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Improving Pre-Service Teachers' Conceptualisation of Isometric Drawing through AutoCAD-Based Simulation

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Abstract. This qualitative study aimed to address the ongoing issue of poor performance in isometric drawing, which has been a persistent problem. Each year, Grade 12 moderators' reports consistently highlight learners' difficulties with this section. This ongoing challenge suggests that teachers also face difficulties when teaching this concept. Consequently, this study focused on pre-service teachers to address this educational gap. The choice to concentrate on pre-service teachers from a university of technology training as Engineering Graphics and Design (EGD) teachers was strategic. As future educators, these individuals have significant potential to act as agents of change in the teaching and learning of isometric drawing. This potential for educational transformation compelled the need to explore the effect of technology-enhanced learning in improving the conceptualisation of isometric drawing. To address the research objectives, forty first-year pre-service teachers enrolled in EGD were purposively selected to participate in this study. The theoretical foundation combined the Zone of Proximal Development and technology framework with Self-Directed Learning theory to underpin this qualitative enquiry. Data was gathered through photovoice and reflective diaries to evaluate the impact of AutoCAD in enhancing the conceptualisation of isometric drawing. The collected data was examined through narrative analysis to document and interpret the effects of the AutoCAD intervention. Findings from this analysis suggest that technology-enhanced learning, specifically AutoCAD-based pedagogy, significantly enhances the conceptualisation of isometric drawing and improves fundamental spatial visualisation skills. The implications of these findings indicate that EGD teachers should adopt technology-based learning approaches in their classrooms. Therefore, this study recommends that all EGD teachers become proficient in operating AutoCAD to integrate this sophisticated drawing software into their teaching methodologies effectively.

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1. Introduction

Spatial visualisation skills remain one of the fundamental skills not only in technology education but also in sectors such as arts, engineering and mathematics education. This critical cognitive ability involves manipulating and rotating objects mentally and converting 2-dimensional orthographic views to 3-dimensional figures. This viewpoint is supported by a study of engineering graphics students by Zorn et al. (2021), which established that the best predictor of success in technical drawing tasks was spatial visualising skill. Spatial visualising skills accounted for 40% of the variation in student performance.

Building on this evidence, Ha and Fang (2018) demonstrated through regression analysis that spatial visualisation skills were more predictive of isometric drawing performance than prior academic achievement or general intelligence measures. This research emphasises the centrality of spatial visualisation skills in engineering education. Despite its recognised importance, a lack of this fundamental skill remains prevalent among learners and students, contributing to poor performance in isometric drawing tasks. The same concerns are also echoed by other scholars such as (Sorby, 2012; Branoff and Dobelis, 2012).

The implications of these findings extend naturally to instructional approaches and pedagogical interventions. These pedagogical interventions include integrating technology tools such as YouTube, modelling and AutoCAD. In this study, the intervention refers to AutoCAD simulation which has been lauded as the game changer in improving students' spatial abilities. Van Merriënboer and Kirschner (2017) demonstrated that explicit instruction in visualisation strategies improved technical drawing performance by 28% over control groups.

Similarly, Delialioğlu and Aslan (2016) found that augmented reality tools designed to scaffold spatial visualisation led to significant improvements in isometric drawing abilities among pre-engineering students. These studies point to a promising solution: explicit instruction in visualisation strategies through technology-enhanced learning approaches such as AutoCAD and simulations. Recent research consistently supports the efficacy of these technology-based interventions in improving spatial ability. For instance, Mlambo and Mkhwanazi (2024) maintain that technology-infused pedagogy aids in improving spatial ability among students.

Complementing this perspective, Rikza et al. (2024) argue that technology forms an integral part of spatial ability training and should be systematically incorporated to improve students' spatial competencies. The importance of technology integration is further emphasised by Morudu (2025), who asserts that automative teachers need robust technological knowledge to successfully infuse technology within their pedagogies, thereby maximising knowledge construction. This same principle can be applied to Engineering Graphics and Design (EGD) teachers to ensure optimal knowledge construction in teaching

isometric drawing. Given the convergence of evidence regarding both the importance of spatial visualisation skills and the potential of technology-enhanced learning, this study sought to explore the impact of AutoCAD on the conceptualisation of isometric drawing. To address this objective, the study was guided by the following research question: What is the impact of AutoCAD-based instruction on pre-service teachers' conceptualisation of isometric drawing?

2. Literature Review

2.1 Modern technologies in Engineering Graphics and Design classrooms

Engineering Graphics and Design is a subject mainly based on abstract concepts rather than concrete concepts, whereby students can engage with the physical aspects of the subject. Unlike in other trade subjects like Civil Technology, where students can see the actual brick or copper pipe, which aids in understanding the taught concept better, the abstract nature of EGD causes some students to struggle with EGD topics like isometric drawing, assembly drawing and perspective drawing, which are commonly known as pictorial drawings; they require a student to have the ability to form a picture in the mind (Khoza, 2013).

