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Research Article

Utilization and Impact of Online Learning in Facilitating Engineering Graphics and Design and How the Integration of Technology Has Improved Students' Design Skills

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Abstract

This research explores the integration of technology-enhanced approaches in the teaching and learning of Engineering Graphics and Design (EGD), with a particular focus on the technical drawing skills learners develop through digital instruction. The study examines how emerging technologies have transformed educational practices by improving learner engagement, visualization, and the acquisition of practical drawing competencies. It further highlights the importance of equipping educators with the knowledge and skills required to effectively integrate technology into classroom instruction. The research is underpinned by the Technological Pedagogical Content Knowledge (TPACK) framework, which provides a foundation for understanding the relationship between technology, pedagogy, and subject content in 21st-century education. In addition, the conceptual framework considers issues of technological inclusivity across both public and private schools, particularly during the COVID-19 lockdown in 2020, when digital learning became essential. The study draws on literature relating to Information and Communication Technology (ICT) affordances, the TPACK framework, the ADDIE instructional design model, and EGD pedagogy to demonstrate the need for South African schools to transition towards digitally enabled learning environments. The findings indicate that limited computer literacy among teachers, inadequate technological competence, and insufficient subject knowledge significantly impede the development of learners' spatial reasoning, graphical communication, and visualization skills in Grade 10 EGD. The study concludes that technology should be embedded within pedagogical practice rather than treated as an optional instructional tool. It recommends that teacher education programs incorporate compulsory technology integration modules throughout all four years of undergraduate study to ensure future educators are prepared to adapt to evolving technological innovations and effectively support digital teaching and learning.

Keywords

EGD, TPACK, PCK, ICT, 4IR, SDS

1. Introduction

The subject of Engineering Graphics and Design (EGD), offered to learners in Grades 10 to 12 within the South African Curriculum and Assessment Policy Statement (CAPS), aims to develop learners' cognitive abilities related to graphical communication, problem-solving, critical thinking, and spatial-visual reasoning through the interpretation and production of engineering drawings [1]. EGD is regarded as one of the foundational subjects for careers in engineering, architecture,

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industrial design, manufacturing, and various technical professions because it equips learners with the ability to communicate ideas using internationally recognised graphical conventions [1, 9]. Beyond preparing learners for tertiary education, EGD develops analytical thinking, precision, creativity, and decision-making skills that are increasingly valued in technologically driven industries [1, 4]. These competencies align closely with the demands of the Fourth Industrial Revolution (4IR), where digital literacy and innovation have become essential workplace skills [4, 6].

Numerous studies have addressed the challenges educators face when teaching EGD and the role of technology in enhancing students' design skills [1, 2]. Educators who lack pedagogical and subject content knowledge often struggle to integrate technology into their lessons, primarily due to limited familiarity with the Technological Pedagogical Content Knowledge (TPACK) framework [2, 3]. Many educators continue to rely heavily on traditional chalk-and-talk teaching approaches despite the availability of digital technologies that can enhance learner engagement and conceptual understanding [2, 4]. This often results in lessons that emphasise memorisation rather than conceptual understanding, making it difficult for learners to visualise complex engineering concepts and apply technical drawing principles effectively [2, 9]. Therefore, it is necessary to explore the significant impact of technology on effective EGD instruction and identify methods to equip students with the design skills needed to interpret graphical texts and apply spatial reasoning [1, 2].

The integration of technology into EGD has become increasingly important because learners are expected to develop competencies that extend beyond manual drawing techniques [4, 6]. Modern engineering industries utilise sophisticated Computer-Aided Design (CAD) software, three-dimensional modelling programmes, virtual simulations, and digital collaboration platforms to design products, buildings, and engineering systems [4, 9]. Consequently, schools have a responsibility to expose learners to these technologies to ensure that they are adequately prepared for higher education and the modern workplace [6, 9]. Failure to integrate technology may create a disconnect between classroom learning and the skills required in professional engineering environments [4, 9].

