruments, and research methodology was also presented. This provided a clearer view of the focus of this study.

CHAPTER 5: DATA PRESENTATION AND ANALYSIS

5.1. Introduction

This chapter presents qualitative and quantitative data analyses. Both analyses are done to respond to the main research question and the related sub-questions.

5.2. Data analysis

The data collected are analysed qualitatively and quantitatively. There are three main elements that are analysed, that is, the lesson observation schedule, learners' responses to questions, and the test performance of learners. Data from the lesson observation schedule and the responses of the learners to the questions are qualitatively analysed while the performance of the learners' tests is quantitatively analysed.

5.2.1. Qualitative analysis of data

5.2.1.1. Observation schedule data

The researcher conducted the lesson observations during classroom instruction using an observation schedule. This was done from September 18th to September 20th. An observation schedule was used to capture the observations. The observation schedule classified the two groups of learners as Grade 9A and Grade 9B. However, during data collection, Grade 9A was replaced by Grade 9C (Control group). Grade 9B refers to the experimental group. Researcher notes were made on each observation schedule to capture important interactions during lesson instruction. The lessons' observations focused on important interactions between the teacher and learners. This included some reactions from the learners during the instruction.

The observation schedule also recorded the effectiveness of the teacher in using technology in the classroom, as detailed in the TPACK framework. This included the teacher's ability to connect equipment or resolve hiccups during instruction.

The observations also noted the accessibility of technological facilities/equipment in the school by the teacher.

Day 1 of data collection (18 September)

According to the lesson plan, this day focused on introducing transformations. After the introduction to transformations, translation was discussed.

Grade 9B observation (Experimental)

18/09/2023

14.2. Appendix B
14.2.1. Observation Schedule

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (A or B)
Name of Observer: Mr. N
VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson	✓				
2	Teacher is confident in executing the lesson	✓				
3	Teacher confidently uses VTR's	✓				
4	Learners follow the teacher's explanations using the digital resource	✓				
5	Teacher experiences 'hiccups' during lesson presentation				✓	
6	Teacher provides activities to learners that are connected to digital demonstrations	✓			✓	
7	Learners ask/answer questions based on digital resource				✓	
8	Learners ask/answer about concepts presented without digital resource				✓	

14.2. Hiccups included laptop taking long to boot, or opening a video
Other: Lesson started 23 minutes late owing to plug issues
not working in the classroom. Extension card was in another classroom.
- The pull up projector white board needed a nail hammered for
extra support.
- Some words used in the video, needed explanations e.g.
Vertex/Vertices
- Learners were able to explain Rotation, reflection and translation
after watching the first video.
- Learners enjoyed the videos more than the actual instruction
on the board.
- Lesser interaction was observed during normal instruction.

Figure 11: Day 1 observation schedule for Grade 9B

From the observation schedule (Figure 11), the teacher was confident in executing the lesson and the learners were able to follow the VTRs aided instruction. There were a few 'hiccups' during the lesson. Hiccups are unexpected occurrences when using technology during instruction that are not included in lesson preparation and planning (Clark-Wilson & Noss, 2015). This implies that the teacher does not know what to do during these events. Some of the hiccups included the laptop taking a long time to boot or opening a video, as shown in the observation schedule. This made the teacher not know what to do in the meantime. In fact, the

lesson started 23 minutes late because the plugs did not work in the classroom. An extension cord had to be connected in another classroom.

The learners were interested in watching the video and were able to explain reflection and translation afterwards. It was observed that some words used in the video needed explanations, e.g., vertex/vertices. The VTRs also promoted interactions in the classroom. The teacher showed a rich understanding of technology usage, as stipulated in the TPACK framework. The teacher demonstrated a deep understanding of managing technological resources in the classroom while instructing learners and creating meaningful classroom interactions.

Grade 9C (Control)

18/07/2023

14.2. Appendix B
14.2.1. Observation Schedule

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (For B)
Name of Observer: Mr. N

VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson					✓
2	Teacher is confident in executing the lesson	✓				
3	Teacher confidently uses VTR's					✓
4	Learners follow the teacher's explanations using the digital resource					✓
5	Teacher experiences 'hiccups' during lesson presentation					✓
6	Teacher provides activities to learners that are connected to digital demonstrations					✓
7	Learners ask/answer questions based on digital resource					✓
8	Learners ask/answer about concepts presented without digital resource			✓		

1Hr.

Other:- Normal instruction in an overcrowded classroom (70 learners)

Translation

- Learners struggled to visualise 'translation'
- Teacher and learners used a lot of gestures during instruction
- Learners struggled with words like 'translate', 'vertex' and 'image'
- Class started on time
- Teacher used activities connected to concept of translation.

Figure 12: Day 1 observation schedule for Grade 9C

This was a normal lesson in an overcrowded classroom (70 learners) without the aid of VTRs. The observation schedule (Figure 12) indicated that the teacher and learners used a lot of gestures during instruction. The learners struggled with terms such as transformation, translation, and reflection. The class started on time and the teacher used activities connected to the translation. The teacher was confident in executing the lesson. There were very minimal interactions between the teacher and learners. It was as though the teacher could not be asked about the concepts. The learners simply took the teacher's instruction as something that could not be challenged. It is important to point out that the lesson was presented punctually.

Day 2 of data collection (19 September)

According to the lesson plan, this day focused on continuing with transformations. After the recapitulation of the transformations, reflections were discussed. These were reflections in the x and y axes.

Grade 9B (Experimental)

19/09/2023

14.2. Appendix B
14.2.1. Observation Schedule

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (A or B)
Name of Observer: Mr. N
VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson	✓				
2	Teacher is confident in executing the lesson	✓				
3	Teacher confidently uses VTR's	✓				
4	Learners follow the teacher's explanations using the digital resource	✓				
5	Teacher experiences 'hiccups' during lesson presentation				✓	
6	Teacher provides activities to learners that are connected to digital demonstrations	✓				
7	Learners ask/answer questions based on digital resource				✓	
8	Learners ask/answer about concepts presented without digital resource				✓	

1 Hr - Lesson started 7 minutes later owing to setting up and the projector.
Other: laptop and white board.
Observation
- The accent used in videos was American, and it required some words to be repeated by the teacher.
- After the learners needed an explanation of the word 'distorted'.
- Learners used video explanations to describe what 'reflection' means.

Figure 13: Day 2 observation schedule for Grade 9B

As shown in the observation schedule (Figure 13), the lesson started 7 minutes later owing to setting up the projector, laptop, and white board. The accent used in the videos was American, and it required some words to be repeated and explained by the teacher e.g., distorted (See Figure 13). The learners continued to follow the video explanations of translation and reflection. There were fewer hiccups on this day. This may have been aided by the teacher's experience in setting up and working with the learners. The classroom interactions were based more on the videos than on the teacher's traditional instruction.

Grade 9C (Control)

19/09/2023

14.2. Appendix B
14.2.1. Observation Schedule

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (A or B)
Name of Observer: Mr. N

VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson					✓
2	Teacher is confident in executing the lesson	✓				
3	Teacher confidently uses VTR's					✓
4	Learners follow the teacher's explanations using the digital resource					✓
5	Teacher experiences 'hiccups' during lesson presentation			✓		
6	Teacher provides activities to learners that are connected to digital demonstrations					✓
7	Learners ask/answer questions based on digital resource					✓
8	Learners ask/answer about concepts presented without digital resource	✓				

1hr-
 Other:- Lesson started on time.
 - Teacher relied on learners' imagination to explain reflection.
 Reflection:- Teacher folded an A4 page to illustrate where reflected images would be located.
 - Learners could not explain what the 'reflect' meant in their own words.
 - Reflection in the x and y-axes.

Figure 14: Day 2 observation schedule for Grade 9C

The observation schedule notes (Figure 14) indicate that the lesson started on time. The teacher relied on the learners' imagination to explain reflection. The teacher folded an A4 page to illustrate where reflected points or images would be located. The learners failed to explain what 'reflect' meant in their own words. Although the lesson was well presented, the learners struggled to interact with the teacher owing to lack of concept development of the transformations.

Day 3 of data collection (20 September)

This day focused on continuing with transformations. After the recapitulation of the transformations, reflections were discussed. These were reflections in the line $y = x$.

Grade 9B (Experimental)

20/09/2023

14.2. Appendix B
14.2.1. Observation Schedule

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (A or B)
Name of Observer: Mr. N

VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson	✓				
2	Teacher is confident in executing the lesson	✓				
3	Teacher confidently uses VTR's	✓				
4	Learners follow the teacher's explanations using the digital resource	✓				
5	Teacher experiences 'hiccups' during lesson presentation				✓	
6	Teacher provides activities to learners that are connected to digital demonstrations	✓				
7	Learners ask/answer questions based on digital resource				✓	
8	Learners ask/answer about concepts presented without digital resource				✓	

Other: Learners were confident in explaining the concepts of reflection and translation.

21

Figure 15: Day 3 observation schedule for Grade 9B

There were meaningful and engaging interactions in the classroom. The observation schedule notes (Figure 15) indicate that the learners were confident in explaining the concepts of reflection and translation. The lesson started normally. This suggested that the more the teacher used VTRs in the classroom, the better they became in setting up the technological resources punctually.

Grade 9C (Control)

20/09/2023

14.2. Appendix B
14.2.1. Observation Schedule

Observation Schedule
Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.
Name of Grade 09 Teacher: Ms M
Grade 9 (A or B)
Name of Observer: Mr. N
 VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTR's used during lesson					✓
2	Teacher is confident in executing the lesson	✓				
3	Teacher confidently uses VTR's					✓
4	Learners follow the teacher's explanations using the digital resource					✓
5	Teacher experiences 'hiccups' during lesson presentation					✓
6	Teacher provides activities to learners that are connected to digital demonstrations					✓
7	Learners ask/answer questions based on digital resource				✓	
8	Learners ask/answer about concepts presented without digital resource	✓				

Other notes:
 - Started on time.
 - Learners asked when the teacher would bring videos to their class like in other classes.
 - Only 45 mins of learners participated consistently.
 - A drop in the number of learners attending the class.
 - Reflection across line y=x

Figure 16: Day 3 observation schedule for Grade 9C

The lesson started on time. According to the observation schedule notes (Figure 16), the learners asked the teacher when they would be bringing the VTRs to their class. This came after they found out that the other class had received VTRs aided instruction. This implies that there was significant interest arising from VTRs usage in the classroom. It was evident that the usage of VTRs aided the teacher and learners to conceptualise transformations better. VTRs also improved classroom interactions while the traditional instruction method did not catalyse engagement of learners with the teacher or concepts.

It was also observed that the TPACK framework was central to using VTRs in the classroom efficiently.

5.2.1.2. Learners' scripts analysis

This section is based on learners' responses to the written test questions. There were a total of five questions learners responded to. The questions were designed to test the conceptual gains of the learners. The analysis of the learners' scripts was done for both the experimental (Grade 9B) and control (Grade 9C) groups. Each question was analysed for each group. There are categories of learner responses that have been designed to effectively categorise the learners' responses to each question. Responses from learners who leave a question unanswered were categorised as 'Not attempted'. Such a question was blank on the learners' script. Learners' responses which are incorrect were categorised as 'Incorrect answer/calculation/procedure'. The answer was evaluated for relevance and meaning. Learners' responses which are not entirely correct were categorised as 'Partly correct answer/calculation/procedure'. This means that the learner presented an answer that contains certain parts that are correct while other parts of the presented solution may be deemed incorrect. Responses to questions that are correct were categorised as 'Correct answer/calculation/procedure'.

Table 3 is presented to show the available categories for learners' responses to a test question. The performance of the learners in both classes indicates that there are more learners who achieved below 50% in the written test. This implies that a better analysis of the scripts from both classes may only be done when analysing the scripts of the top achievers from both groups. This is because in the top achievers' group, learners attempted the most questions and consequently had more written responses than any other groups in this study. This will provide more content to analyse on the learners' scripts. The top 6 achievers were sampled from both groups in this study and their scripts were analysed per question.

Table 3: Categorised learner responses to the test questions

Category	Explanation
Not attempted	No answer provided by learner/Space left blank
Incorrect answer/calculation/procedure	The answer provided is incorrect/irrelevant
Partly correct answer/calculation/procedure	The answer provided contains correct and incorrect elements.
Correct answer/calculation/procedure	The correct answer was provided (Full marks)

Question 1 responses

Question 1 is discussed in Figure 6, Section 4.5.2. The findings from both groups are presented below.

Grade 9B responses

Table 4: Question 1 analysis of the experimental group

Question 1: 1. Complete the following statements. 1.1. Translation a shape. (2) 1.2. Reflection a shape. (2)	
Learners' responses	Explanation
	<u>Correct answer</u> The learner correctly identified the changes that translation and reflection bring to a shape. This demonstrates a clear conceptual understanding of both concepts. In translation, the learner uses the words, 'move or slide' a shape. This shows a deeper understanding of the concept.
	<u>Correct answer</u> The learner correctly identified the changes that translation and reflection bring to a shape. It is important to note that the VTRs used in this study explained and demonstrated translation and reflection by the words 'move' and 'flip' respectively.
	<u>Partly correct answer</u> The first part of the question was answered correctly, demonstrating a clear understanding of translation. The incorrect response is given on reflection. The learner failed to explain what a reflection does to a shape. The word 'reflects' is given as a response, making the statement meaningless.

ITY 1 GRADE 09..... TRANSFORMATION Code: B04 Complete the following statements 1. Translation moves a shape. 2. Reflection Turns flip a shape.	<u>Correct answer</u> The learner correctly identified the changes that translation and reflection bring to a shape. The learner seems to have struggled to recall the effect of reflection on a shape because ‘flip’ is not the initial response. It is important to note that the VTRs used in this study explained and demonstrated translation and reflection by the words ‘move’ and ‘flip’ respectively.
GRADE 09.B... TRANSFORMATION GEO B05 te the following statements. 1. Translation moving or sliding a shape. 2. Reflection flipping a shape.	<u>Correct answer</u> The learner correctly identified the changes that translation and reflection bring to a shape. This demonstrates a clear conceptual understanding of both concepts. In translation, the learner uses the words, ‘moving or sliding’ a shape. This shows a deeper understanding of the concept.
ITY 1 GRADE 09..... TRANSFORMATION GEOMETRY Code: B06 Complete the following statements. 1. Translation Moving a shape. 2. Reflection Flips a shape.	<u>Correct answer</u> The learner correctly identified the changes that translation and reflection bring to a shape. It is important to note that the VTRs used in this study explained and demonstrated translation and reflection by the words ‘move’ and ‘flip’ respectively.

The mean score in the question was 65%. Most learners correctly indicated that translation ‘moves/slides’ a shape while reflection ‘flips’ a shape as shown in Table 4. From the 6 analysed scripts, only one learner failed to get full marks for this question. Learners who obtained 0% in this question wrote meaningless statements. The overall performance indicated that learners could explain translation and reflection as required by the first facet of conceptual knowledge.

Grade 9C responses

Table 5: Question 1 analysis of the control group

Question 1: 1. Complete the following statements. 1.1. Translation a shape. (2) 1.2. Reflection a shape. (2)		
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Learners' responses	Explanation
ACTIVITY 1 GRADE 09... TRANSFORMATION GEOM Learner Code: C01 1. Complete the following statements. 1.1. Translation <u>Moving or rotating</u> a shape. 1.2. Reflection <u>Mirror image of</u> a shape.	<u>Partly correct answer</u> The first part of the question was answered correctly, demonstrating an understanding of translation. The word 'rotating' is also given as part of the answer. This word was ignored when marking. The incorrect response is given on reflection. The learner failed to explain what a reflection does to a shape. The words 'mirror image of a shape' are given as a response, rendering the statement given meaningless.
ACTIVITY 1 GRADE 09... TRANSFORMATION GEOM Learner Code: C02 1. Complete the following statements. 1.1. Translation <u>Triangle of</u> a shape. 1.2. Reflection <u>Triangle of</u> a shape.	<u>Incorrect answer</u> Two incorrect responses are given for the explanations of translation and reflection. The same phrase, 'Triangle of' is used. This is incorrect and shows shallow conceptual knowledge of the two concepts. In fact, the responses given make the statements meaningless.
ACTIVITY 1 GRADE 09... TRANSFORMATION GEO Learner Code: C03 1. Complete the following statements. 1.1. Translation <u>Triangle of</u> a shape. 1.2. Reflection <u>Triangle of</u> a shape.	<u>Incorrect answer</u> Two incorrect responses are given for the explanations of translation and reflection. The same phrase, 'Triangle of' is used. This is incorrect and shows shallow conceptual knowledge of the two concepts. In fact, the responses given make the statements meaningless.
ACTIVITY 1 GRADE 09... TRANSFORMATION GEOM Learner Code: C04 1. Complete the following statements. 1.1. Translation <u>is a movement</u> a shape. 1.2. Reflection <u>is a changes of</u> a shape.	<u>Partly correct answer</u> The first part of the question was answered correctly, demonstrating an understanding of translation. An incorrect response is given on reflection. The learner failed to explain what a reflection does to a shape. The words 'is a changes of' are given as a response, rendering the statement given meaningless. Shallow conceptual knowledge is demonstrated on this question.
ACTIVITY 1 GRADE 09... TRANSFORMATION GEO Learner Code: C05 1. Complete the following statements. 1.1. Translation <u>is a movement</u> a shape. 1.2. Reflection <u>is a changes of</u> a shape.	<u>Incorrect answer</u> An incorrect response is given for the explanation of translation. The answer 'is a movemet' was provided and marked incorrect. This is because it is unclear if the learner knows the concept or not. The spelling written and no attempt to explain reflection alluded to a lack of understanding of the concepts. For reflection, no attempt was made to give a response to the question. This is incorrect and shows shallow conceptual knowledge of the two concepts. In fact, the response given about translation makes the statements meaningless.