Over the years, technology has taken the world by storm and introduced us to technologies that can be used to aid in teaching and learning. Many scholars have recommended these technologies. These technologies can aid in the improvement of spatial visualisation skills, which according to some authors (Khoza, 2013, 2017; Mlambo, 2023; Mlambo et al., 2023; Mlambo & Mkhwanazi, 2024; Singh-Pillay & Sotsaka, 2020; Singh-Pillay & Sotsaka, 2016; Sotsaka & Singh-Pillay, 2020; Sotsaka, 2019) is regarded as the cornerstone of EGD.

Many scholars believe that technology in teaching and learning EGD is crucial, such as Mlambo (2023), who posits that using technology in EGD lessons assists in transforming abstract concepts into concrete concepts. The same assertion is echoed by Mlambo et al. (2023) that some crucial skills in EGD can be best taught using technologies such as AutoCAD and simulations. This shows the role modern technologies play in teaching and learning EGD to improve results. The literature above has shown that most students are performing poorly in isometric drawing because of poor spatial visualisation skills, and this crucial skill in EGD can be manipulated by using modern technologies in EGD lessons.

As a result, some scholars (Mlambo, 2023; Mlambo et al., 2023; Mlambo & Mkhwanazi, 2024) advance that technology such as AutoCAD can translate abstract concepts into concrete concepts. The above assertion shows the impact modern technologies play in the teaching and learning of EGD; hence, in this study, the role of AutoCAD and simulation in EGD are discussed below, as these two technologies align with the objectives of this study.

2.2 Roles of AutoCAD in Engineering Graphics and Design

The infusion of modern technologies into teaching and learning has been deemed imperative, as it can assist students in easily manipulating abstract concepts into concrete concepts; modern technologies can develop students'

spatial visualisation skills. (Mlambo et al., 2023). Bornman (2016) postulates that modern technologies involve technological tools, such as computers and tablets, that allow individuals to access, create and modify information. As per the definitions given to modern technologies above, some technologies that can be used in teaching and learning of EGD are interactive whiteboard (IWB), an overhead projector and AutoCAD. AutoCAD is a 2D and 3D computer-aided design software application developed by Autodesk. This software assists in aspects of EGD, such as being efficient, getting drawings done quickly, and easily converting 2D diagrams into 3D. The above is further attested to by Khabia and Khabia (2012) that teaching isometric drawing using a conventional way has always been a daunting task, as students with fewer visualisation abilities find it challenging to understand the translation from 2D to 3D, but with the use of AutoCAD, this has dramatically improved students' understanding.

The significance of using AutoCAD in EGD lessons to improve students' visualisation ability has been applauded by many scholars. For example, results in an experimental study between two groups showed a significant difference in favour of a group taught with AutoCAD (Bayaga & Kok, 2019). Similarly, Eteli and Eniekenemi (2016) said that students who were taught ID with AutoCAD performed better than their counterparts taught with the conventional lecture method. Eteli and Eniekenemi (2016) further assert that students who were taught with AutoCAD had a high level of interest; consequently, they recommended that teachers be trained in using AutoCAD in EGD.

The above recommendation emanates from the fact that AutoCAD has been observed to improve students' spatial visualisation. On the contrary, findings in a study conducted by Yue and Chen (2001) indicate that there is no evidence that AutoCAD improves spatial visualisation ability as both groups that were under study recorded a score mean of 76% (one group was the experimental group, and the other being the control group). This means that AutoCAD has no significant impact on improving spatial ability.

However, it can be argued that the study was conducted in 2001, and after that, there have been many improvements on AutoCAD, as an updated version is produced yearly. In light of these contrasting ideas, this study sought to uncover the effect of AutoCAD on improving spatial visualisation by exposing EGD PST to AutoCAD. Studies by some scholars (Etel & Eniekenemi, 2016; Khabia & Khabia, 2012; Kösa & Karakuş, 2018; Pando Cerra et al., 2014; Reffold, 1998; Yue & Chen, 2001) advocate for the usage of AutoCAD in teaching and learning of EGD to enhance spatial visualisation skills in students.

2.3 Features of AutoCAD for Engineering Graphics and Design

As mentioned above, AutoCAD is a widely used design software that offers numerous features for creating 2D and 3D designs. These twelve key features are very useful in improving spatial skills; hence, they are used in various fields such as engineering, architecture, education, manufacturing, and construction. According to Autodesk official website, the following are some key features of AutoCAD:

1. **2D Drawing and Drafting:** AutoCAD allows users to create precise 2D drawings, including lines, arcs, circles, and other geometric shapes. It is widely used for technical drawings and blueprints.
2. **3D Modelling and Visualisation:** The software offers powerful 3D modelling tools, allowing users to create, view, and edit 3D models. This includes solid, surface, and mesh modelling.
3. **DWG File Format Support:** AutoCAD uses the DWG file format, which is a widely accepted standard for storing design data, ensuring compatibility with other CAD applications.
4. **Layer Management:** AutoCAD allows users to organise designs into layers, which helps manage different parts of a drawing independently and simplifies the design process.
5. **Blocks and Reusability:** Users can create blocks or reusable objects (e.g., symbols or components), which can be inserted into different drawings, improving efficiency.
6. **Annotations and Dimensions:** It provides tools to add text, dimensions, and annotations to drawings for clear communication and detailing.
7. **Parametric Constraints:** This feature helps users maintain relationships between objects, such as parallel lines or concentric circles, by adding constraints to control the behaviour of design elements.
8. **Support for Customisation:** AutoCAD allows users to create custom workflows using APIs, scripts, and custom user interfaces, improving automation and productivity.
9. **Cloud Collaboration:** Users can access and share drawings through the cloud, enabling collaboration across different teams and devices in real time.
10. **Rendering and Visualisation:** For 3D models, AutoCAD provides rendering tools to visualise designs with realistic lighting, shading, and textures.
11. **Print/Plot Features:** Users can prepare designs for printing or plotting with customisable settings, ensuring high-quality outputs.
12. **Integration with Other Software:** AutoCAD integrates with other Autodesk software as well as third-party applications, allowing seamless data transfer and collaboration.

The above key features are found in all AutoCAD versions that are produced yearly. Currently, the 2025 version is available for download. As can be seen above, one of the key features of AutoCAD is to assist in ensuring a smooth translation from 2D to 3D, which is what isometric drawing is all about. Therefore, AutoCAD is an integral software to use in teaching and learning of isometric drawing to enhance conceptualisation. AutoCAD further enhances visualisation ability; hence, this study investigated the effects of AutoCAD on the conceptualisation of isometric drawing.

2.4 Simulation-based learning in practical-based subjects

Engineering Graphics and Design is a practical subject, including Physical Sciences, Life Sciences, and Mathematics, and all these subjects have proven to be difficult for students when taught using a conventional method of teaching. In support, an experimental Mathematics study done in Bangladesh by Aziz and Hossain (2010) revealed that students taught using a conventional method were

significantly outperformed by those taught using a non-conventional method. The same concern is echoed by Abah (2020, p. 2), who “affirms that students taught instructional content conventionally are always underperforming compared to those taught the same content via a different methodology”. This signals the impact of using non-conventional teaching methods to teach practical subjects. As a result, simulation-based teaching has been seen as a better method to teach practical subjects than the conventional teaching approach.

Conventional teaching methods, such as books, pencil drawings and physical models, cannot improve students' spatial visualisation skills (Bayaga & Kok, 2019). This underscores the importance of moving away from the conventional approach, which many scholars see as no longer bearing fruit. Campos et al. (2020) add that simulation-based teaching involves using simulation software and tools to enhance teaching and learning. This software can represent abstract concepts in real-life situations, making it easier to understand subjects like EGD, which are abstract. This teaching approach has gained prominence lately as the educational sectors have taken a more technologically inclined approach after Covid-19 took the world by storm.

In the context of EGD, where most of the taught content is abstract, conventional teaching has been preferred less because it does not assist students in improving spatial visualisation skills, which can be best done by adopting a simulation-based teaching approach. Simulation teaching is the best way for students to learn practical subjects, as they can practise until they achieve skill competency (Aebersold, 2018).

Engineering Graphics and Design is a practical subject, meaning that learning through simulation-based teaching will assist students immensely, as stated above. In support of the above notion, a study conducted by Koh et al. (2010) to explore the impact of simulation-based learning on Engineering students revealed that students exposed to simulation-based learning had a high mean score compared to their peers who were taught in a conventional way. Engineering courses are known to be practical-oriented, just like EGD, which means that simulation-based learning does play a huge role in practical-based subjects.

Froyd et al. (2012) further point out that simulation-based learning has become an integral part of practical-based courses because they are less expensive than building workshops where students will practise perfecting these crucial skills. Unlike fixed workshops on school premises, students can benefit from using simulations, as they can access them in the comfort of their homes and continue manipulating these simulations to develop and perfect their skills. The nature of EGD demands learners to seek knowledge by engaging with the problem, which can be achieved through simulation-based teaching.

3. Theoretical Framework

This study adopted two complementary theories to serve as the frameworks that underpinned this study. These frameworks are (1) Zone of Proximal

Development (ZPD) and Technology for scaffolding, and (2) self-directed learning theory. By combining Self Directed Learning (SDL) with the ZPD framework, we created a comprehensive approach that balances guided instruction with independent exploration. This combination is particularly suited to the unique challenges of teaching and learning isometric drawing in EGD.

3.1 Zone of Proximal Development and Technology

The relevance of ZPD in EGD education has been demonstrated in studies by Sotsaka (2015, 2019), which examined the teachers' understanding of assembly drawing and how pre-service teachers read and interpret assembly drawings. These studies showed that the ZPD, coupled with scaffolding techniques, helped teachers and learners progress in their ability to read, interpret, and understand assembly drawings.