ACTIVITY 1 GRADE 09... TRANSFORMATION GEO Learner Code: 206 1. Complete the following statements. 1.1. Translation <u>moving or rotating</u> a shape. 1.2. Reflection <u>is the image (reflecting)</u> a shape.	<u>Partly correct answer</u> The first part of the question was answered correctly, demonstrating an understanding of translation. However, the meaningless word 'roleting' was given as an alternative. This showed a lack of understanding on the side of the learner. An incorrect response is given on reflection. The learner failed to explain what a reflection does to a shape. The words 'is the image (reflecting)' of are given as a response, rendering the statement given meaningless. Shallow conceptual knowledge is demonstrated on this question.
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The mean score for this question was 21%. There was no learner who obtained total marks for this question in the control group. The most marks were 2 out of 4, shown in

Table 5. This group did not demonstrate a rich knowledge of transformations. Some learners wrote meaningless statements for this question. The main challenge was in explaining what translation and reflection meant.

Question 2 responses

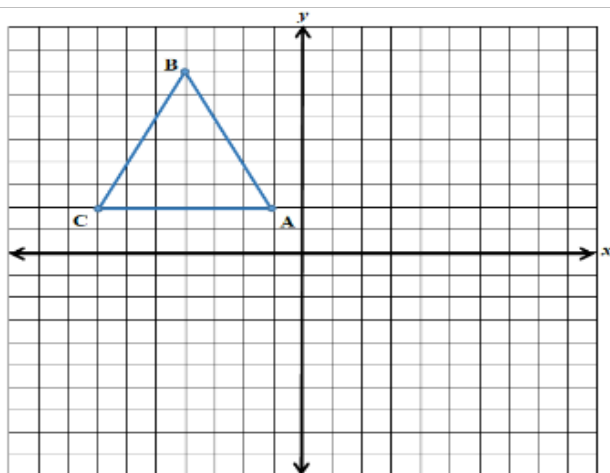
Question 2 is discussed in Figure 7, Section 4.5.2. The findings from both groups are presented below.

Grade 9B responses

Table 6: Question 2 analysis of the experimental group

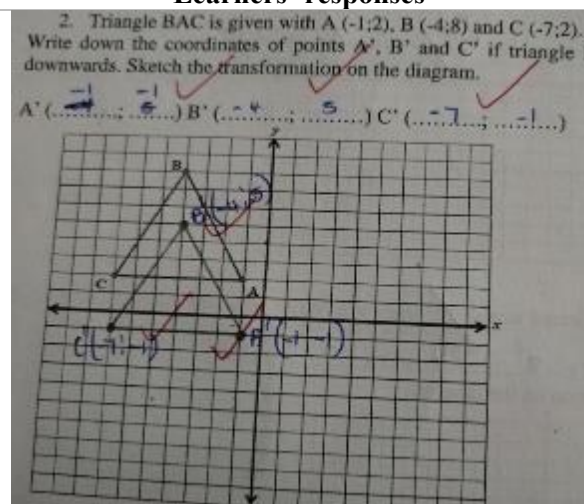
Question 2:

2. Triangle BAC is given with A (-1;2), B (-4;8) and C (-7;2).
Write down the coordinates of points A', B' and C' if triangle BAC is shifted three units downwards.
Sketch the transformation on the diagram.
A' (.....;) B' (.....;) C' (.....;)



(6)

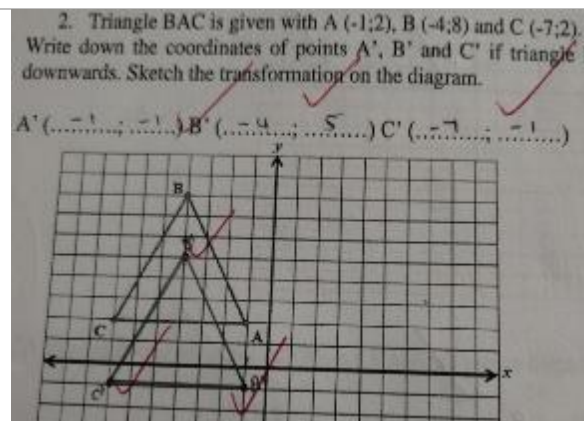
Learners' responses



Explanation

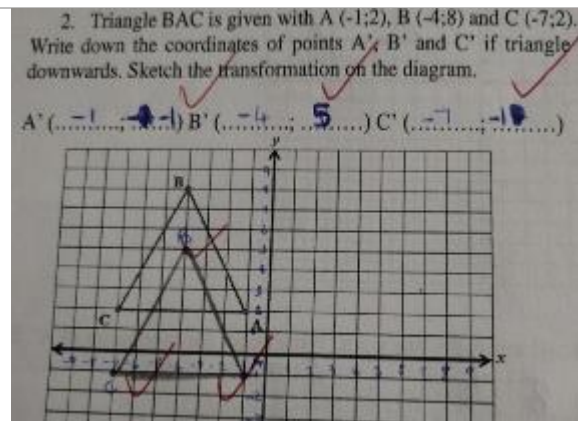
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. This may be a combination of conceptual and procedural skills. Nonetheless, the learner demonstrates a good understanding of the translation concept.



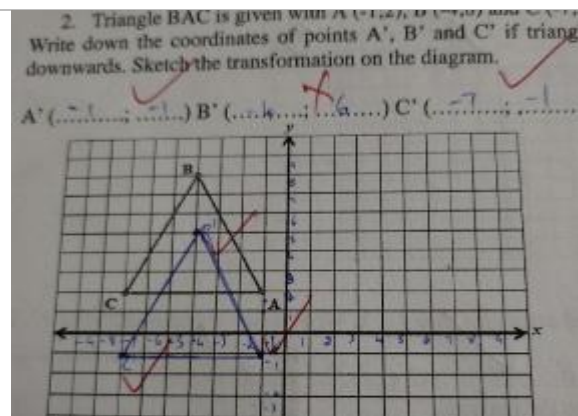
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept.



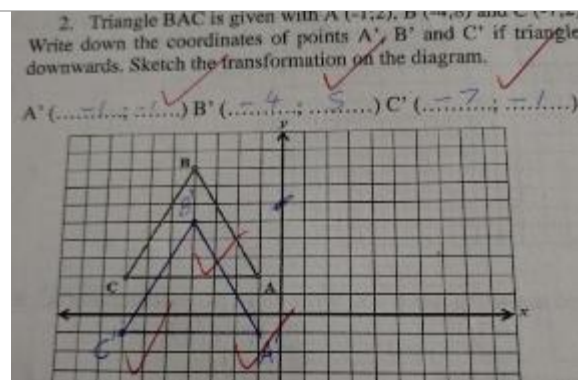
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. It seems the learner struggled to write down the coordinates of the translated points but ultimately arrived at the correct answers. The cancellations of answers allude to the learner struggling at first. The learner demonstrates a good understanding of the translation concept.



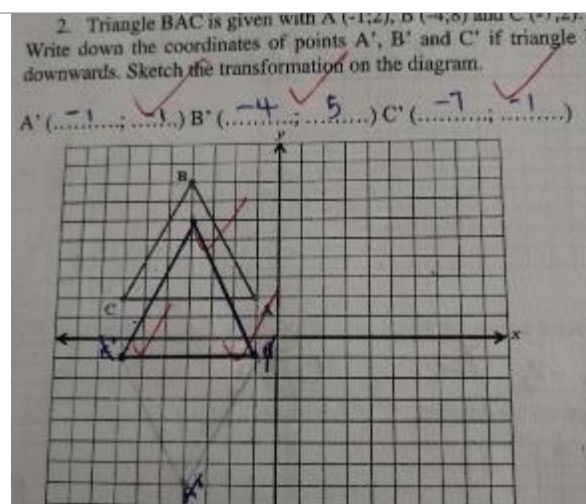
Partly correct answer

The y coordinate of B' was written incorrectly. Instead of 5 units, the learner presented it as 6 units. This appears to be a counting mistake since the learner correctly sketched the translated diagram. The learner demonstrated a reasonable depth of understanding of the concept.



Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept.



Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept. It appears the learner struggled to sketch the correct diagram although it is ultimately presented. This is seen from the clear cancellation on the diagram.

The mean score for this question was 26%. Some learners got the coordinates of one point wrong but were still able to draw the correct sketch as evident in Table 6. There was a trend of learners getting the coordinates of translated points wrong but ultimately drawing the correct sketch for the translation. In this experimental group, the main challenge was in determining the correct coordinates of the translated points. The learners did not display a thorough conceptual knowledge of translation as measured by the second facet of conceptual knowledge. It appears that the learners were able to apply the procedure of translation instead. The top 6 learners in the experimental group generally responded well to this question.

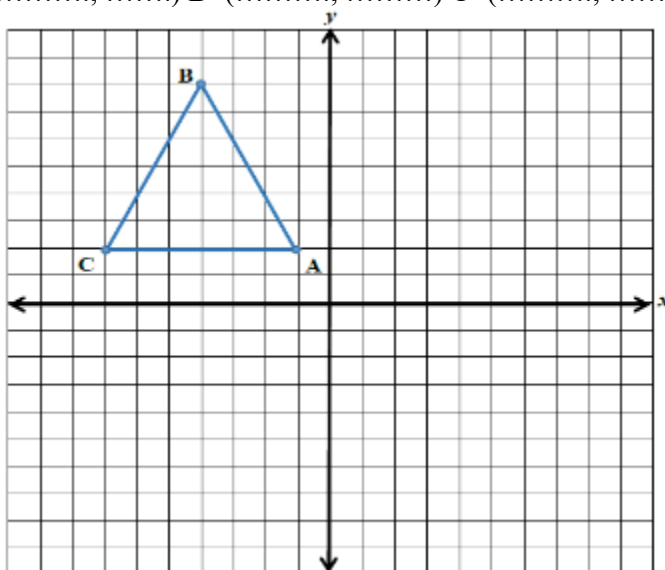
Grade 9C responses

Table 7: Question 2 analysis of the control group

Question 2:

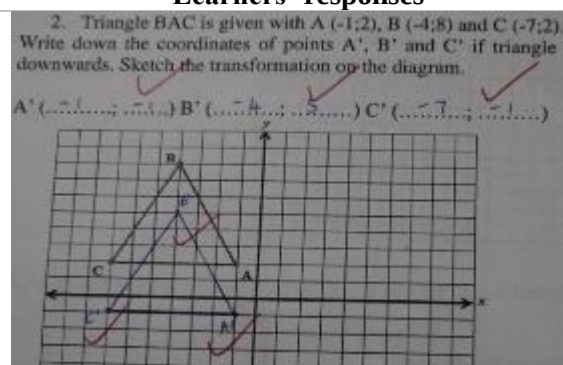
2. Triangle BAC is given with A (-1;2), B (-4;8) and C (-7;2). Write down the coordinates of points A', B' and C' if triangle BAC is shifted three units downwards. Sketch the transformation on the diagram.

A' (.....;) B' (.....;) C' (.....;)



(6)

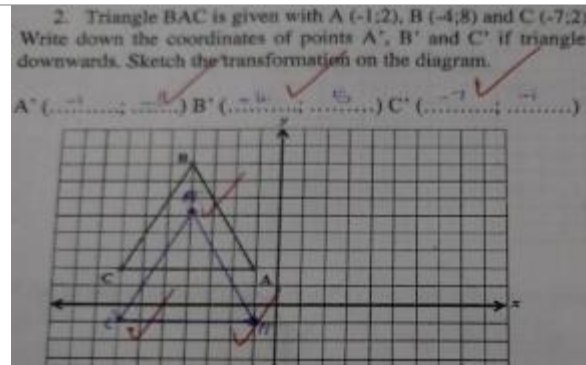
Learners' responses



Explanation

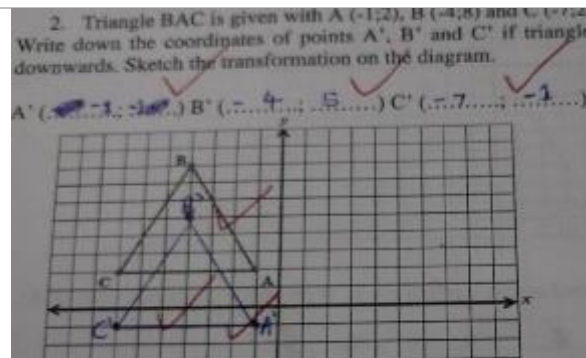
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept.



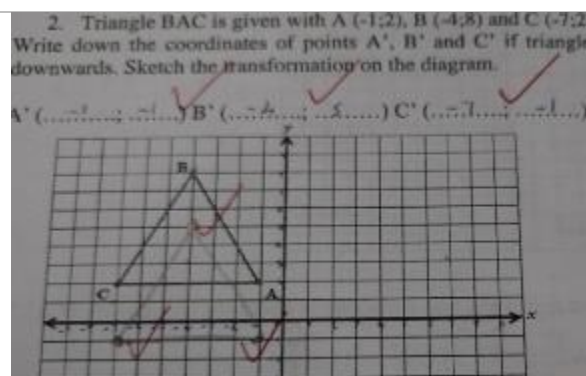
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept.



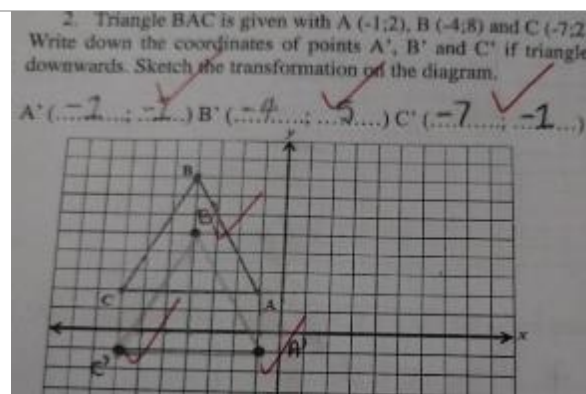
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. It seems the learner struggled to write down the coordinates of the translated points but ultimately arrived at the correct answers. The cancellations of answers allude to the learner struggling at first. The learner demonstrates a good understanding of the translation concept.



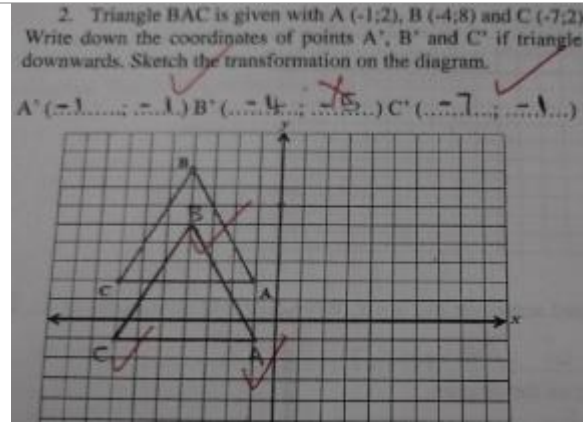
Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept.



Correct answer

The learner was able to write down the correct coordinates of the translated points. The transformation was also sketched correctly. The learner demonstrates a good understanding of the translation concept.



Partly correct answer

The y- coordinate of B' was written incorrectly. Instead of 5, the learner presented it as -5. This appears to be either a counting or a writing mistake since the learner correctly sketched the translated diagram. The learner demonstrated a reasonable depth of understanding of the concept. This means that finding the coordinates of the translated points needed conceptual skills while sketching the translated diagram relied more on procedural skills than.

The mean score for this question was 21%. The learners mainly struggled to obtain the coordinates of the translated points, and this resulted in them failing to draw the correct translated shape. This indicated insufficient conceptual knowledge of translation as measured by the second facet of conceptual knowledge. The top 6 learners in the control group, however, generally responded well to this question.

Question 3 responses

Question 3 is discussed in Figure 8, Section 4.5.2. The findings from both groups are presented below.

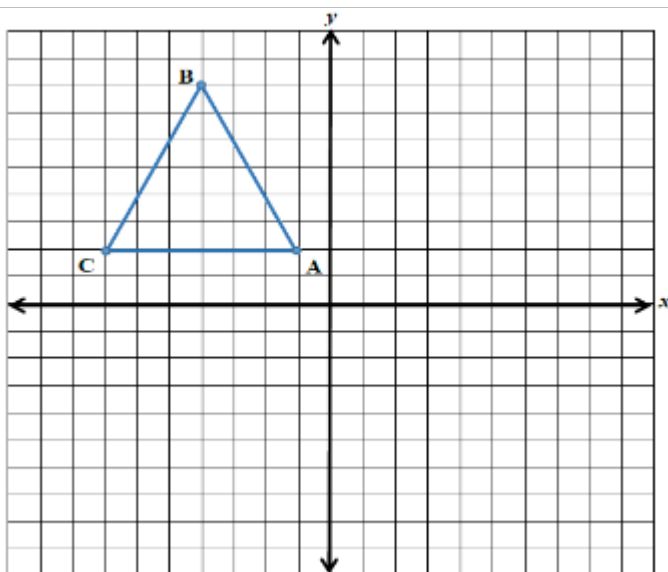
Grade 9B responses

Table 8: Question 3 analysis of experimental group

Question 3:

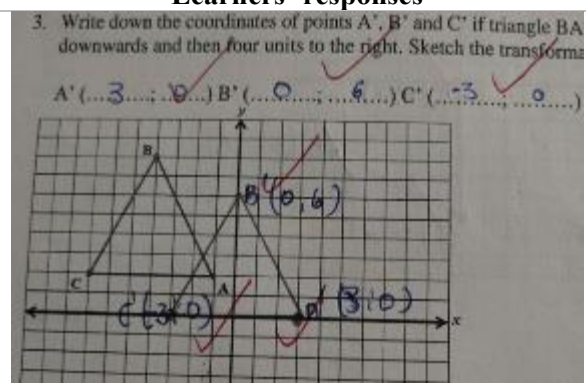
3. Write down the coordinates of points A', B' and C' if triangle BAC is shifted two units downwards and then four units to the right. Sketch the transformation on the diagram.

A' (.....;) B' (.....;) C' (.....;)



(6)

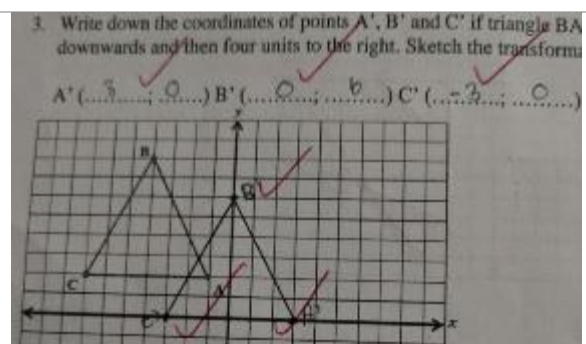
Learners' responses



Explanation

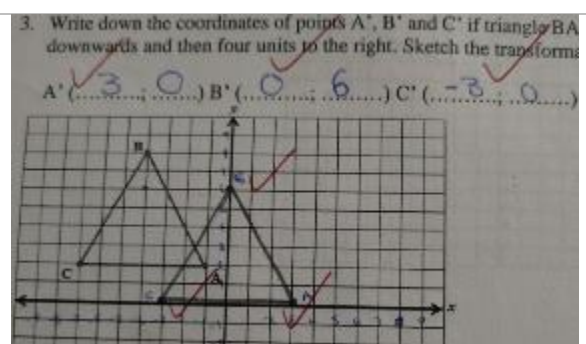
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of translation.



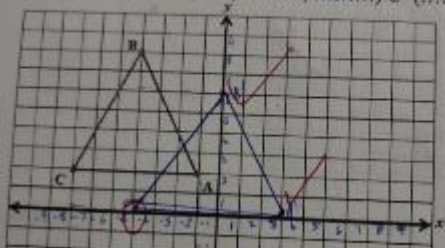
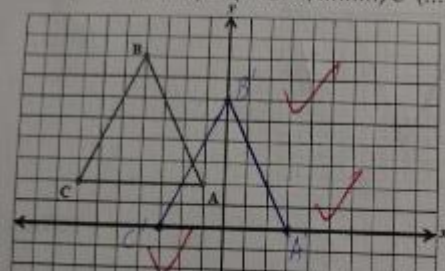
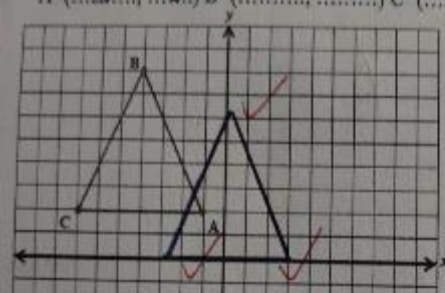
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of translation. The sketch was correctly drawn even though the coordinates of each point were not indicated.



Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of translation. The sketch was correctly drawn even though the coordinates of each point were not indicated.

3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Partly correct answer/calculation/procedure</u> The learner was unable to determine the coordinates of the transformed points A' and C' of the triangle. This was followed by a sketch representing the transformation. Point C' on the sketch was incorrect whereas point A' was represented correctly. This means the learner has not demonstrated adequate conceptual knowledge of translation.
3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Correct answer/calculation/procedure</u> The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of translation. The sketch was correctly drawn even though the coordinates of each point were not indicated.
3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Correct answer/calculation/procedure</u> The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of translation. The sketch was correctly drawn even though the coordinates of each point were not indicated. The transformed points were also not indicated in the translated sketch.

This question had a mean score of 28%. The main problem in this question was obtaining the correct coordinates of the translated points. There were two transformations which needed to be performed. Most learners did not demonstrate sufficient conceptual knowledge in this question. The top 6 learners were able to respond to this question without struggling. There was one learner who was not able to find the coordinates of A' and C', as shown in Table 8.

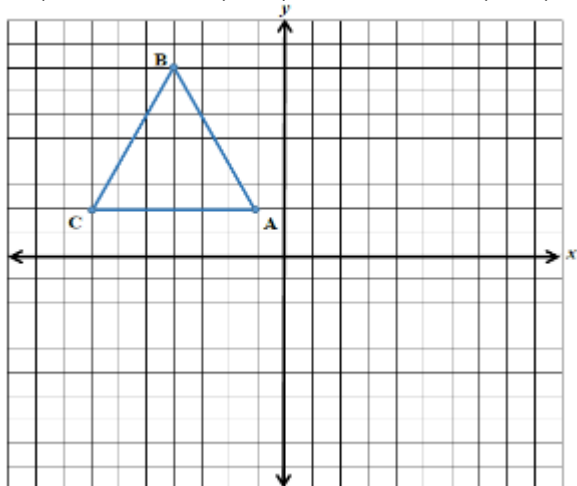
Grade 9C responses

Table 9: Question 3 analysis of control group

Question 3:

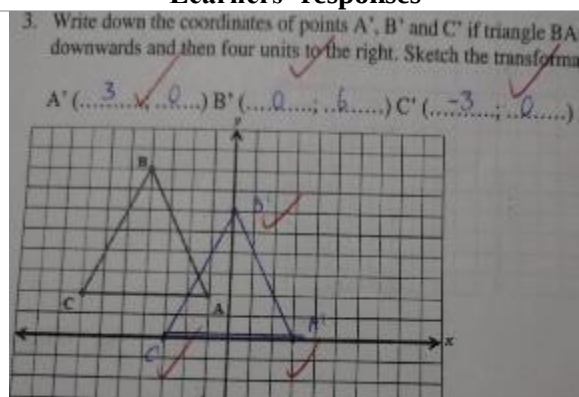
3. Write down the coordinates of points A', B' and C' if triangle BAC is shifted two units downwards and then four units to the right. Sketch the transformation on the diagram.

A' (.....;) B' (.....;) C' (.....;)



(6)

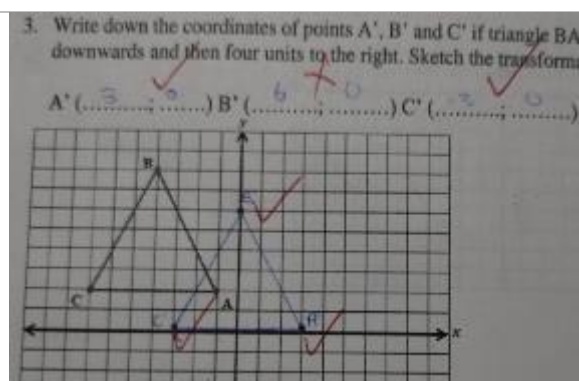
Learners' responses



Explanation

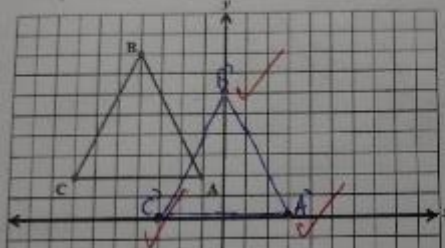
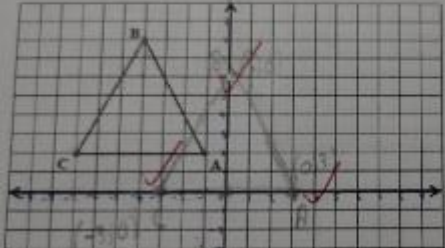
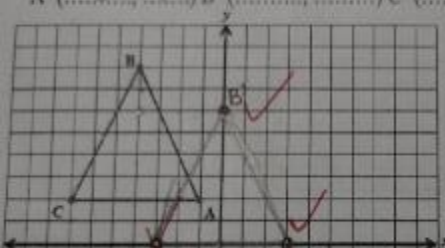
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of translation. The coordinates of the transformed points were not written on the translated sketch.



Partly correct answer/calculation/procedure

The learner was unable to determine the coordinates of the transformed point B' of the triangle. This was followed by a correct sketch representing the transformation. Point B' was represented correctly on the transformed sketch. This may mean the learner is more fluent procedurally than conceptually. Therefore, the learner has not demonstrated adequate conceptual knowledge of translation.

3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Partly correct answer/calculation/procedure</u> The learner was unable to determine the coordinates of the transformed point B' of the triangle. This was followed by a correct sketch representing the transformation. Point B' was represented correctly on the transformed sketch. This may mean the learner is more fluent procedurally than conceptually. Therefore, the learner has not demonstrated adequate conceptual knowledge of translation.
3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Partly correct answer/calculation/procedure</u> The learner was unable to determine the coordinates of the transformed point A' and B' of the triangle. This was, however, followed by a correct sketch representing the transformation. Points A' and B' were represented correctly on the transformed sketch. This may mean the learner is more fluent procedurally than conceptually. Therefore, the learner has not demonstrated adequate conceptual knowledge of translation.
3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Partly correct answer/calculation/procedure</u> This is one of the cases whose pattern was observed on a few scripts. The learner was unable to determine the coordinates of the transformed points A', B' and C' of the triangle. This was, however, followed by a correct sketch representing the transformation. All the points were represented correctly on the transformed sketch. This may mean the learner is more fluent procedurally than conceptually. Therefore, the learner has not demonstrated adequate conceptual knowledge of translation.
3. Write down the coordinates of points A', B' and C' if triangle BA downwards and then four units to the right. Sketch the transform A' (.....) B' (.....) C' (.....) 	<u>Partly correct answer/calculation/procedure</u> The learner was unable to determine the coordinates of the transformed point C' of the triangle. This was followed by a partly correct sketch representing the transformation. Point B' was represented correctly on the transformed sketch. Point C' was also represented correctly although its written coordinates were incorrect. Point A' is sketched incorrectly although its coordinates were written correctly. This may mean the learner is more fluent procedurally than conceptually. Therefore, the learner has not demonstrated adequate conceptual knowledge of translation.

This question had a mean of 18%. The main challenge in this question was obtaining the correct coordinates of the translated points, as shown in Table 9. This means learners did not understand

what translation does to a point or shape. Some learners obtained incorrect coordinates of the translated points but still drew the correct translated shape. This was a repeating trend in the control group. It is however evident that the learners’ performance in this question was unsatisfactory, and their conceptual gains were not sufficient.

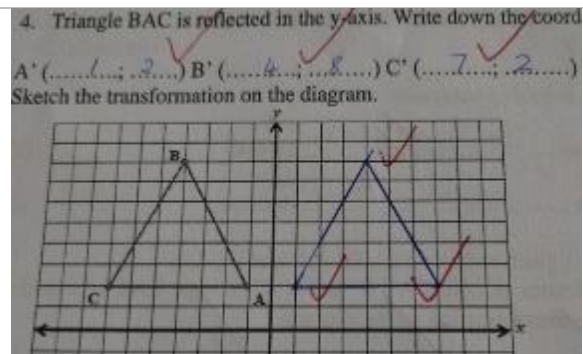
Question 4 responses

Question 4 is discussed in Figure 9, Section 4.5.2. The findings from both groups are presented below.

Grade 9B responses

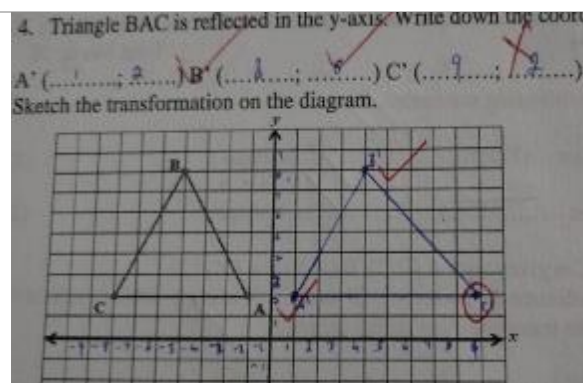
Table 10: Question 4 analysis of the experimental group

Question 4: 4. Triangle BAC is reflected in the y-axis. Write down the coordinates of A', B' and C'. A' (.....;) B' (.....;) C' (.....;) Sketch the transformation on the diagram. (6)	
Learners' responses	Explanation <u>Partly correct answer/calculation/procedure</u> The learner was able to write down the coordinates of the transformed points A', B', and C'. Writing the coordinates of the reflected points required conceptual knowledge of what reflection does to an object. The learner then failed to draw the correct sketch of the reflected triangle. Sketching the reflected triangle requires both conceptual and procedural knowledge. The learner has therefore demonstrated partial conceptual knowledge fluency.



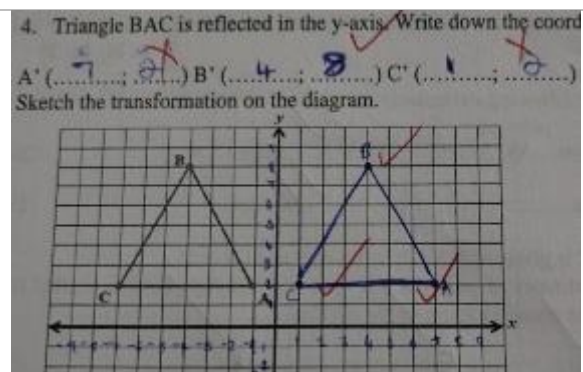
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were not written on the reflected sketch.



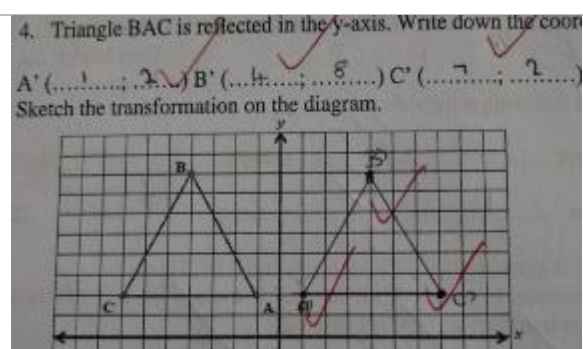
Partly correct answer/calculation/procedure

The learner was unable to determine the coordinates of the transformed point C' of the triangle. This was followed by a partly correct sketch representing the transformation. Point C' was represented correctly, according to its determined coordinates, on the transformed sketch. The point is marked incorrect since the learner used incorrect coordinates to sketch it. This may mean the learner made a counting mistake to obtain '9' as the x coordinate of point C' instead of '7'. If the learner had obtained '7', they would have sketched the reflected triangle correctly. Therefore, the learner has demonstrated adequate conceptual knowledge of reflection.



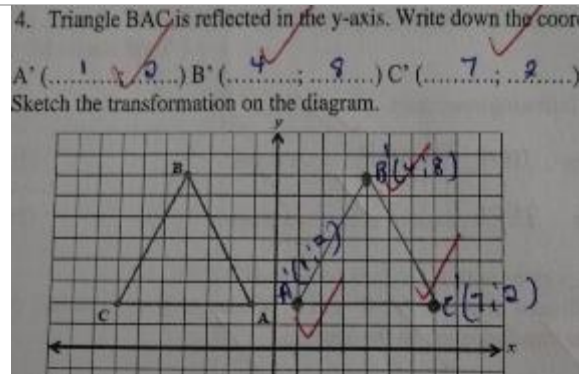
Partly correct answer/calculation/procedure

The learner was unable to determine the coordinates of the transformed points A' and C' of the triangle. This was, however, followed by a correct sketch representing the transformation. Points A' and C' were represented correctly on the transformed sketch. This may mean the learner is more fluent procedurally than conceptually. Therefore, the learner has not demonstrated adequate conceptual knowledge of reflection.



Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were not written on the reflected sketch.



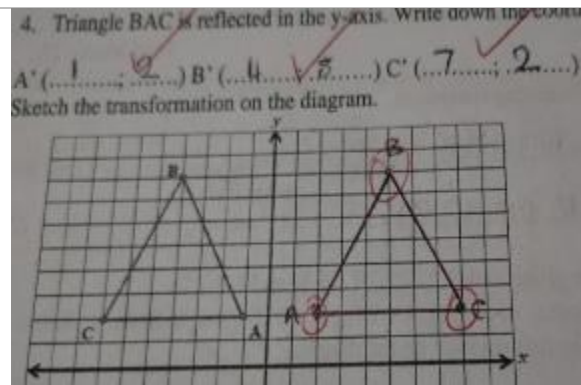
Correct answer/calculation/procedure
 The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were also written on the reflected sketch.

The mean score for this question was 24%. Some learners were still obtaining incorrect coordinates of the reflected points but drawing the correct sketch, as shown in Table 10. Some learners did not demonstrate any form of conceptual knowledge in this question. The learners did not thoroughly grasp the meaning of reflecting a shape. This restricted their ability to obtain correct coordinates for reflected points. Table 10 also shows one learner who obtained full marks for this question.