Based on the above, this study deemed adopting ZPD necessary to respond to the main aim of this study which is to improve pre-service teachers understanding of isometric drawing through AutoCAD-based simulation. While the original notion of ZPD was limited to humans as MKO, this study expands the definition of MKO to technological tools. As a result, AutoCAD was adopted as the MKO to aid pre-service teachers improve their conceptualisation of isometric drawing. The rationale behind this is that technological tools can provide immediate feedback, allow for experimentation, and offer visual representations that enhance spatial understanding.

In this study, pre-service teachers were subjected to AutoCAD intervention with the aim of improving their conceptualisation of isometric drawing and subsequently improves their spatial visualisation skill which is regarded as the cornerstone of EGD. Figure 1 below, shows that the MKO is responsible to aid students in navigating through complex problems that are beyond their understanding. From the it can also be deduced that the role of the MKO is played by technology which in this case is the AutoCAD software.

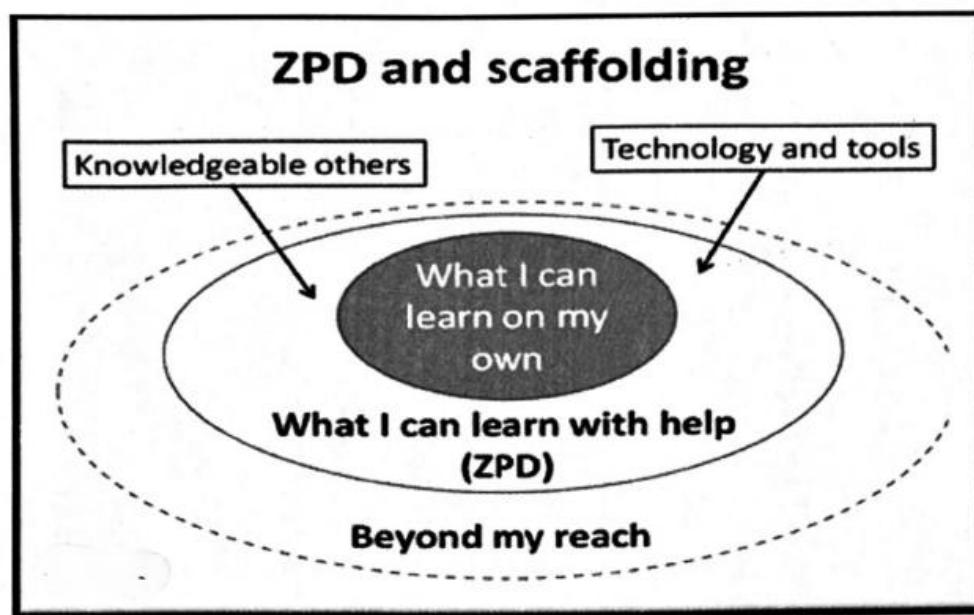


Figure 1: ZPD with Technology for scaffolding

Figure 1 above shows the framework that framed this study which is the ZPD with technology for scaffolding that draws from the works of Vygotsky. Embracing a broader perspective of the ZPD and MKO in EGD education carries several implications:

Personalized Learning: Technology can customize the educational journey to align with each student's Zone of Proximal Development (ZPD), offering challenges that are appropriately balanced between too easy and too difficult.

Improved Visualization: Tools such as AutoCAD provide dynamic 3D models that help enhance spatial reasoning abilities.

Ongoing Feedback: Technological MKOs offer immediate and impartial feedback, enabling students to quickly refine and enhance their work.

Integrating Theory with Practice: Simulation tools enable students to apply theoretical concepts in real-world scenarios, thereby improving their comprehension and retention. This supports the study's decision to implement an expanded Zone of Proximal Development (ZPD)

3.2 Self-Directed Learning Theory

Complementing the ZPD framework, we also adopted Self-Directed Learning (SDL) theory. SDL aligns well with the practical nature of EGD, emphasising student autonomy and self-reliance in the learning process (Breed, 2016).

Looking at the nature of EGD, this approach is tailor-made for EGD as students are struggling with spatial visualisation, and to develop this skill, they need to work themselves, encounter problems and develop strategies/skills to solve problems in EGD. Literature has shown that spatial skills can be developed

through adopting relevant teaching approaches (Delialioğlu & Aslan, 2016; Francis et al., 2022; Gecu-Parmaksiz & Delialioğlu, 2020). It has been suggested that one of the reasons students struggle with spatial skills is that teachers are using methods that do not assist students in developing their spatial abilities.

According to Van Honga and Trib (2021), self-directed learning can enhance the teaching and learning environment and support student's development as autonomous learners. This framework was adopted because the nature of this study wanted pre-service teachers to engage with AutoCAD for the purpose of improving their visualisation ability through trial-and-error technique of which is what SDL advocates for. In this exercise, the lecturer occupied the role of a facilitator aiding students where they are struggling.

In addition, self-directed learning is particularly relevant in this study because:

- It allows students to engage independently with practical tasks, improving their autonomy and self-reliance.
- It aligns with the abstract nature of EGD, enabling students to develop crucial problem-solving skills.
- It supports the development of spatial visualisation skills through hands-on engagement and personal exploration.