Grade 9C responses

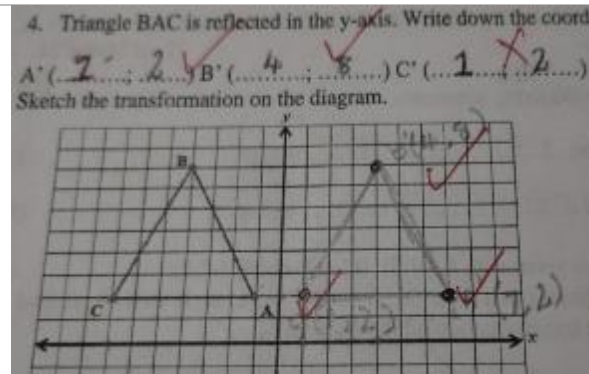
Table 11: Question 4 analysis of control group

Question 4: 4. Triangle BAC is reflected in the y-axis. Write down the coordinates of A', B' and C'. A' (.....;), B' (.....;), C' (.....;) Sketch the transformation on the diagram.	
(6)	
Learners' responses	Explanation



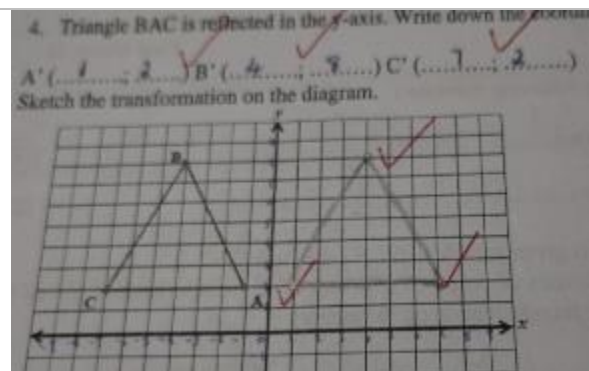
Partly correct answer/calculation/procedure

The learner was able to write down the coordinates of the transformed points A', B', and C'. Writing the coordinates of the reflected points required conceptual knowledge of what reflection does to an object. The learner then failed to draw the correct sketch of the reflected triangle. Sketching the reflected triangle requires both conceptual and procedural knowledge. The learner has therefore demonstrated partial conceptual knowledge fluency.



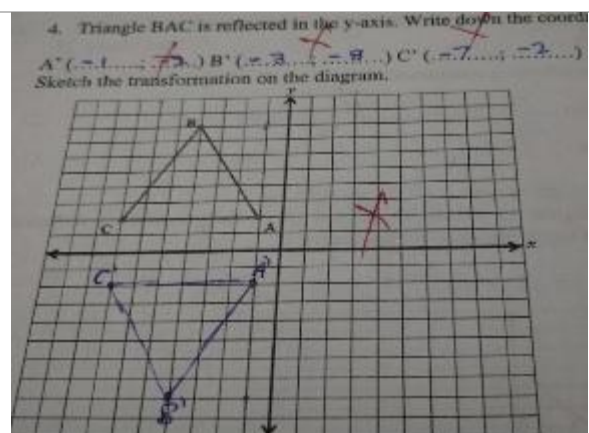
Partly correct answer/calculation/procedure

The learner was unable to determine the coordinates of the transformed point C' of the triangle. This was, however, followed by a correct sketch representing the transformation. Point C' was represented correctly on the transformed sketch. If the learner had obtained '7' as the x coordinate of the point C', they would have obtained full marks. This may mean the learner is more fluent procedurally than conceptually. It may also mean there was a counting mistake in determining the coordinates of point C'. Therefore, the learner may be said to have demonstrated partial conceptual knowledge of reflection.



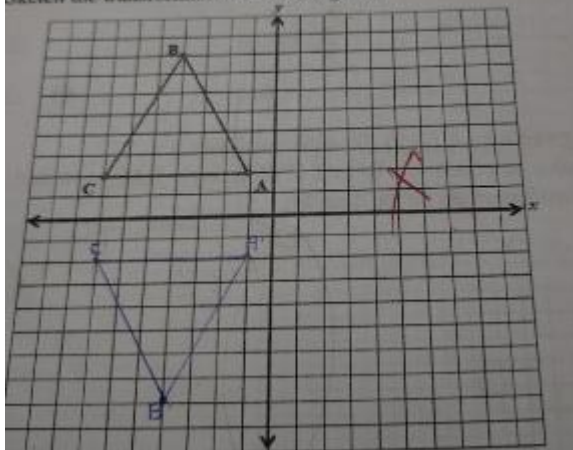
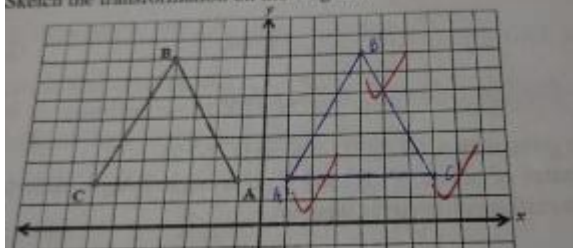
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were also written on the reflected sketch.



Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. For points A' and C', the signs of the reflected points are incorrect. This means the learner did not understand the effect of reflection along the y axis. Point B' is also determined incorrectly. The sign of its y - coordinate is incorrect. The x coordinate of point B' is also incorrect. This means that the learner has not sufficiently developed conceptual knowledge of reflection. It should be noted, however, that the sketch the learner presents is in line with the determined coordinates, except for point B'. This may indicate that there has been satisfactory procedural knowledge development.

4. Triangle BAC is reflected in the y-axis. Write down the coordinates of the reflected points A', B' and C'. Sketch the transformation on the diagram. 	<u>Incorrect answer/calculation/procedure</u> The learner was unable to obtain the coordinates of the reflected points correctly. For points A' and C', the signs of the reflected points are incorrect. This means the learner did not understand the effect of reflection along the y axis. Point B' is also determined incorrectly. The sign of its y coordinate is incorrect. The x coordinate of point B' is also incorrect. This means that the learner has not sufficiently developed conceptual knowledge of reflection. It should be noted, however, that the sketch the learner presents is in line with the determined coordinates, except for point B'. This may indicate that there has been satisfactory procedural knowledge development.
4. Triangle BAC is reflected in the y-axis. Write down the coordinates of the reflected points A', B' and C'. Sketch the transformation on the diagram. 	<u>Correct answer/calculation/procedure</u> The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were also written on the reflected sketch.

The mean score in this question is 11%. This indicated that learners did not understand what reflecting across the y axis meant. Table 11 shows that some learners from this group obtained full marks in this question. This means that they were able to determine coordinates of reflected points and sketch the transformation correctly. Some learners, however, drew the correct reflected sketch from incorrect coordinates of reflected points. This was a trend observed from the control group. Learners generally did not perform well in this question. This means that the development of conceptual knowledge was inadequate.

Question 5 responses

Question 5 is discussed in Figure 10, Section 4.5.2. The findings from both groups are presented below.

Grade 9B responses

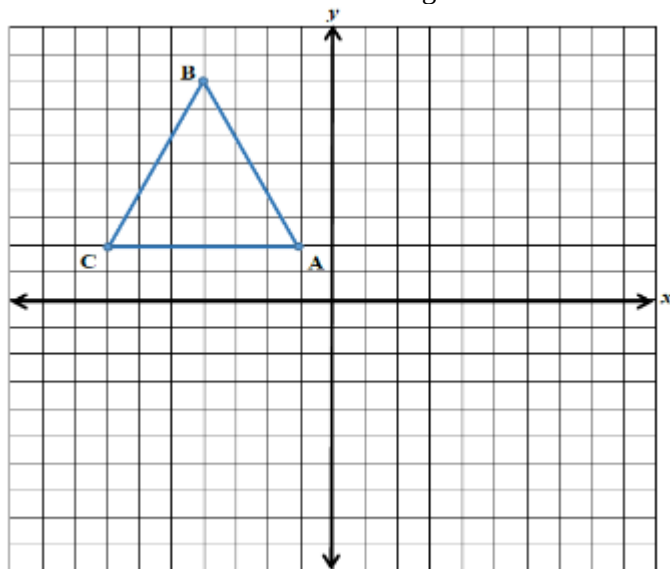
Table 12: Question 5 analysis of the experimental group

Question 5:

5. Triangle BAC is reflected across the line $y = x$. Write down the coordinates of A', B', C'.

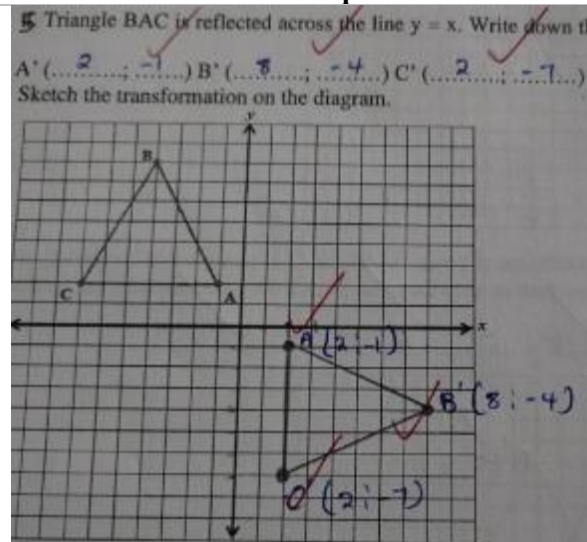
A' (.....;) B' (.....;) C' (.....;)

Sketch the transformation on the diagram.



(6)\

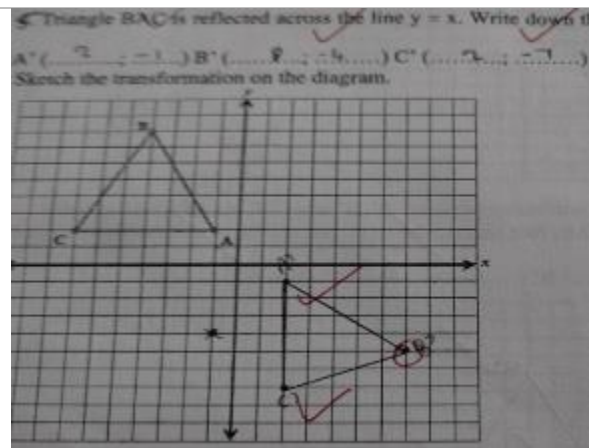
Learners' responses



Explanation

Correct answer/calculation/procedure

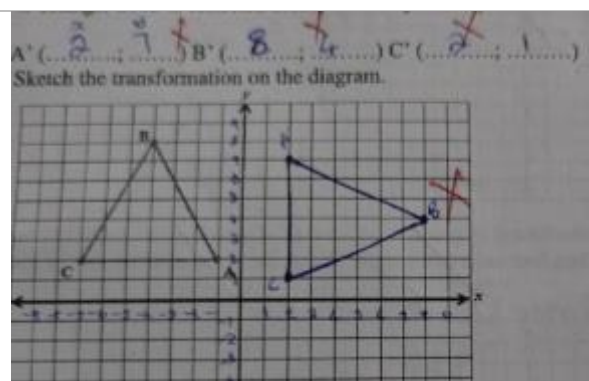
The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were also written on the reflected sketch.



Partly correct answer/calculation/procedure

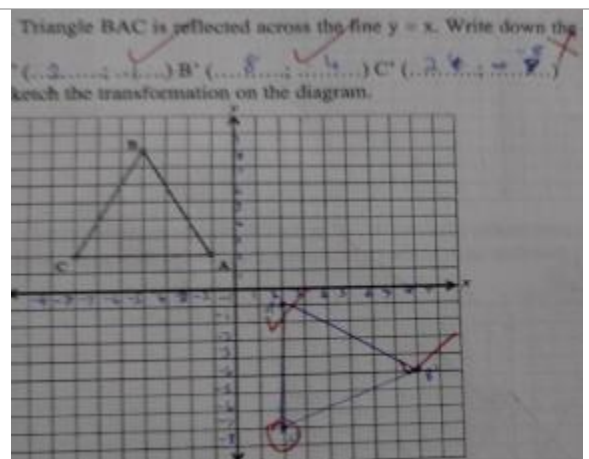
The learner was able to determine the coordinates of the transformed points correctly. This shows a sufficient development of conceptual knowledge of reflection along the line $y = x$. The learner correctly represented points A' and C' on the cartesian plane.

However, there seems to have been a counting mistake when locating point B' on the cartesian plane. The x coordinate of point B' is off by 1 unit to the right. The y coordinate of point B' is off by 1 unit upwards. This may be resulting from time constraints or writing fatigue. It can therefore be concluded that the learner demonstrated adequate conceptual knowledge in this question



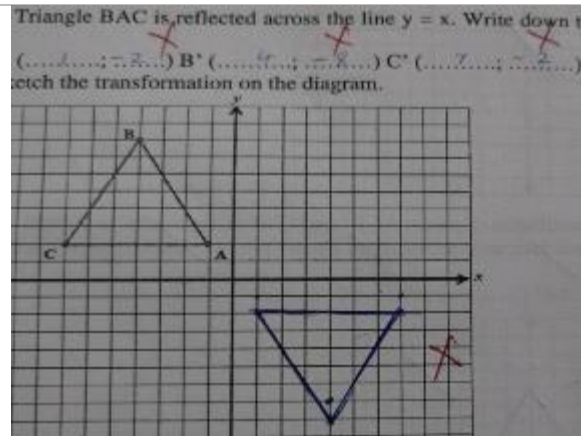
Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. For points A' and C', the signs of the reflected points are incorrect. This means the learner did not understand the effect of reflection along the line $y = x$. The y coordinate of point A' is incorrect. Point B' is also determined incorrectly. The sign of its y coordinate is incorrect. This means that the learner has not sufficiently developed conceptual knowledge of reflection along the line $y = x$. It should be noted, however, that the sketch the learner presents is in line with the determined coordinates. This may indicate that there has been satisfactory procedural knowledge development.



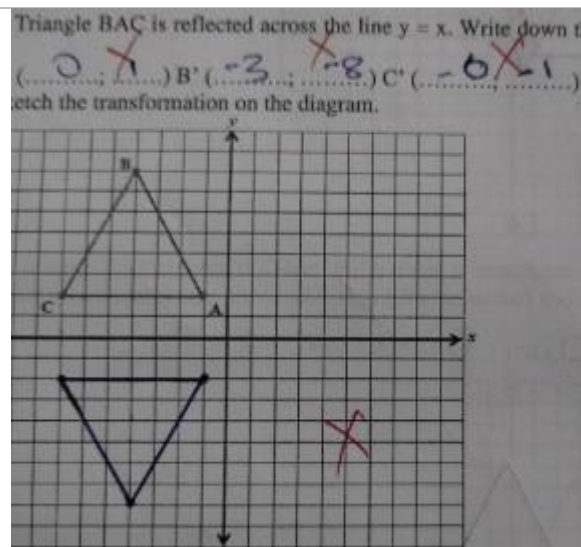
Partly correct answer/calculation/procedure

The learner was able to determine the coordinates of point C' correctly. This seems to have been a counting mistake since the y coordinate of point C' is off by one unit. The coordinates of points A' and B' were determined correctly. The determined coordinates were sketched correctly. Point C' was marked incorrect on the diagram because incorrect coordinates were applied. This means the learner has demonstrated sufficient conceptual knowledge in this question, even though maximum marks were not obtained.



Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. An incorrect reflection was performed by the learner. This shows that the learner has not adequately developed conceptual knowledge of the reflection along the line $y = x$. It is important, however, to note that the transformed shape is sketched correctly based on determined coordinates. The transformed triangle is marked incorrect owing to the incorrect coordinates determined on the first part of the question. This suggests that the learner may have a well-developed procedural fluency.



Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. There seems to be no procedure followed in determining the coordinates of the reflected points. Triangle BAC was reflected along the x-axis instead. This shows that there are no signs of procedural or conceptual knowledge gains demonstrated by the learner. The determined coordinates of the transformed point were not sketched correctly on the cartesian plane.

This question had a mean score of 12%. This is the lowest mean score in this group. Learners were not able to obtain incorrect coordinates of the reflected points but draw the correct sketch. Some learners got one point wrong and that affected their final sketch as shown in Table 12. Other learners got the coordinates of the transformed points correct but got the sketch wrong. This is the only question where the control group outperformed the experimental group. This may be explained by the fact that reflections across the line $y = x$ were not covered by the VTRs. The main challenge was in obtaining the coordinates of the reflected points. The conceptual knowledge of learners was minimal in this question.

Grade 9C responses

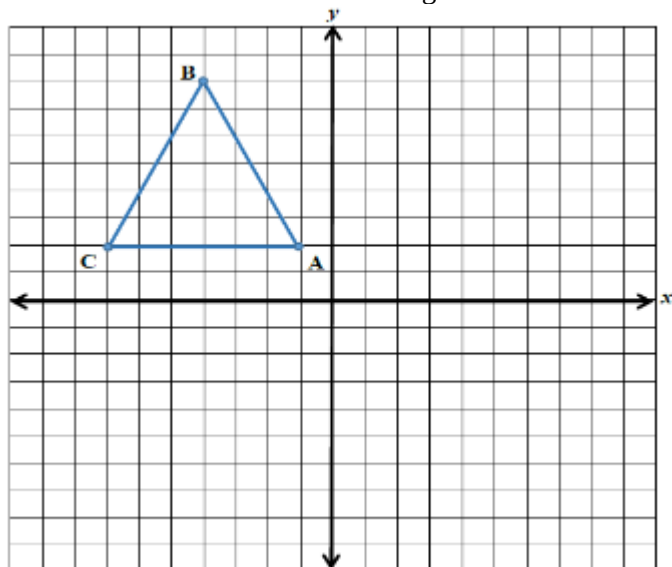
Table 13: Question 5 analysis of control group

Question 5:

5. Triangle BAC is reflected across the line $y = x$. Write down the coordinates of A', B', C'.

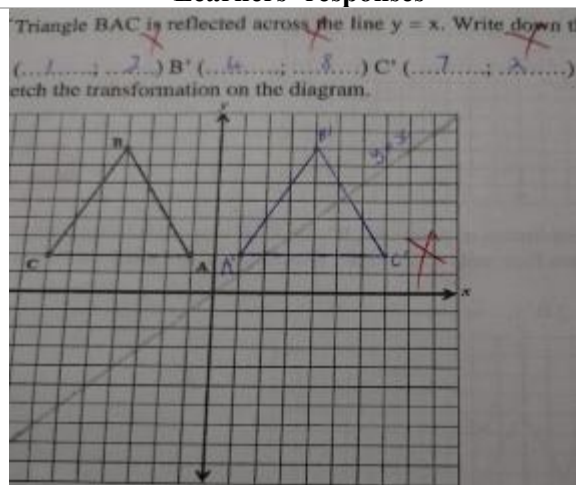
A' (.....;) B' (.....;) C' (.....;)

Sketch the transformation on the diagram.