By combining SDL with the ZPD framework, we created a comprehensive approach that balances guided instruction with independent exploration. This combination is particularly suited to the unique challenges of teaching and learning isometric drawing in EGD. During the intervention, pre-service teachers were initially shown how to operate AutoCAD. They were then given tasks to work on independently, aiming to enhance their self-reliance and autonomy. This exercise provided an opportunity for them to assist each other while the lecturer acted as a facilitator (MKO) to make learning AutoCAD easy and smooth.

4. Methodology

4.1 Research approach

This study adopted a qualitative approach to gather in-depth insight from the pre-service teachers about the impact of AutoCAD exposure on the conceptualisation of isometric drawing and the improvement of spatial visualisation skills. This aligns with the advantages of employing a qualitative approach echoed by Bhandari (2023) and Bhat (2020). Qualitative research is significant in educational research as it addresses the "how" and "why" research questions and enables a deeper understanding of experiences and phenomena under investigation. Qualitative research allows one to ask questions that cannot be easily put into numbers to understand human experience. Hence, it was deemed relevant to be employed in this study to exploit its advantages.

4.2 Participants and sampling

This study was conducted at MP University where the lead author is employed; therefore, it was deemed fit to adopt convenience sampling, which advocates for easy access to the study site. Drawing from the above, convenience sampling was used because participants can be accessed quickly and are readily available. Convenience sampling was also used because it overcomes many limitations, as

it is very cheap and easy to use compared to other techniques (Taherdoost, 2016). In addition to convenience sampling, this study adopted the purposive sampling technique to sample forty first-year EGD pre-service teachers to participate in AutoCAD-based intervention to measure the impact it has on improving the conceptualisation of isometric drawing. This sampling technique was employed because it is the technique used by researchers to deliberately select individuals with certain qualities to gather information that cannot be obtained from other choices (Taherdoost, 2016).

Similarly, Mulisa (2022) states that, in purposive sampling, the researcher chooses participants based on his/her discretion. In this study, the researcher purposively selected first-year EGD pre-service teachers as participants based on specific criteria: (1) they were currently enrolled in the Engineering Graphics and Design module, (2) isometric drawing forms a core component of their first-year curriculum, and (3) they had recently been introduced to AutoCAD as part of their training and all participants never had prior exposure to AutoCAD before this intervention. These characteristics ensured that the participants had relevant foundational knowledge and recent exposure to the concepts under investigation, making them well-positioned to provide rich and meaningful insights aligned with the study's objectives.

Although both sampling techniques are cost-effective and easy to implement, a key limitation is that their findings cannot be generalised to larger populations. For instance, this study was only conducted on forty pre-service teachers from one university of technology in South Africa. These limitations were overcome through thick rich engagement with the participants to gather depth insight. The participants were selected on the basis that they were enrolled for EGD and the curriculum included isometric drawing which is a chapter that done in the first year. As a result, this study ended up including forty first year pre-service teachers . These participants were deemed relevant to provide responses to the phenomena under investigation.

4.3 Data collection and analysis

Data for this study was gathered through two main methods. The first method, photovoice, involved pre-service teachers taken photographs during their exposure to AutoCAD as a source of data. This qualitative approach captures participants' experiences in images that are later analysed and narrated to transform these experiences into actionable knowledge (Asaba et al., 2014; Milne & Muir, 2019; Sutton-Brown, 2014). The second phase utilized reflective diaries where the pre-service teachers reflected on how AutoCAD-based pedagogy affected their understanding of isometric drawing.

According to Gamira (2019), reflective diaries offer an in-depth insight into one's learning journey by encouraging introspection and critical reflection on encountered learning experiences. These methods were incorporated into the various data collection stages of the larger PhD study. Their purpose was to capture real-time reflections from pre-service teachers, offering an alternative to

conducting interviews post-intervention. The photographs taken served as these immediate reflections.

As indicated above, this tool provided valuable insights into the pre-service teachers' engagement with AutoCAD through critical self-reflection. These multiple streams of collecting data ensured validity and reliability of data through triangulation, which is one of the ways used in research to ensure that results emerge reliably by gathering data from multiple sources (Natow, 2020).

Through maintaining triangulation, data that emerged followed a narrative analysis of what transpired through the AutoCAD intervention. The intervention was carried out for 30 days where students were repeatedly given isometric drawing tasks to draw throughout the intervention. On the lecturer for the first few days demonstrated how AutoCAD can be used and later on assumed the role of the facilitator guiding students while engaging on self-directed environment. Students were given isometric drawing tasks to put together using AutoCAD which they did repeatedly for 30 days.

This study used qualitative approach that had the following advantages:

- Exploring the experiences and perceptions of pre-service teachers
- Providing a way to validate findings through triangulation of data from different sources.
- Uncovering unexpected results that might be missed by a single-method approach.
- Allowing for a more nuanced understanding of the complex process of developing spatial visualisation skills in the context of Engineering Graphics and Design education.

4.4 Ethical considerations

This study collected sensitive and private information from the participants during the collection and presentation of data; therefore, participants' anonymity and confidentiality were ensured using pseudonyms. After data was collected, participants were subjected to a member-checking process to validate the collected data. The study and its procedure were approved by the Research Ethics Committee at the University of KwaZulu Natal (HSSREC/00007769/2024). The leading researcher author in this study occupied a unique insider-outsider position. As a lecturer in the department of education at MP University of Technology, the researcher has insider knowledge of the institutional context and the educational program.

However, by choosing to study students taught by another lecturer, the researcher also maintains a degree of outsider status in relation to the specific participants. Additionally, informing students that the pre and post-test results are not for promotional purposes and emphasizing their right not to participate aligns with ethical research practices. This approach adheres to the principle of voluntary participation. To further address ethical considerations and power dynamics, the following considerations were ensured:

- Obtaining informed consent from all participants, clearly explaining the study's purpose, procedures, and how data will be used and protected.

- Ensuring anonymity and confidentiality in data collection, analysis, and reporting.
- Providing opportunities for participants to review and comment on their data or the study's findings (member checking).

With the above considerations in place, I tried to mitigate research biasness, and power dynamics

5. Results and Discussion

5.1 Presentation of data from Photovoice and reflective diaries

This paper was based on a PhD study that gathered data from various sources, including pre- and post-tests, focus group interviews, photovoice activities, and reflective diaries. The findings presented here specifically relate to the information collected after an AutoCAD intervention was implemented. Initially, the pre-test results indicated that students faced challenges with freehand sketching of isometric drawings, highlighting the necessity for this intervention. In its second phase, data from focus group interviews revealed through discussions with pre-service teachers that inadequate spatial skills contribute significantly to poor conceptualization of isometric drawing. The third phase involved collecting insights from photovoice exercises and reflective diaries; these findings are discussed below.

Nozomi Kugisati's Photovoice



Figure 2: Nozomi Kugisati's continued engagement with AutoCAD

"The above picture shows the first task we were doing in the final stages of construction. I must say that, at the end of it all, the engagement with AutoCAD was a nice experience that assisted in the better conceptualisation of Isometric Drawing. The body gesture sums up the

entire experience. Challenges were there, but despite the difficulties, the exercise provided a broader understanding of how to visualise objects, helping us piece together different sides to create a 3D model. My skills have improved through this practice, and it would be more beneficial to introduce this approach earlier in the course to maximise learning outcomes”.

Nozomi Kugisati’s Reflective diary

Below Nozomi alluded to difficulties using AutoCAD and that it consumes a lot of time:

“Using AutoCAD is hard, and it takes too much time to complete the given task compared to the traditional paper and drawing board . However, it gives a better visual perspective in terms of the shape in the 3D form and can be rotated in all directions, which makes it even more worth the time invested. Overall, the experience was nicely packed with challenges but does improve the way I see and conceptualise isometric drawing”.

Chris Gumede’s Photovoice



Figure 3: Chris Gumede’s engagement with AutoCAD

“The figure above shows me (white t-shirt and the hat) engaging with AutoCAD, which was my first time using AutoCAD for any purpose. Since it was my first time, I encountered a lot of challenges, such as not understanding the complex commands, and taking too much time to complete a simple Isometric drawing, which, at some point, I wanted to give up. But my persistence eventually produced fruits as it became a great experience building Isometric blocks from scratch, and being able

to rotate them in different views really made me see isometric drawing in a better light than before, which further deepened my understanding of isometric drawing. In conclusion, my overall expression is that AutoCAD is something that needs someone's full attention and that it requires an individual with computer skills, but it does sharpen one's skill in how they conceptualise isometric drawing".

Chris Gumede's Reflective Diary

Building up on Nozomi's experience with exposure to AutoCAD for an enhanced conceptualisation of isometric drawing, Chris Gumede revealed that using AutoCAD requires a lot of time but is very useful in improving the conceptualisation of isometric drawing. Below are his utterances:

"Well, using AutoCAD for the first time was not easy for me because some of the things require an individual with the background of a computer, which was not the case for me. The first few sessions were difficult. However, as I attended more sessions, it started to become clearer and simpler to execute some commands. Drawing an isometric drawing using AutoCAD also needs someone who was taught before how to use or rather draw an isometric drawing using AutoCAD. I can say without a doubt that using AutoCAD requires computer skills for an individual to be able to draw. Still, on the bright side, I was able to understand and improve the way I visualise isometric drawing, and my speed improved immensely. So going forward, I would like to be taught using AutoCAD".