(6)

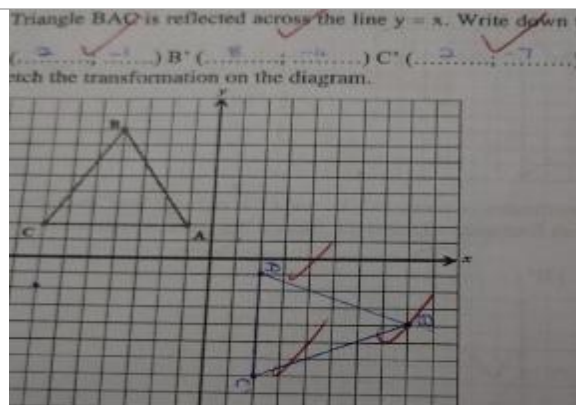
Learners' responses



Explanation

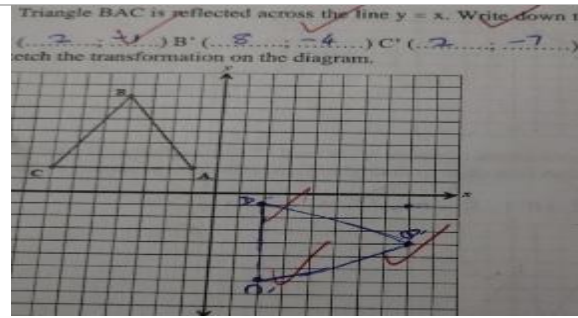
Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. An incorrect reflection was performed by the learner. It seems a reflection along the y axis was performed instead. This means that the learner has not demonstrated adequate development of conceptual knowledge. Furthermore, the sketch of the transformed triangle was incorrect owing to the incorrect determined coordinates of the reflected points. However, based on the determined coordinates, the points were represented correctly on the cartesian plane. This means the learner demonstrated adequate procedural fluency instead.



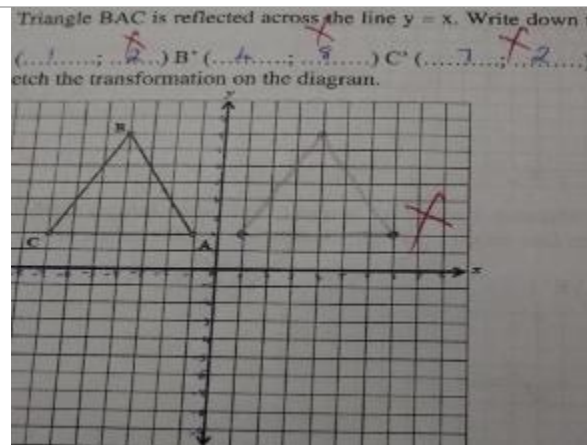
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were also written on the reflected sketch.



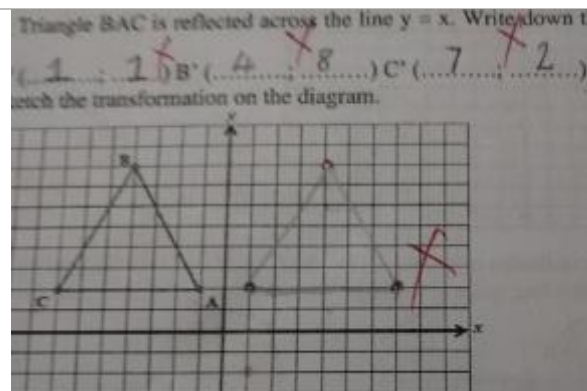
Correct answer/calculation/procedure

The learner was able to determine the coordinates of the transformed points of the triangle. This was followed by a correct sketch representing the transformation. This means the learner has demonstrated adequate conceptual knowledge of reflection. The coordinates of the transformed points were also written on the reflected sketch.



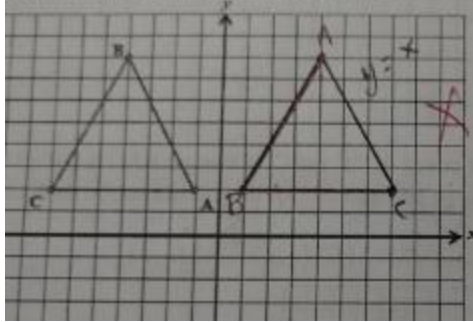
Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. An incorrect reflection was performed by the learner. It seems a reflection along the y axis was performed instead. This means that the learner has not demonstrated adequate development of conceptual knowledge. Furthermore, the sketch of the transformed triangle was incorrect owing to the incorrect determined coordinates of the reflected points. However, based on the determined coordinates, the points were represented correctly on the cartesian plane. This means the learner demonstrated adequate procedural fluency instead.



Incorrect answer/calculation/procedure

The learner was unable to obtain the coordinates of the reflected points correctly. An incorrect reflection was performed by the learner. It seems a reflection along the y axis was performed instead. There is no clear procedure followed to obtain coordinates for point A'. This means that the learner has not demonstrated adequate development of conceptual knowledge. Furthermore, the sketch of the transformed triangle was incorrect owing to the incorrect determined coordinates of the reflected points. However, based on the determined coordinates, the points were represented correctly on the cartesian plane. This means the learner demonstrated adequate procedural fluency instead.

Triangle BAC is reflected across the line $y = x$. Write down the coordinates of the reflected points B' and C'. Sketch the transformation on the diagram. 	<u>Incorrect answer/calculation/procedure</u> The learner was unable to obtain the coordinates of the reflected points correctly. An incorrect reflection was performed by the learner. It seems a reflection along the y axis was performed instead. This means that the learner has not demonstrated adequate development of conceptual knowledge. Furthermore, the sketch of the transformed triangle was incorrect owing to the incorrect determined coordinates of the reflected points. However, based on the determined coordinates, the points were represented correctly on the cartesian plane. This means the learner demonstrated adequate procedural fluency instead.
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The mean score for this question was 14%. Performance in this question was unsatisfactory in this group. Obtaining the correct coordinates of the reflected points was also a challenge for learners in this question, as shown in Table 5. This means that the learners did not understand the concept of reflecting a shape across the line $y = x$. The conceptual knowledge of the learners for this question was not adequate.

Based on the analysed scripts of the top six learners, it can be determined that learners struggled to explain the meaning of reflection and translation in this study. According to the two facets of conceptual knowledge, this implies that their knowledge of general principles was inadequate to respond to questions. However, it is evident that the experimental group demonstrated a comparatively better knowledge of general principles.

A careful analysis of the learners' scripts also revealed that learners were unable to obtain the coordinates of transformed points in questions. This was mostly for Questions 4 and 5 which tested reflections along the y axis and reflections along the line $y = x$, respectively. These questions tested the knowledge of the principles underlying the procedures as discussed by Crooks and Alibali (2014). Question 2 and 3 also tested the knowledge of principles underlying procedures. Learners from the experimental group also outperformed their control group counterparts in questions of this nature. Both groups showed shallow conceptual knowledge in this study.

5.2.2. Quantitative analysis of data

5.2.2.1. Test performance of learners

The sample size for this study was 92. There were 47 participants from Grade 9B (Experimental group) and 45 participants from Grade 9C (Control group). Both groups of learners were given a test to write. The test had a total of five questions and was scored out of 28 marks. The marks were then expressed as percentages. The performances of Grade 9B and 9C are presented in the subsequent sections.

Grade 9B performance (Experimental)

Grade 9B had a total of 47 participants. The learners' marks are shown in Figure 17.

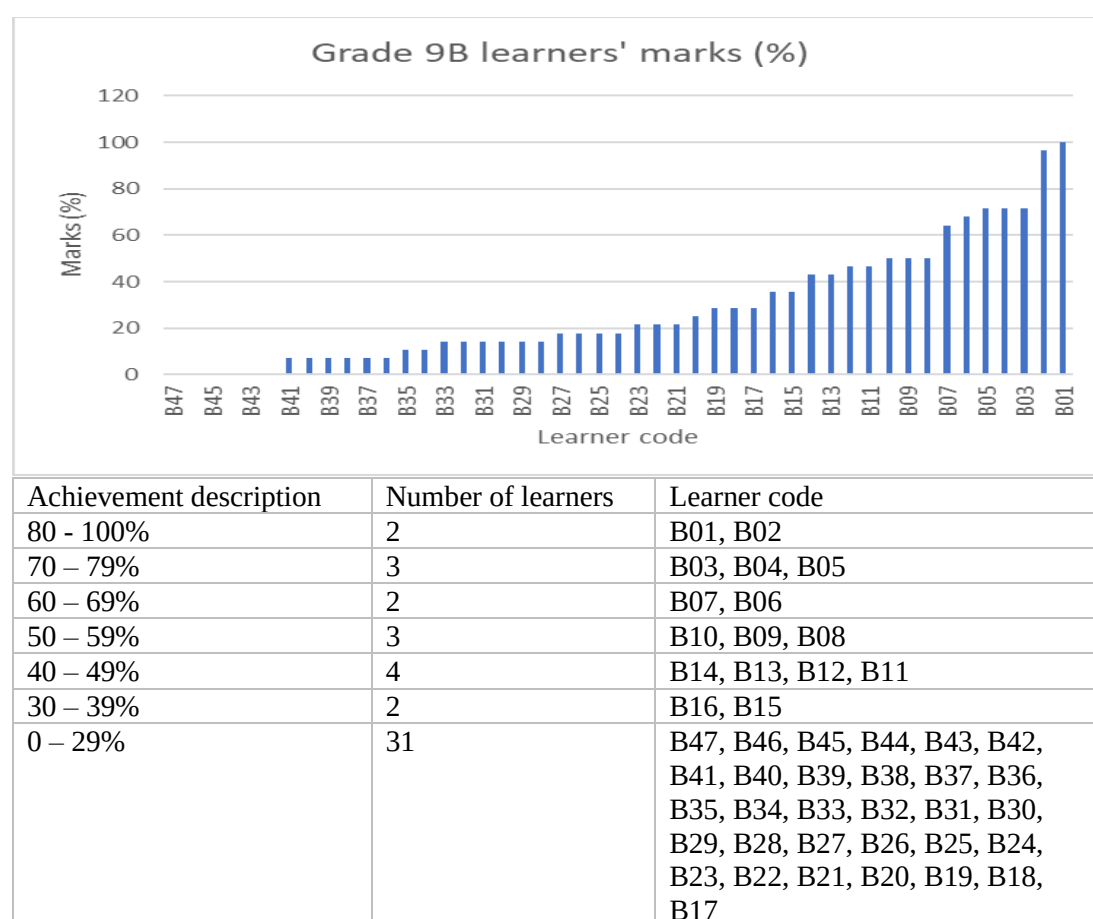


Figure 17: Grade 9B learners' marks (%) and achievement levels (Experimental)

The striking feature of Figure 17 is the high number of learners who achieved marks below 30%. There are a total of 31 learners in this category. The next category comprises only two learners who obtained marks between 30 – 39%. Four learners were in the 40 – 49% band.

There were 3 learners in the 50 – 59% category; 2 learners in the 60 – 69% category; 3 learners in the 70 – 79% category and 2 learners in the 80 – 100% category.

Grade 9C performance (Control)

Grade 9C marks are shown in Figure 18.

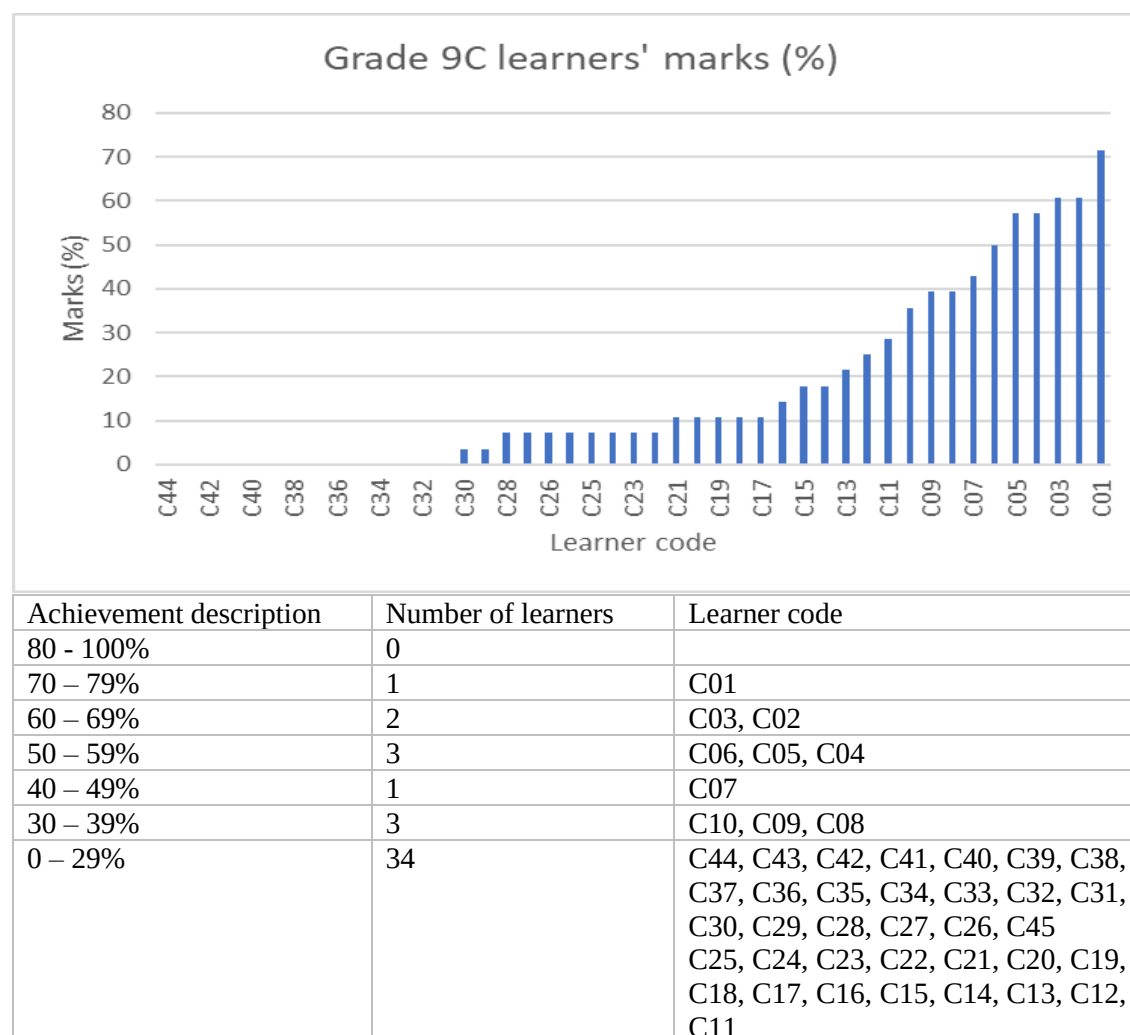
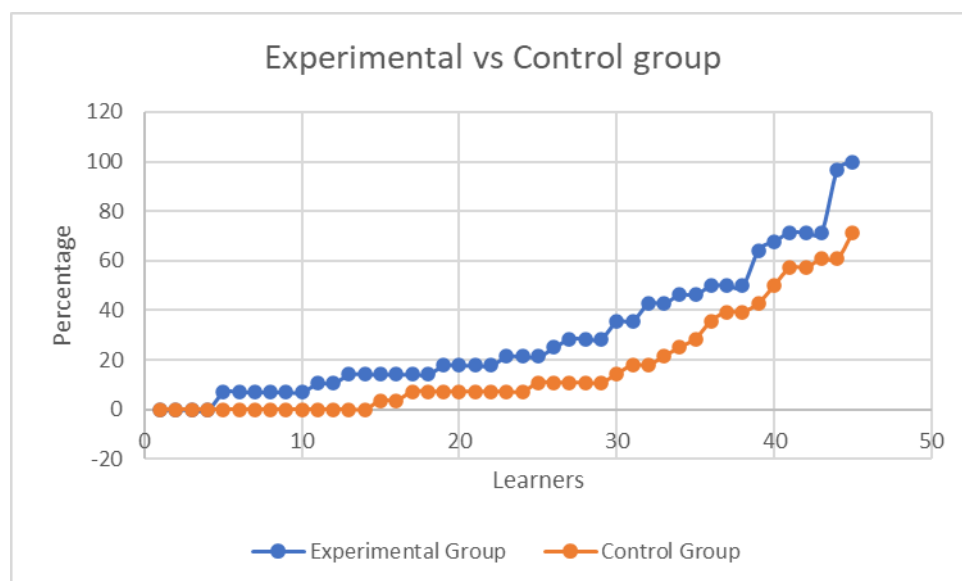


Figure 18: Grade 9B learners' marks (%) and achievement levels (Control)

The striking feature of Figure 18 is still the high number of learners who achieved marks below 30%. There are a total of 34 learners in this category. The next category comprises only three learners who obtained marks between 30 and 39%. One learner was in the 40 – 49% band. There were 3 learners in the 50 – 59% category; 2 learners in the 60 – 69% category; 1 learner in the 70 – 79% category and no learner in the 80 – 100% category.

The performances of both groups in the Transformation Geometry test are clearly not satisfactory. However, there are important results that can be drawn from the quantitative data obtained.

Figure 19 shows the performances of the experimental group (Grade 9B) and the control group (Grade 9C).



% (6 out of 45 learners) in the middle achievers band. This means that 30 % of the learners in the experimental group performed above 40% in the test given to the learners, while only 16% of the learners in the control group performed above 40%. 33 learners (70%) in the experimental group performed below 40%, while 38 learners (84%) in the control group performed below 40%. There is a higher number of low achievers in the control group than in the experimental group. Table 14 also shows that the mean percentage score (learners' average percentage per group) of the learners in the experimental group (28%) is higher than that of the control group (17%).