Dimpho Mokoena's Photovoice



Figure 4: Dimpho Mokoena's engagement with AutoCAD

“The above figure shows myself having engagement with AutoCAD, which was a life-changing experience in how I visualise isometric drawing, yes there were challenges at first because this was my first encounter with AutoCAD, so it required me to dig deep to understand its complex commands and tools. During the intense exposure to AutoCAD, I developed technical drawing skills and spatial visualisation capabilities through immersive simulations, and activities. I have also acquired expertise in crafting isometric drawings and effortlessly visualising the drawn 3-dimensional figures. This exposure has indeed enhanced my spatial visualisation skills and how I used to conceptualise isometric drawing. Based on the impact it had on how I conceptualise isometric drawings, I would highly recommend AutoCAD to be used in teaching complex topics such as Isometric Drawing”.

Dimpho Mokoena’s Reflective diary

Unlike the two pre-service teachers above who experienced struggles with AutoCAD, Dimpho Mokoena had nothing but praises for AutoCAD and how it has made her life easier when it comes to isometric drawing, a topic she was struggling to understand. Below are her utterances:

“Using AutoCAD has revolutionised my approach to technical drawing and spatial visualisation. AutoCAD has enabled me to create complex 2D and 3D models with precision to employ dynamic inputs snap and grid tools for accuracy. AutoCAD has significantly improved my ability to visualise and manipulate objects in 3D space, enhancing my spatial reasoning skills. I have mastered drawing and editing tools like line, circle and creating arcs. I have also mastered modified tools: to move, copy, and rotate, among other useful commands. I learnt that you press control and A to delete. You press pull if you want your drawing to be a block”.

5.2 Discussion of the findings

The photovoice and reflective diary entries were fed into NVIVO to generate word/tag clouds. The most frequent feedback comments to pre-service teachers appear in the largest font. In conjunction with the tag clouds, the photovoice and reflective diaries were read repeatedly to note patterns of similarities and divergences in terms of pre-service teachers’ engagement with AutoCAD before these could be generated.



Figure 5: Tag cloud

The above figure shows the themes that emerged from data that were fed onto NVivo. For this study, only three themes were discussed below, as they were deemed crucial in responding to the objective of this study.

Theme 1: Cognitive Load

Students often experience cognitive challenges when learning new technical software in educational settings. The reflection by Nozomi, Chris and Vandross highlights what Sweller et al. (2019) describe as cognitive load challenges when learning new technological tools. The statements "at first it seemed easy to use AutoCAD, but it becomes frustrating when I had to apply all the techniques", "not understanding the complex commands" and "I really struggled with AutoCAD, more especially in the first few sessions when everything was still new" align with research on technology adoption in educational contexts.

According to Chen and Yan (2016), this form of cognitive load is particularly pronounced when learning complex software interfaces while simultaneously attempting to develop spatial visualisation skills. Similarly, Mishra and Koehler (2006) assert that the integration of technological knowledge with content knowledge creates a complex learning environment that initially demands significant cognitive resources and is time-intensive. These initial struggles with AutoCAD reflect what Paas et al. (2003) term extraneous cognitive load-cognitive burden imposed by instructional design factors rather than the inherent complexity of the material itself.

However, despite the initial barriers encountered when using AutoCAD, Safiee et al. (2019) maintain that AutoCAD remains a valuable, if complicated, tool that

requires consistent training to master its complex features. They argue that the initial investment in learning pays significant dividends in spatial visualisation development. This perspective is further supported by Kaljun (2024) research acknowledging AutoCAD's complexity while highlighting the effectiveness of supplementary resources such as YouTube video tutorials in providing comprehensive training for students across skill levels.

Theme 2: Transformation in Spatial Visualisation

Pre-service teachers in Engineering Graphics and Design (EGD) often struggle with spatial visualisation concepts essential to technical drawing. This analysis examines how AutoCAD software impacts students' spatial thinking development, drawing from their photovoice and reflective diary entries. The progression documented in these reflections reveals important insights about technology-enhanced learning in developing crucial spatial reasoning skills.

Despite initial difficulties, the photovoice and reflective diary entries document a clear transformation in students' spatial thinking abilities. This progression mirrors what Chi and Wylie (2014) describe as the transition from passive to constructive engagement with learning tools, where students move from struggling with interface mechanics to actively employing the tool for cognitive development. One student noted that AutoCAD "gives a better visual perspective in terms of the shape in the 3D form" and that being "able to rotate it in different views really made me see isometric drawing in better light." This development demonstrates what Sorby (2009) identifies as dynamic spatial ability—the capacity to mentally manipulate 3D objects from different viewpoints. This process also exemplifies what Vygotsky (1978) terms the "zone of proximal development", where the tool enables learning that would not be possible without technological assistance.

Theme 3: Digital Literacy

Mthethwa's qualification that AutoCAD "may only be effective for learners or students who are familiar with computers" highlights what van Van Deursen and Van Dijk (2019) identified as the "digital divide in skills," where technological competence mediates access to educational benefits. Similarly, student Chris's reflection highlights a critical dimension in technology-enhanced learning: the prerequisite digital literacy required for effective engagement.

The statement that AutoCAD "requires an individual with computer skills" aligns with research by Hodges and Hunger (2011), who identified digital literacy as a significant predictor of success in CAD-based learning environments. The observation that "some of the things require an individual with the background of a computer" further validates what Öman and Hashemi (2015) term the "digital threshold" that must be crossed before meaningful learning with technological tools can occur.