This suggests that the class that was instructed with integrated VTRs in the lesson demonstrated conceptual knowledge gains greater than their non-VTR counterparts, as evidenced in Figure 19 and Table 14.

5.2.2.2. Mean score per question

A critical analysis of the data obtained in the study lies in comparing the mean scores of both groups of learners for each question. This will also require checking the mean scores against the questions, as discussed in Section 4.5.2.

A summary of the mean scores per question for both groups of learners is shown in Figure 20.

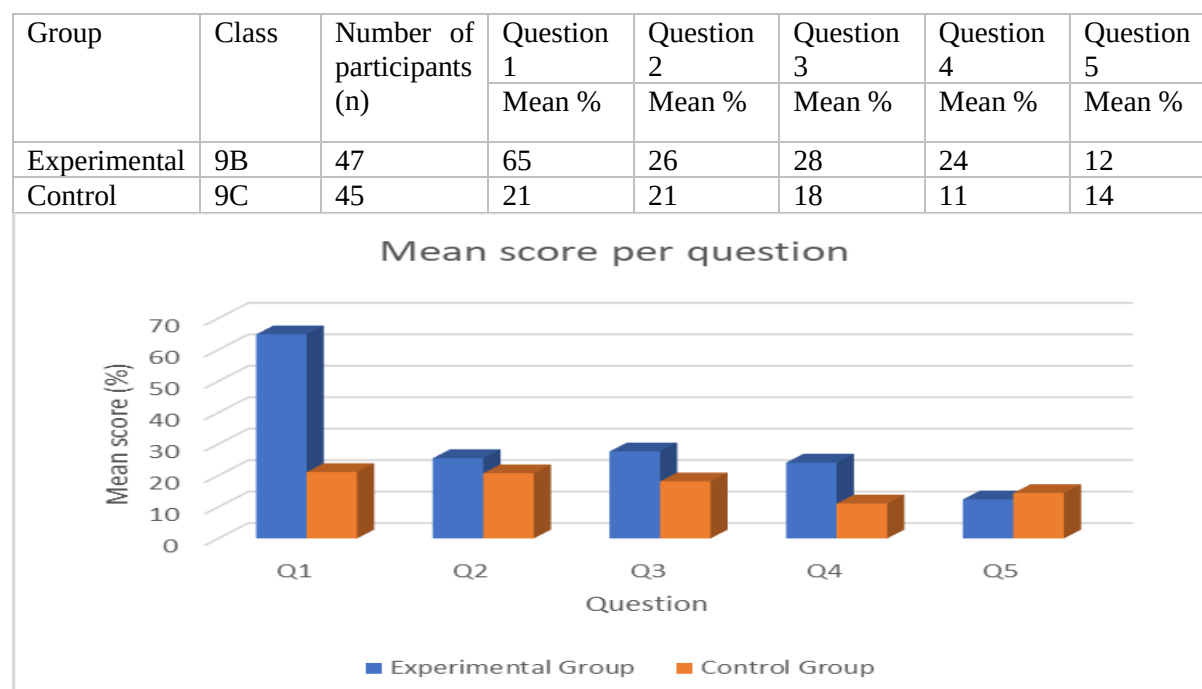


Figure 20: Mean scores of learners per question for both groups

In **Question 1**, the experimental group performed better than the control group, as shown in Figure 20. The mean scores of 9B and 9C were 65% and 21%, respectively. It is important to

mention at this stage that the VTRs used in this study stressed the meanings of translation and reflection while demonstrating both transformations. This may have helped the experimental group obtain higher mean scores than those of the control group.

In **Question 2**, the mean scores of the experimental and control groups are 26% and 21%, respectively, as shown in Figure 20. It is important to note that the mean score of the control group remains the same for the first two questions (21%). This may imply consistency in their conceptual knowledge as evaluated against the two facets of conceptual knowledge as explained by Crooks and Alibali (2014). The experimental group shows a significant drop in the mean score (from 65% to 26%). However, the experimental group outperformed their control group counterparts in this question.

In **Question 3**, the learners in the experimental group outperformed their counterparts in the control group, as shown in Figure 20. The mean scores for Grade 9B and 9C are 28% and 18%, respectively. This is a slight increase in the experimental group indicating that the knowledge of the principles underlying the procedures was higher in this group, as this question was designed to be more challenging than **Question 2**. There is a slight decrease in the mean score of the control group compared to the previous question.

Figure 20 shows that the learners in the experimental group outperformed their counterparts in the control group in Question 4. The mean scores for Grades 9B and 9C are 24% and 11%, respectively.

Question 5 was important because both groups were taught this reflection in the traditional method. The VTRs did not demonstrate this kind of reflection. The mean scores of both groups in this question are therefore interesting to analyse. The learners in the control group outperformed their counterparts in the experimental group for the first time in the study. The mean scores for Grades 9B and 9C are 12% and 14% respectively. It is also important to note that the difference in the mean scores in this question is the lowest across all the questions.

These performance analyses indicate that the learners in the experimental group generally outperformed their control group counterparts in the written test.

Therefore, it can be deduced that the use of VTRs improved the conceptual knowledge of Transformation Geometry for Grade 9 learners, although the performance of learners in the

written test was below par. This was concluded after a performance analysis, observation analysis and learners' scripts analysis.

5.2.2.3. Independent samples t-test

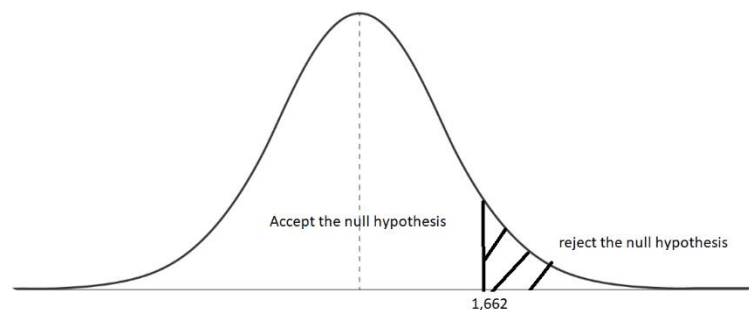
The study is testing the difference between the mean of the experimental group (Class taught with VTRs) and the control group (Class taught without VTRs). The main research question seeks to find out the influence of VTRs on the conceptual knowledge of Transformation geometry.

The research hypothesis (H_1) states that the experimental group that was taught using VTRs performed better in the test than the control group. The null hypothesis (H_0) states that there is no difference in the performance of the experimental and control groups. The data given below were used to apply the independent samples t-test.

$n_E = 47$; $\bar{x} = 7.98$; $s = 7.24$, where n_E is the number of learners in the experimental group; $\bar{x}$ is the mean of the experimental group and s is standard deviation.

$n_C = 45$; $\bar{x} = 4.71$; $s = 5.78$, where n_C is the number of learners in the experimental group; $\bar{x}$ is the mean of the experimental group and s is standard deviation.

Critical region: $t_{0.05;90} = 1.662$



Decision rule: Accept H_0 : if the t statistic is less than 1.662

Reject H_0 : if t statistic is greater than 1.662

Since the two samples are independent, therefore we check which learner t distribution we use by calculating the ratio of the variances.

$$\frac{s_E^2}{s_C^2} = \frac{(7.24)^2}{(5.78)^2} = 1.57$$

Since the ratio of the variances is between $\frac{1}{2}$ and 2, therefore use learner t distribution for the difference in mean for pooled variance.

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2 - 2} = \frac{46 (7.24)^2 + 44 (5.78)^2}{47+45-2} = \frac{2\,411.2096 + 1\,469.9696}{90} = 43.124213333$$

$$s_p = 6.5669$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{(7.98 - 4.71) - 0}{6.5669 \sqrt{(\frac{1}{47} + \frac{1}{45})}} = 2.388$$

The t statistic is greater than the critical value 1.662, therefore we conclude with 95% confidence that the experimental group performed better than the control group. This means that teaching grade 9 learners with VTRs improves their understanding of the transformation geometry concept.

5.3. Summary and conclusion

This chapter focused on presenting the results of this study. The results were presented in their two forms, that is, quantitative and qualitative data. The quantitative data presented was analysed in terms of the learners' scores on the written test and the mean scores they obtained per question. The experimental group (Grade 9B) generally outperformed the control group (Grade 9C) in both criteria. Inferential statistics, in the form of the independent samples t-test, also confirmed the conclusion of the descriptive statistical data. This means that the findings can also be generalised for a larger sample size. The qualitative data presented was analysed in terms of the findings from an observation schedule and an evaluation of the learners' responses to the questions in the written test. The results indicated that using VTRs in the classroom presented challenges in an under-resourced school. The responses of the experimental group had more depth than the control group.

CHAPTER 6: DATA INTERPRETATION, CONCLUSIONS, AND IMPLICATIONS OF THE STUDY

6.1. Introduction

In this chapter, the presented results of the study are interpreted. The results of the study focused on the performance of the learners on the written test. The results were analysed qualitatively and quantitatively. Interpretation of the data presented is carried out in accordance with the research questions of the study. The main research question is given as:

- What is the influence of VTRs on learners' conceptual knowledge of Transformation Geometry?

This question is followed up by two sub-questions given below:

- What are the factors that may affect the use of VTRs in classroom instruction of Transformation Geometry?
- What are the challenges (if any) that learners have in understanding Transformation Geometry?

These research questions will be answered using the two facets of conceptual knowledge framework accompanied by the TPACK framework.

6.2. Responses to research questions

The results and analyses presented in Chapter 5 responded to the research questions of this study.

6.2.1. What are the factors that may affect the use of VTRs in classroom instruction of Transformation Geometry?

This sub-question was grounded in the anticipation that implementing VTRs in the classroom may potentially present challenges to teachers. This was important since it helped to structure the methodology of the study. The question also becomes even more pertinent since it can provide insight into why teachers can be restricted to using VTRs during instruction, although it may improve the conceptual knowledge of learners.

6.2.1.1. Findings from the observation schedule

The findings of this study indicate that the use of VTRs can be affected by a lack of resources in a school. As discussed in the findings of the observation schedule notes (Chapter 5), the school in this study did not have the equipment required for the use of VTRs in the classroom. The classroom did not have a plug socket to connect the projector, laptop, and speaker system. The teacher had to improvise to ensure that the lesson was conducted with VTRs. The pull-up projector also required a nail to be fixed on the wall for support as explained in the observation schedule of the first day (18 September 2023). This resulted in the lesson starting late, implying that teaching time was negatively affected.

On day two of the study, the nail that was fixed to the wall to support the projector was missing, causing more teaching time to be lost due to the use of VTRs. This means that a lack of resources in a school may not motivate teachers to use VTRs in the classroom due to time constraints and curriculum delivery objectives. The computer, projector, and all associated components need to be fixed in each classroom for easier access.

Another factor that may affect the use of VTRs in the classroom is the reality of hiccups during VTR instruction. On the first day of instruction, the researcher notes indicate that there were hiccups when the laptop took longer to boot and when opening videos. The teacher needed to improvise to move past the hiccups. Hiccups also take away from teaching time. This may make teachers reluctant to use VTRs in the classroom.

An important finding from the observation schedule notes was that there were words within the videos that the learners did not understand. The words included ‘distorted’ and ‘vertices’. This was exacerbated by the accent used in the videos. The accents were American. The school selected in this study was rural and under-resourced. This means that there may have been a language barrier during the playing of the videos used in this study. This may discourage teachers from using VTRs if they are not tailor-made for their community.

The VTRs may need to be made with the intended audience in mind to cater to different learners’ needs. The accent used in VTRs may also need to be familiar for maximum benefit of learners.

The factors discussed here may not only inhibit teachers from using VTRs but may also determine the effectiveness of VTRs during classroom instruction.

6.2.1.2. Relating the findings to literature

As discussed in Chapter 2, when schools lack the necessary technological infrastructure as well as teacher skills, VTRs may not be used during classroom instruction (Padaychee, 2017; Muhazir and Retnamati, 2020; Das, 2020). If VTRs are used, they may be used to a limited extent. This is in line with the findings of this study. The amount of time lost while setting up VTRs in the classroom may not motivate teachers to use them for future lessons or concepts.

6.2.2. What are the challenges (if any) that learners have in understanding Transformation Geometry?

This research question seeks to present the main challenges learners have in understanding Transformation Geometry. The link between this sub question and the main research question lies in understanding that to use VTRs in the classroom, there should be anticipated challenges from learners by the teacher. Understanding the challenges may also help focus lesson preparation on the anticipated challenges. This study indicates that learners have various challenges in understanding Transformation Geometry.

6.2.2.1. Findings from the written test

As discussed in Chapter 5, the first question of the written test required learners to suggest what reflection and translation do to shape. Although the mean score for this question in the experimental group was 65%, there were learners who were unable to correctly explain the two transformations. The control group had a mean score of 21% on this question, indicating that the learners could not correctly explain reflection and translation. This seems to be the fundamental challenge that learners face in understanding Transformation Geometry. The experimental group demonstrated a better understanding of the transformation terms. This may be due to the explanations presented in the VTRs used during the instruction.

The subsequent questions tested the learners on determining the coordinates of transformed shapes. The learners were then asked to sketch the transformed shapes afterwards. The mean scores for both groups were below 30%, indicating that the learners had difficulty determining the coordinates of transformed shapes. This may still be attributed to their challenge of explaining transformations of a shape. A lack of visualisation of transformations seems to inhibit the conceptual development of Transformation Geometry by learners.

6.2.2.2. *Relating findings to literature*

As discussed in Chapter 2, Guven (2012) discussed that learners struggle to understand translation and reflection. This remains the underlying challenge learners have in understanding transformation geometry. Noto et al. (2018) indicated that learners struggle to visualise geometric objects. This is still connected to not being able to understand what the transformations mean. In this study, the learners were still struggling to demonstrate correctly what the transformations mean and how they should be performed. This is in line with the literature as discussed in Chapter 2.

6.2.3. What is the influence of VTRs on learners' conceptual knowledge of Transformation Geometry?

This study was rooted in investigating the potential influence of visual technological resources on the conceptual knowledge of learners.

6.2.3.1. *Quantitative interpretation*

Quantitatively, the test scores of the two groups of learners indicate that the experimental group outperformed the control group as discussed in Chapter 5. The mean score for the experimental group was 28% while the mean score for the control group was 11%. The mean score of the experimental group is more than twice the mean score of the control group. A reasonable conclusion may be made that the use of VTRs aided the experimental group to meaningfully understand Transformation Geometry.

It is also significant to note that there were only 6 learners who scored 0% in the written test of the experimental group compared to the 14 learners of the control group. This may arguably be a consequence of the use of VTRs during instruction. The experimental group also presented two learners scoring above 90% (including 100%) in the written test while the control group's highest score was 71%. Therefore, VTRs may have a positive influence on the conceptual knowledge of Transformation Geometry.

In addition to the evaluated test scores, the mean scores of the experimental group were also generally higher than the mean score of the control group. This was shown in the first four questions of the written test. The last question (Question 5), however, displayed a different trend. The control group obtained a higher mean score (14%) than the experimental group (12%) as discussed in Chapter 5. Question 5 was intentionally instructed without VTRs to both groups. The slightly higher score of the control group may indicate that the experimental group

was outperforming their counterparts owing to the positive influence of VTRs on their conceptual knowledge.

6.2.3.2. Qualitative interpretation

Since it may be argued that the test scores of the learners may not primarily reflect the conceptual knowledge of the learners, it is important to interpret the qualitative findings as presented in Chapter 5.

As measured from the two facets of conceptual knowledge, the questions in the written test were designed to evaluate the conceptual gains of the learners. This means that a higher mean score per question may directly imply deeper conceptual knowledge of the test group. Qualitatively, the solution paths of the experimental group indicated a deeper level of conceptual understanding as compared to their control group counterparts.

As discussed in Chapter 5, a higher number of learners from the control group did not conceptually adequately understand the transformations. This intimates that the use of VTRs during classroom instruction positively influences the development of conceptual knowledge of learners.

6.2.3.3. Relating the findings to literature

As discussed in Chapter 2, Olive et al. (2009) explained that using technological resources in the classroom enhances teaching and learning. This is because it enables the teacher to have new ideas about presenting concepts to learners. This was also echoed by Attard and Holmes (2020) when they explained that technology usage in the classroom creates multiple opportunities for learning mathematics. Therefore, the opportunities presented are beneficial for teaching and learning mathematics.

Mofolo-Mbokane et al. (2013) indicated in their study that the use of technology in mathematics instruction brings the abstract concepts to life. This means learners are enabled to develop conceptual knowledge deeply when technological resources are used during mathematics instruction.

Ocal (2017) supported that the use of digital software in mathematics learning improved the conceptual knowledge of learners. This finding was also corroborated by Bwalya (2019) when investigating the influence of technological software on mathematics learning of

Transformation Geometry. Bwalya (2019) showed that the technological software (Geogebra) improved learners' understanding of Transformation Geometry.

Mlotshwa et al. (2020) also concluded that technological resources improved learners' conceptual knowledge of mathematical functions.

The literature presented here is consistent with the findings of this study that the use of VTRs aids in improving the conceptual knowledge of learners.

6.3. Summary and conclusion

The study investigated the influence of VTRs on the conceptual knowledge of learners. This was done by giving two groups of learners an opportunity to learn with and without VTRs. The conceptual knowledge gains of the learners in both groups were compared and analysed after they wrote the same test. The usage of VTRs improved the conceptual knowledge of Transformation Geometry for the experimental group learners. Learners from the experimental group outperformed their control group counterparts in the written test and in the observed classroom interactions.

This chapter focused on responding to the research questions of this study. VTRs were found to improve learners' conceptual knowledge of Transformation Geometry (Main research question). This means that VTRs have a positive influence on learners' conceptual knowledge development. The experimental group therefore outperformed the control group.

It was found that 30 % of the learners in the experimental group performed above 40% in the test given to the learners. 16% of the learners in the control group performed above 40%. This means that only 23% of the total sample size (21 out of 92 learners) performed above 40%. This also means that only one in four learners were able to pass the test. It can therefore be concluded that Transformation Geometry is a difficult topic for Grade 9 learners. Inferential statistics, in the form of the independent samples t-test, also confirmed the descriptive statistical data conclusion. Therefore, the findings can be generalised to a larger sample size. A t statistic value of 2.388 was obtained. This value was greater than the critical value of 1.662. Therefore, it was concluded with 95% confidence that the experimental group performed better than the control group.

The main challenge of using VTRs in an under-resourced school is the lack of facilities. The teacher in this study lost teaching time setting up equipment for each lesson. This may result

in teachers not using VTRs. Hiccups were also found to be a factor that may affect the use of VTRs during classroom instruction of mathematical topics (First research sub question).

Learners were found to struggle with understanding transformation terms (translation and reflection). Learners also struggled to sketch images of transformed shapes (Second research sub question). These challenges were studied from the solutions of the learners. The top six learners from both groups were selected and their scripts were analysed. Both groups displayed shallow conceptual knowledge in this study. Most of the learners in both groups were unable to obtain the coordinates of transformed points from the questions presented. It is worth reporting that there were learners who were unable to obtain the correct coordinates of reflected points but were able to represent the transformed shape on the Cartesian plane correctly.

These conclusions were made after a performance analysis, an observation schedule analysis, and a learners' scripts analysis.

The TPACK framework and the two facets of the conceptual knowledge framework were successfully used in the research design and data analysis of this study.

6.4. Recommendations

- Schools should invest in the technological infrastructure and resources that are planted in classrooms.
- Mathematics teachers should integrate VTRs in classroom instruction of Transformation Geometry.
- Teachers should undergo thorough training in TPACK.
- VTRs should be used across all mathematics topics.
- Future studies should investigate the influence of VTRs on mathematics learning in both primary and secondary schools.
- Future studies should also interview participants to capture their attitudes towards using VTRs in the classroom instruction of mathematics topics.

6.5. Limitations of the study

This study was conducted toward the end of the third term of the school year 2023. This was done from the 18th to the 21st of September. This was a time when Senior phase learners had completed their term tasks. There was learner absenteeism during this time.

The expected sample size was 143 learners. The actual sample size was ultimately 92 learners. The actual sample size was acceptable for the study to be conducted.

6.6. Reflections of the study

This study has been insightful in understanding the scope of challenges learners have when learning Transformation Geometry. Although learners can be considered heterogeneous in the classroom, the challenges are more similar than different. The implication is that Transformation Geometry is a difficult topic for learners. This may imply that Transformation Geometry is presented to learners in an abstract form.

The scarce literature on how Transformation Geometry should be instructed and the learning challenges learners experience during its instruction in South Africa led to a conclusion that it may be deemed insignificant in the Senior phase curriculum. Transformation Geometry requires more mathematical skills than those imparted by teachers to learners in classrooms. In fact, its scope and time allocated may require a widening to allow learners to gain significantly from its instruction.

Integration of technology in rural schools still appears to be minimal. Although there is a push in many countries to integrate technology during instruction, there exists a strong belief that the curriculum can be completed effectively without it. It seems there exists a resistance from teachers towards using technology in the classroom. The main challenge may be accessibility to the technology. Time constraints may also contribute to the challenges.

The impact of effectively integrated technology in its various forms in the classroom cannot be denied. Technology, in its full spectrum, should be mandatory in mathematics education and teaching in general.

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APPENDICES

Appendix A

Activity 1

ACTIVITY 1 GRADE 09..... TRANSFORMATION GEOMETRY DATE:

Learner Code:

Total Marks: 28

1. Complete the following statements.

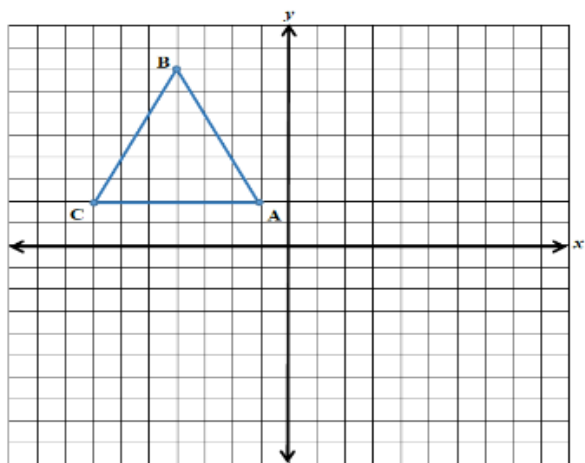
1.1. Translation a shape. (2)

1.2. Reflection a shape. (2)

2. Triangle BAC is given with A (-1;2), B (-4;8) and C (-7;2).

Write down the coordinates of points A', B' and C' if triangle BAC is shifted three units downwards. Sketch the transformation on the diagram.

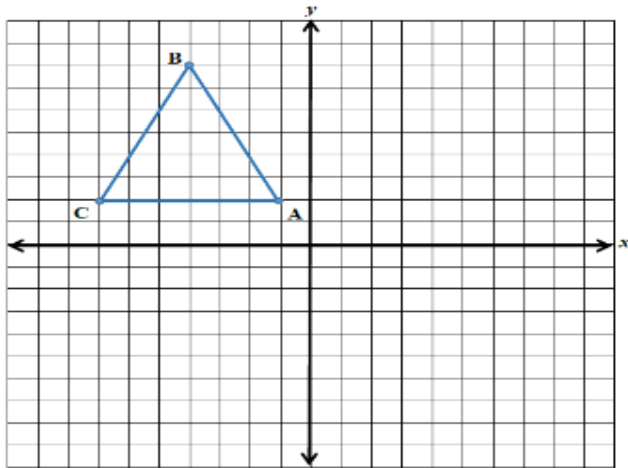
A' (.....;) B' (.....;) C' (.....;)



(6)

3. Write down the coordinates of points A', B' and C' if triangle BAC is shifted two units downwards and then four units to the right. Sketch the transformation on the diagram.

A' (.....;) B' (.....;) C' (.....;)

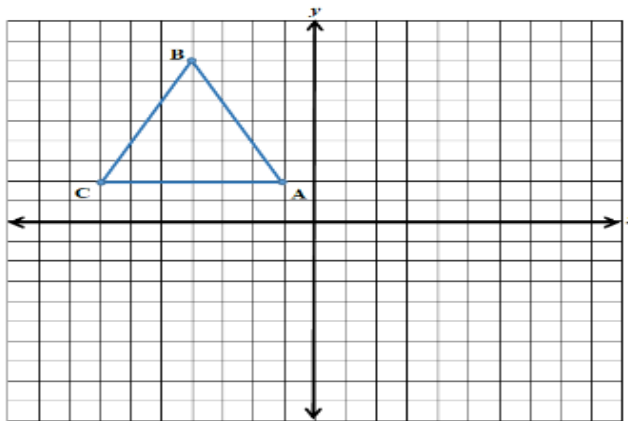


(6)

4. Triangle BAC is reflected in the y-axis. Write down the coordinates of A', B' and C'.

A' (.....;) B' (.....;) C' (.....;)

Sketch the transformation on the diagram.

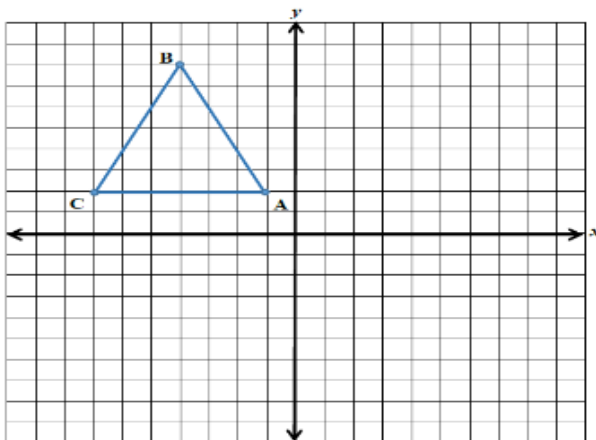


(6)

4. Triangle BAC is reflected across the line $y = x$. Write down the coordinates of A', B', C'.

A' (.....;) B' (.....;) C' (.....;)

Sketch the transformation on the diagram.



(6)

TOTAL: 28

Appendix B

Observation Schedule

Observation Schedule

Directions: Observe the classroom environment, learner-teacher behaviour, learner participation and interaction as the following given elements and mark according to their occurrences.

Name of Grade 09 Teacher: Ms M

Grade 9 (A or B)

Name of Observer: Mr. N

VO=Very Often, O=Often, SM=Sometimes, S=Seldom, N=Never

No.	Element Observed	VO	O	SM	S	N
1	VTRs used during lesson					
2	Teacher is confident in executing the lesson					
3	Teacher confidently uses VTRs					
4	Learners follow the teacher's explanations using the digital resource					
5	Teacher experiences 'hiccups' during lesson presentation					
6	Teacher provides activities to learners that are connected to digital demonstrations					
7	Learners ask/answer questions based on digital resource					
8	Learners ask/answer about concepts presented without digital resource					

Appendix C

Participant Information sheet for Principal



Participant Information Sheet for Principal

Dear Sir / Madam

My name is **Nndileleni Nedambale**. I am a Masters student in the Faculty of Humanities, School of Education at the University of the Witwatersrand, Johannesburg. My supervisor is Dr Batseba Mofolo-Mbokane. I am conducting a research study about learning Mathematics using visual technological resources (Videos).

The study title is 'The influence of visual technological resources on Grade 09 learners' conceptual knowledge of transformation geometry'.

I am inviting your school (Grade 09 mathematics teacher and Grade 09 learners) to take part in the study that involves lesson observations and a test. You will not be a direct participant of the study. The study seeks to explore the challenges learners may have in understanding transformation geometry and the influence visual technological resources would have on learners' conceptual knowledge. The study will also explore the nature of the interaction between teacher and learners during classroom interaction of Transformation geometry. This will be done by selecting two Grade 09 classes in your school with about 70 to 90 learners and giving them lessons on transformation geometry. One class will be taught transformation geometry without using visual technological resources. The other class will be taught transformation geometry using visual technological resources. The lessons will be conducted

by the school's Grade 09 mathematics educator. The lessons will take place in the third term of the 2023 academic year. It will run from the 18th of September until the 22nd of September. The lessons will run for a total of five days. A Term 4 topic will be introduced towards the end of the third term. The lessons will be conducted after school to avoid interfering with the school's programme. On each day, the class taught without VTRs, and the class taught through VTRs will remain after normal teaching hours together with their teacher. Since normal school teaching hours at your school run from 07h45 until 14h20 from Monday to Thursday, the first class will be taught from 14h20 until 14h50. This will be the class taught without VTRs. The second class will be taught from 15h00 until 15h30. This is the class that will be taught using VTRs. On the last day (Friday), the lessons run from 07h45 until 13h30. This is the day the learners (both classes) will be writing the test. The test will run from 13h40 until 14h20. The culture of the school already promotes teachers and learners staying behind after school for extra and enrichment classes. These classes are designed to benefit learners in the school. This will be to the advantage of this study since the learners will be required to stay behind.

The test will be set by the researcher (Nndileleni Nedambale) so that the questions draw on the conceptual knowledge of the learners as part of the research's objectives. The learners' worksheets will be marked by the researcher, so their conceptual knowledge is analysed as part of the research's objectives. The test scores and worksheets of learners will be compared to evaluate the influence of visual technological resources on the conceptual knowledge of learners. Copies of the marked scripts will be made and kept by the researcher while the original scripts are returned to your mathematics teacher for his/her own analyses.

Classroom observations will be conducted to explore learner-teacher interactions during instruction on Transformation geometry. The participation of your school in this research study will last for 1 week (5 days).

The teaching and assessing will take place at the school after normal school teaching hours.

With your permission, I would like to capture the scores of the given test. This data will be stored in digital form with all identifying features removed in a password protected computer for future secondary analysis. Only the researcher will have access to the data.

The test scores analyses will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify the school and all the participants. With your permission, other researchers may use the data collected from

this research study, but the names and any personal information of all participants will not be used or passed on.

If you decide to allow your school to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits, or rights you would normally have if you decided not to join. Taking part in the research study will not cost you anything. The learners who opt out of the study will not be coerced to participate and will not lose out on normal classroom instruction since the study will be conducted after normal school hours. The class that was initially instructed without VTRs will be afforded an opportunity to be taught with VTRs after data collection. The third class (Grade 9C) will also be afforded an opportunity to learn using VTRs since it was not selected for the study.

The risks for this research study are no more than what happens in everyday life. This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Nndileleni

Researcher: Nndileleni Nedambale, 0710786D@students.wits.ac.za, 0820531452

Supervisor: Dr. Batseba Mofolo-Mbokane, Batseba.Mbokane@wits.ac.za, 011 717 1000

Participant Information sheet for Teacher



Participant Information Sheet for Teacher

Dear Sir / Madam

My name is **Nndileleni Nedambale**. I am a Masters student in the Faculty of Humanities, School of Education at the University of the Witwatersrand, Johannesburg. My supervisor is Dr Batseba Mofolo-Mbokane. I am conducting a research study about learning Mathematics using visual technological resources (Videos).

The study title is 'The influence of visual technological resources on Grade 09 learners' conceptual knowledge of transformation geometry'.

I am inviting you to take part in a study that involves lessons, lesson observations and a test. The study seeks to explore the challenges learners have in understanding transformation geometry and the influence visual technological resources would have on learners' conceptual knowledge. This study will also explore the teacher and learners' interaction during instruction of Transformation geometry. This will be done by selecting two Grade 09 classes in your school with about 70 to 90 learners and giving them lessons on transformation geometry. One class will be taught transformation geometry without using visual technological resources. The other class will be taught transformation geometry using visual technological resources. The lessons will be conducted by you, as the Grade 09 mathematics teacher. This will be followed by giving both groups of learners a test after both forms of lessons on transformation geometry. The test will be set by the researcher (Nndileleni Nedambale) so that the questions draw on the conceptual knowledge of the learners as part of the research's objectives. The learners'

worksheets will be marked by the researcher, so their conceptual knowledge is analysed as part of the research's objectives. The test scores and worksheets of learners will be compared to evaluate the influence of visual technological resources on the conceptual knowledge of learners. Copies of the marked scripts will be made and kept by the researcher while the original scripts are returned to you for your own analyses. Classroom observations will be conducted to explore learner-teacher interactions during instruction on Transformation geometry. If you decide to take part, your participation in this research study will last for 1 week (5 days). The teaching and assessing will take place at the school after normal school teaching hours. The lessons will take place in the third term of the 2023 academic year. They will run from the 18th of September until the 22nd of September. The lessons will run for a total of five days. This will require permission from the school to introduce a Term 4 topic towards the end of the third term. The lessons will be conducted after school to avoid interfering with the school's programme. On each day, the class taught without VTRs, and the class taught through VTRs will remain after normal teaching hours together with you. Normal school teaching hours at the school run from 07h45 until 14h20 from Monday to Thursday. The first class will be taught from 14h20 until 14h50. This will be the class taught without VTRs. The second class will be taught from 15h00 until 15h30. This is the class that will be taught using VTRs. On the last day (Friday), the lessons run from 07h45 until 13h30. This is the day the learners (both classes) will be writing the test. The test will run from 13h40 until 14h20. The culture of the school already promotes teachers and learners staying behind after school for extra and enrichment classes. These classes are designed to benefit learners in the school. This will be to the advantage of this study since you and the learners will be required to stay behind.

With your permission, I would like to capture the scores of the given test. This data will be stored in digital form with all identifying features removed in a password protected computer for future secondary analysis. Only the researcher will have access to the data.

The test scores analyses will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify you. With your permission, other researchers may use the data collected from this research study, but your name and any personal information will not be used or passed on.

If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose

to join the research study. You will not lose any services, benefits, or rights you would normally have if you decided not to join. Taking part in the research study will not cost you anything. The learners who opt out of the study will not be coerced to participate and will not lose out on normal classroom instruction since the study will be conducted after normal school hours. The class that was initially instructed without VTRs will be afforded an opportunity to be taught with VTRs after data collection. The third class (Grade 9C) will also be afforded an opportunity to learn using VTRs since it was not selected for the study.

The risks for this research study are no more than what happens in everyday life.

This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Nndileleni

Researcher: Nndileleni Nedambale, 0710786D@students.wits.ac.za, 0820531452

Supervisor: Dr. Batseba Mofolo-Mbokane, Batseba.Mbokane@wits.ac.za, 011 717 1000

Participant Information sheet for Parents



Participant Information Sheet for Parents

Dear Sir / Madam

My name is **Nndileleni Nedambale**. I am a Masters student in the Faculty of Humanities, School of Education at the University of the Witwatersrand, Johannesburg. My supervisor is Dr Batseba Mofolo-Mbokane. I am conducting a research study about learning Mathematics using visual technological resources (Videos).

The study title is 'The influence of visual technological resources on Grade 09 learners' conceptual knowledge of transformation geometry'.