This digital literacy foundation directly influences students' ability to develop technical proficiency and vocabulary. The reflection from student Mokoena reveals significant development of technical vocabulary, with confident discussions of "dynamic inputs snap and grid tools" and "modified tools." This

lexical development aligns with Lave and Wenger (1991) concept of legitimate peripheral participation, where mastery of domain-specific language indicates movement from peripheral to central participation in a community of practice. Crismond and Adams (2012) note that the acquisition of technical vocabulary frequently correlates with conceptual understanding in design education.

Moreover, Mokoena's statement about having "mastered drawing and editing tools" indicates high technological self-efficacy, which Bandura (1977) identified as a powerful determinant of persistence with challenging tasks. The progression from initial challenge ("as was the case for me after few attempts") to competence ("but later I managed to execute most of the commands") demonstrates what Zull (2023) identifies as the experiential learning cycle, where initial failure and persistence lead to competence development. These student experiences reinforce what Azodo (2017) argues: technical drawing education must embrace digital literacy as a foundational component rather than assuming students possess these skills.

6. Conclusion and recommendations

The findings from the photovoice and reflective diaries revealed that AutoCAD is a very sophisticated drawing software with complex commands and tools that require a lot of time to be invested when using it. This underscores the need for intense training on how to use this software. Secondly, the findings established that pre-service teachers encountered challenges in the first few sessions of the exposure to AutoCAD, but with persistence and guidance from the facilitator, they pulled through. The findings revealed that through scaffolding students the areas of concern yielded positive results.

The integration of technology (AutoCAD simulation) to expand the role of MKO was evident which support the initial idea present in the framework above that MKO can be more than a human. During the intervention (AutoCAD) students were seen engaging on their own which speaks directly to the notion of SDL that guided this enquiry. Furthermore, the lecturer merely occupied the role of being a facilitator. This supports the idea of employing ZPD and SDL as complimentary frameworks and the findings indicated that these two frameworks best support one another.

Furthermore, the above analysis uncovered that pre-service teachers find the whole experience of using AutoCAD to draw isometric drawings worthwhile, which resulted in an enhanced conceptualisation of isometric drawings. Additionally, AutoCAD improved the way they visualise and translate the given views (2-dimensional views) into a 3-dimensional figure effortlessly because of commands such as rotate, which allow the drawing to be manipulated and rotated in different views.

This, therefore, signals the significant impact technology has not only in the conceptualisation of isometric drawing but also in the teaching and learning of EGD in general. Viewing AutoCAD implementation through a Vygotskian lens reveals why the software, despite its initial challenges, ultimately enhances

spatial visualisation capabilities. As a complex cultural tool, AutoCAD creates a distinctive ZPD where students, with appropriate scaffolding, can develop spatial reasoning capabilities beyond what traditional methods alone might achieve.

The documented improvements in spatial visualisation abilities represent successful progression through the ZPD with effective scaffolding, resulting in the internalisation of external operations as enhanced cognitive capabilities. This theoretical framing explains both the challenges and successes reported by students while providing a robust foundation for designing optimal implementation strategies. As a result, this study recommends scaffolding intervention to be embedded in pedagogical practices such as technology-enhanced learning and practice-based approaches, which tie in well with the concept of self-directed learning.

AutoCAD is a very sophisticated software yet helpful in so many ways; however, the cost of this software prevents under-resourced schools to access this software. Therefore, this study recommends that the department of basic education should forge relationships with Autodesk to negotiate best pricing. Furthermore, education should also provide all schools that offer EGD with computer labs where teachers can conduct their AutoCAD lessons.

7. Limitations and future research

The study was conducted within ethical guidelines, and rigour was observed to be robust. However, some limitations existed—for example, the limited intervention period, the use of a single institutional site, and a non-generalizable sample size. These are discussed in detail below.

Pre-service teachers were exposed to a month-long intervention with AutoCAD where they were given a set of instructions to follow but mostly taking the exploration route with the lecturer occupying a facilitators stance. This speaks to the exposure being done in a very short time to be accurately effective.

It is also worth noting that this intervention included forty students all in one group which lacked the control group. This, therefore, defies the essence of explanatory research which argues that there should be two groups exposed to the same treatment. Additionally, the study was conducted on a single institutional site which brings in the concern of a sample being not generalizable.

The above limitations provided grounds for future studies. As a result, future studies should ensure that exposure is done for a longer period of time in the form of longitudinal exploratory studies to accurately measure the effect of the intervention. Secondly, there should also be the control group so that findings can be compared. Lastly, future studies should be conducted on multi-sites to increase the generalizability of the findings.

Data Availability

The data of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study and its procedure were approved by the Research Ethics Committee at the University of KwaZulu Natal (HSSREC/00007769/2024).

Informed Consent

Informed consent was obtained from all individual participants included in the study.

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Conflict of Interest

The authors declare no competing interests.

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