I am inviting your child to take part in the study that involves lessons, lesson observations and a test. The study seeks to explore the challenges learners have in understanding transformation geometry and the influence visual technological resources would have on learners' conceptual knowledge. The study also seeks to explore the teacher and learners' interaction during classroom instruction of Transformation geometry. This will be done by selecting two Grade 09 classes in the school your child attends with about 70 to 90 learners and giving them lessons on transformation geometry. One class will be taught transformation geometry without using visual technological resources. The other class will be taught transformation geometry using visual technological resources. The lessons will be conducted by the school's mathematics educator. This will be followed by giving both groups of learners a test after both forms of lessons on transformation geometry. The test will be set by the researcher (Nndileleni Nedambale) so that the questions draw on the conceptual knowledge of the learners as part of

the research's objectives. If you decide to allow your child to take part, your child's participation in this research study will last about 1 week (5 days). The teaching and assessing will take place at the school after normal school teaching hours.

With your permission, I would like to capture the test scores of the learners involved in the study (including your child). This data will be stored in digital form with all identifying features removed in a password protected computer for future secondary analysis. Only the researcher will have access to the data.

The test scores analyses will be confidential and anonymous. When I share the results of the research study, I will not include your child's name or anything else that could identify him/her. With your permission, other researchers may use the data collected from this research study, but your child's name and any personal information will not be used or passed on.

If you decide to let your child take part in the research study, it should be because you want to volunteer. Your child does not have to take part. Your child can stop being in the study at any time. Your child does not have to answer any questions if he/she does not want to. Your child will not get any direct benefits if you choose to join the research study. Your child will not lose any services, benefits, or rights you would normally have if you decided not to join. Taking part in the research study will not cost you anything. The learners who opt out of the study will not be coerced to participate and will not lose out on normal classroom instruction since the study will be conducted after normal school hours. The lessons will take place in the third term of the 2023 academic year. They will run from the 18th of September until the 22nd of September. The lessons will run for a total of five days. This will require permission from the school to introduce a Term 4 topic towards the end of the third term. The lessons will be conducted after school to avoid interfering with the school's programme. On each day, the class taught without VTRs, and the class taught through VTRs will remain after normal teaching hours together with their mathematics teacher. Normal school teaching hours at the school run from 07h45 until 14h20 from Monday to Thursday. The first class will be taught from 14h20 until 14h50. This will be the class taught without VTRs. the second class will be taught from 15h00 until 15h30. This is the class that will be taught using VTRs. On the last day (Friday), the lessons run from 07h45 until 13h30. This is the day the learners (both classes) will be writing the test. The test will run from 13h40 until 14h20. The culture of the school already promotes teachers and learners staying behind after school for extra and enrichment classes. These classes are

designed to benefit learners in the school. This will be to the advantage of this study since the mathematics teacher and the learners will be required to stay behind.

The class that was initially instructed without VTRs will be afforded an opportunity to be taught with VTRs after data collection. The third class (Grade 9C) will also be afforded an opportunity to learn using VTRs since it was not selected for the study.

The risks for this research study are no more than what happens in everyday life.

This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,

Nndileleni

Researcher: Nndileleni Nedambale, 0710786D@students.wits.ac.za, 0820531452

Supervisor: Dr. Batseba Mofolo-Mbokane, Batseba.Mbokane@wits.ac.za, 011 717 1000

Participant Information sheet for learners



Participant Information Sheet for Learners

Dear Sir / Madam

My name is **Nndileleni Nedambale**. I am a Masters student in the Faculty of Humanities, School of Education at the University of the Witwatersrand, Johannesburg. My supervisor is Dr Batseba Mofolo-Mbokane. I am conducting a research study about learning Mathematics using visual technological resources (Videos).

The study title is 'The influence of visual technological resources on Grade 09 learners' conceptual knowledge of transformation geometry'.

I am inviting you to take part in the study that involves lessons, lesson observations and a test. The study seeks to explore the challenges learners have in understanding transformation geometry and the influence visual technological resources would have on learners' conceptual knowledge. The study will also explore teacher and learners' interaction during classroom instruction of Transformation geometry. This will be done by selecting two Grade 09 classes in your school with about 70 to 90 learners and giving them lessons on transformation geometry. One class will be taught transformation geometry without using visual technological resources. The other class will be taught transformation geometry using visual technological resources. The lessons will be conducted by your mathematics educator. This will be followed by giving both groups of learners a test after both forms of lessons on transformation geometry. The test will be set by the researcher (Nndileleni Nedambale) so that the questions draw on the conceptual knowledge of the learners as part of the research's objectives. If you decide to take

part, your participation in this research study will last for 1 week (5 days). The teaching and assessing will take place at the school after normal school teaching hours. The lessons will take place in the third term of the 2023 academic year. They will run from the 18th of September until the 22nd of September. The lessons will run for a total of five days. This will require permission from the school to introduce a Term 4 topic towards the end of the third term. The lessons will be conducted after school to avoid interfering with the school's programme. On each day, the class taught without VTRs, and the class taught through VTRs will remain after normal teaching hours together with their mathematics teacher. Normal school teaching hours at the school run from 07h45 until 14h20 from Monday to Thursday. The first class will be taught from 14h20 until 14h50. This will be the class taught without VTRs. the second class will be taught from 15h00 until 15h30. This is the class that will be taught using VTRs. On the last day (Friday), the lessons run from 07h45 until 13h30. This is the day the learners (both classes) will be writing the test. The test will run from 13h40 until 14h20. The culture of the school already promotes teachers and learners staying behind after school for extra and enrichment classes. These classes are designed to benefit learners in the school. This will be to the advantage of this study since the mathematics teacher and the learners will be required to stay behind.

The class that was initially instructed without VTRs will be afforded an opportunity to be taught with VTRs after data collection. The third class (Grade 9C) will also be afforded an opportunity to learn using VTRs since it was not selected for the study.

With your permission, I would like to capture the score of the given test. This data will be stored in digital form with all identifying features removed in a password protected computer for future secondary analysis. Only the researcher will have access to the data.

The test scores analyses will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify you. With your permission, other researchers may use the data collected from this research study, but your name and any personal information will not be used or passed on.

If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits, or rights you would normally

have if you decided not to join. Taking part in the research study will not cost you anything. The learners who opt out of the study will not be coerced to participate and will not lose out on normal classroom instruction since the study will be conducted after normal school hours.

The risks for this research study are no more than what happens in everyday life.

This research study will be written up as a research report. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you.

If you have any questions during or afterwards about this research study, feel free to contact me or my supervisor on the details listed below. If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za.

Yours sincerely,
Nndileleni

Researcher: Nndileleni Nedambale, 0710786D@students.wits.ac.za, 0820531452

Supervisor: Dr. Batseba Mofolo-Mbokane, Batseba.Mbokane@wits.ac.za, 011 717 1000

Appendix D

Consent Form for Teacher



Consent Form for Teacher

Title of project: The influence of visual technological resources on grade 09 learners' conceptual knowledge of transformation geometry

Name of researcher: NNDILELENI NEDAMBALE

I, ..., agree to participate in this research project. I consent to all activities as detailed in the teacher participation sheet. These include teaching mathematics lessons and giving them a test after normal school hours.

I further agree to the following:

(Please circle the relevant options below)

The research study was explained to me through the Participant Information Sheet. I understand what this study is about.	YES	NO
--	-----	----

I understand that I can volunteer to take part in the study	YES	NO
I agree that the lessons may be observed and observations recorded on an observation sheet	YES	NO
I agree that direct quotations from the lesson may be used by the researcher in their research report	YES	NO
I agree that my participation will remain anonymous (my name will not be used by the researcher in their research report)	YES	NO
I agree that other researchers may use the information I provide in the lesson (depending on their own ethics clearance being obtained) but no names and personal information will be used or passed on	YES	NO
The research study will not interfere with the normal teaching time of learners.	YES	NO
Learners who opt out of the study will not lose out on any form of classroom instruction	YES	NO

..... (signature)

..... (name of participant)

..... (date)

..... (signature)

..... (name of researcher/person seeking consent)

..... (date)

Consent Form for Parents



Consent Form for Parents

Title of project: The influence of visual technological resources on grade 09 learners' conceptual knowledge of transformation geometry

Name of researcher: NNDILELENI NEDAMBALE

I, ..., agree, that my child will participate in this research project. I consent to all activities as detailed in the parent participation sheet. These include allowing my child to attend mathematics lessons and write a test after normal school hours.

I further agree to the following:

(Please circle the relevant options below)

The research study was explained to me through the Participant Information Sheet. I understand what this study is about.	YES	NO
I understand that my child can volunteer to take part in the study	YES	NO

I agree that the lessons may be observed and observations recorded on an observation schedule	YES	NO
I agree that direct quotations from the lesson may be used by the researcher in their research report	YES	NO
I agree that the participation of my child will remain anonymous (the child's name will not be used by the researcher in their research report)	YES	NO
I agree that other researchers may use the information my child provides in the lesson (depending on their own ethics clearance being obtained) but no names and personal information will be used or passed on	YES	NO
The research study will not interfere with the normal teaching time of learners.	YES	NO
Learners who opt out of the study will not lose out on any form of classroom instruction	YES	NO

..... (signature)

..... (name of participant)

..... (date)

..... (signature)

..... (name of researcher/person seeking consent)

..... (date)

Assent Form for Learners



Assent Form for Learners

Title of project: The influence of visual technological resources on grade 09 learners' conceptual knowledge of transformation geometry

Name of researcher: NNDILELENI NEDAMBALE

I, ..., as a minor, agree to participate in this research project. My participation will be confirmed by a consent form signed by my parent/legal guardian. I assent to all activities as detailed in the learner participation sheet. These include attending mathematics lessons and writing a test after normal school hours.

I further agree to the following:

(Please circle the relevant options below)

The research study was explained to me through a Participant information sheet. I understand what this study is about.	YES	NO
I understand that I can volunteer to take part in the study	YES	NO
I agree that the lessons may be observed	YES	NO

I agree that direct quotations from the lesson activity may be used by the researcher in their research report	YES	NO
I agree that my participation will remain anonymous (my name will not be used by the researcher in their research report)	YES	NO
I agree that other researchers may use the information I provide in the lessons (depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on	YES	NO

..... (signature)

..... (name of participant)

..... (date)

..... (signature)

..... (name of researcher/person seeking consent)

..... (date)

Appendix E

Permission Letter from Limpopo province DBE

 **LIMPOPO**
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA
**DEPARTMENT OF
EDUCATION**

CONFIDENTIAL

Ref: 2/22 Enq: Makola MC Tel No: 015 290 9448 E-mail: MakolaMC@edu.limpopo.gov.za

Nedambale N
27 St Andrews
Rd, Parktown
Johannesburg
2193

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal; "The influence of visual technological resources on Grade 9 learners' conceptual knowledge of transformation geometry".
3. The following conditions should be considered:
 - 3.1 The research should not have any financial implications for Limpopo Department of Education.
 - 3.2 Arrangements should be made with the Circuit Office and the School concerned.
 - 3.3 The conduct of research should not in any way disrupt the academic programs at the schools.
 - 3.4 The research should not be conducted during the time of Examinations especially the fourth term.
 - 3.5 During the study, applicable research ethics should be adhered to; in particular the principle of voluntary participation (the people involved should be respected).
 - 3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

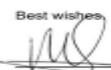
REQUEST FOR PERMISSION TO CONDUCT RESEARCH : NEDAMBALE N Page 1

Cnr 113 Bliccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X 9489, Polokwane, 0700
Tel: 015 290 7600 / 7702 Fax 086 218 0569

The heartland of Southern Africa-development is about people

4. Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.
5. The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes,


Mashaba KM
DDG: CORPORATE SERVICES

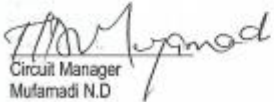
17/07/2023
Date

REQUEST FOR PERMISSION TO CONDUCT RESEARCH : NEDAMBALE N Page 2

Cnr 113 Bliccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X 9489, Polokwane, 0700
Tel: 015 290 7600 / 7702 Fax 086 218 0569

The heartland of Southern Africa-development is about people

Permission Letter from Education Circuit office

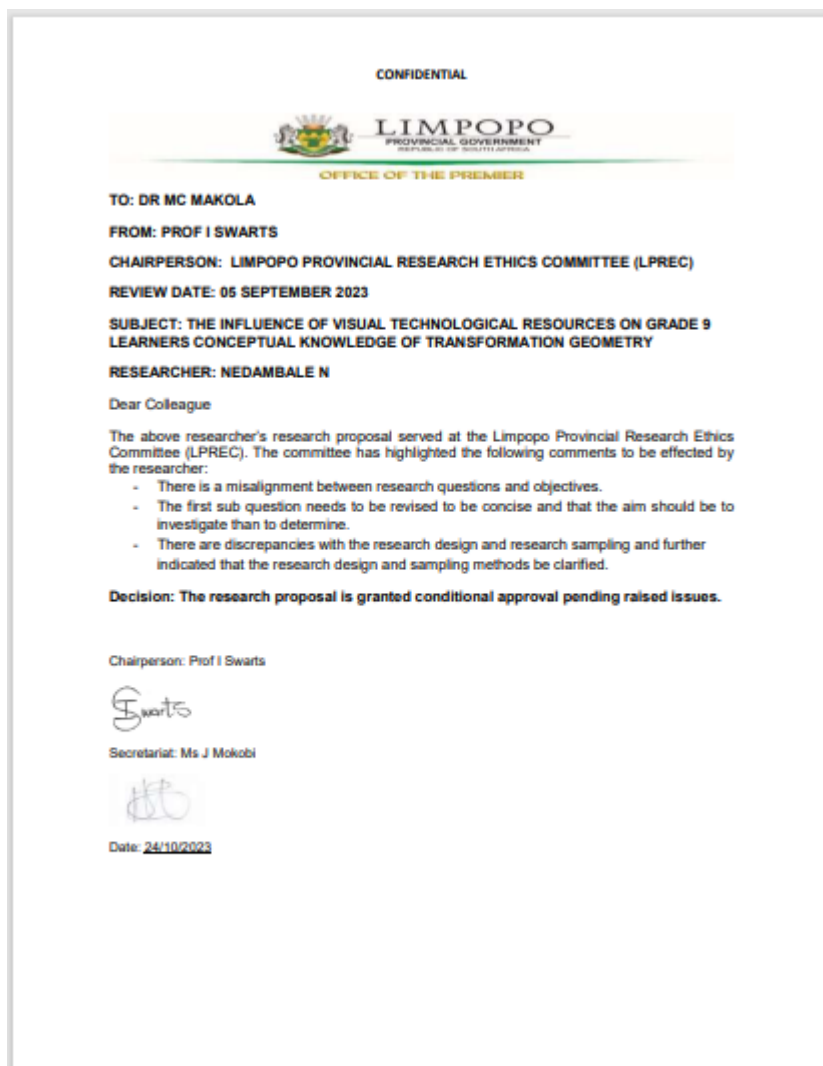
 LIMPOPO PROVINCIAL GOVERNMENT REPUBLIC OF SOUTH AFRICA DEPARTMENT OF EDUCATION MOGALAKWENA DISTRICT POTGIETERSRUS CIRCUIT
ENQ.: MASOGA M.J 3rd August 2023 072 6523 812/061 411 3203
To: Nendambale N Gwenane Secondary School P.O. Box 2009 MAHWELERENG 0626
SUBJECT: PERMISSION TO CONDUCT RESEARCH: 1. The above matter bears reference:- 2. This office acknowledge receipt of letter of permission to conduct research from the Department of Education dated 17th July 2023. 3. This office further grant permission to conduct research at school under Potgietersrus Circuit. 4. We further wish you good luck in your endeavour. Thanking you in advance.  Circuit Manager Mufamadi N.D

Permission Letter from Gwenane Secondary school

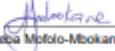
GWENANE SEC SCHOOL	
	PO BOX 2009 MAHWELERENG 0626
EMAIL: gwenanesecond@gmail.com	
EMS NO: 921120279 EMQ : MJ KGOSANA CELL : 072 724 5071/015 483 8032 ATTENTION NEDAMBANE N. 20 MAGNOLIA IMPALA PARK MOKOPANE 0601	
RE: PERMISSION TO CONDUCT MATHEMATICS RESEARCH GRADE 9	
1. The matter alluded has reference. 2. This letter serves to grant permission in respect of N. Nedambane to conduct the above research of Mathematics in grade 9 at Gwenane Sec School. 3. Your cooperation and endless effort will be greatly appreciated. 4. Hope you will find the above to be in order	
 M.J. KGOSANA (PRINCIPAL)	

Appendix F

Provincial research ethics clearance



University of the Witwatersrand research ethics clearance

	
<u>SCHOOL OF EDUCATION ETHICS COMMITTEE</u> <u>CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)</u>	
<u>CLEARANCE CERTIFICATE</u>	<u>PROTOCOL NUMBER:</u> 2023ECE024M
<u>PROJECT TITLE</u>	The influence of visual technological resources on Grade 09 learners' conceptual knowledge of transformation geometry
<u>INVESTIGATOR</u>	NNDILELENI NEDAMBALE
<u>SCHOOL/DEPARTMENT OF INVESTIGATOR</u>	Wits School of Education
<u>DATE CONSIDERED</u>	08-May-23
<u>DECISION OF THE COMMITTEE</u>	Approved unconditionally
<u>RISK LEVEL</u>	Minimal risk
<u>EXPIRY DATE</u>	Date of submission of the Research Report
<u>ISSUE DATE OF CERTIFICATE</u>	19-May-23
<u>CHAIRPERSON</u>	 Dr. Batseba Mofolo-Mbokane
cc: Dr Batseba Mofolo-Mbokane	
<u>DECLARATION OF INVESTIGATOR</u> To be completed in duplicate and ONE COPY returned to the Chairperson of the School/Department ethics committee. I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.	
 Signature	Date <u>26 / 05 / 2023</u>
27 St Andrews Road, Parktown, Johannesburg, 2193 P.O. Bag 3, WITS, 2050 T +27 11 717 3007 www.wits.ac.za/education IKUNJESITHI YASOCHWATWATERSRAND YUNJESITHI YA WITWATERSRAND	