In the 21st century, traditional teaching methods have evolved with the integration of innovative technologies aimed at enhancing students' learning experiences [4]. Incorporating technology into classrooms fosters inclusivity, addresses diverse learning needs, and creates an environment conducive to learning [4, 6]. Bailey argued that technology should not be viewed solely as an expensive tool; even simple features like PowerPoint presentations, internet access, and online assignments can positively influence classroom dynamics [5]. Technology fosters students' independent learning and enables engagement with subject content in various ways while facilitating collaborative learning experiences [6, 7].

The rapid advancement of educational technologies has transformed the role of teachers from knowledge transmitters to facilitators of learning [4, 6]. Instead of simply presenting information, educators are expected to design interactive learning experiences that encourage collaboration, creativity, communication, and critical thinking [4, 6]. Within EGD classrooms, technologies such as Learning Management Systems (LMS), AutoCAD, Autodesk Inventor, SolidWorks, Google Classroom, Microsoft Teams, simulation software, interactive whiteboards, and digital assessment tools have significantly improved learner engagement and participation [6, 9]. These technologies provide opportunities for learners to visualise complex engineering concepts that would otherwise be difficult to demonstrate using traditional teaching methods [4, 9].

Technology also supports differentiated instruction by allowing learners to progress at their own pace and revisit learning materials whenever necessary [6, 7]. Recorded demonstrations, instructional videos, virtual practical activities, and online discussion forums create flexible learning opportunities that accommodate learners with varying abilities and learning preferences [6, 7]. This flexibility became particularly significant during the COVID-19 pandemic when schools were forced to transition rapidly from face-to-face teaching to remote and blended learning environments [1, 4].

The COVID-19 pandemic exposed both the strengths and weaknesses of education systems worldwide [1, 4]. Schools that had already invested in digital infrastructure were able to transition relatively smoothly to online learning, whereas schools with limited technological resources experienced significant disruptions [1, 4]. In South Africa, inequalities in internet connectivity, access to digital devices, electricity supply, and teacher preparedness highlighted the persistent digital divide between schools [1, 6]. These disparities affected learners' ability to access quality education and demonstrated that technology integration requires more than simply providing hardware; it also requires continuous teacher training, technical support, curriculum adaptation, and institutional commitment [3, 4].

This study examines the pivotal role of Technological Pedagogical Content Knowledge (TPACK) in EGD classrooms, emphasizing its importance in effectively delivering content knowledge using digital tools [7, 8]. The TPACK framework proposes that effective technology integration occurs when teachers possess a balanced understanding of technology, pedagogy, and subject content [6, 8]. Teachers who possess strong TPACK are better positioned to select appropriate digital resources, design meaningful learning activities, and facilitate deeper learner understanding [6, 8]. Conversely, educators with limited technological competence may struggle to use digital tools effectively, even when adequate technological resources are available within their schools [2, 3].

Technological advancements have rapidly transformed the interpretation of graphical texts, shifting from two-dimensional (2D) to three-dimensional (3D) Computer-Aided Design (CAD) drawings [9]. Engineering drawings have evolved

into a standardized language understood across multiple engineering disciplines [9]. Although AutoCAD software initially supported 2D CAD drawings, it later advanced to include 3D modelling capabilities, revolutionising engineering design [9]. Three-dimensional modelling allows learners to manipulate objects from different perspectives, improving their spatial reasoning and helping them visualise complex engineering structures more effectively than traditional paper-based drawings [9]. This has significantly enhanced conceptual understanding while reducing misconceptions associated with orthographic projection, sectional drawing, and isometric representation [9].

Proficiency in technology is therefore essential for educators teaching EGD [1, 2]. Teachers who continuously update their technological skills are better able to create engaging learning environments that encourage inquiry, collaboration, and innovation [4, 6]. Professional development programmes focusing on digital pedagogy, instructional design, and CAD software are therefore essential to ensure that educators remain responsive to technological developments within education and industry [3, 6].

Furthermore, the emergence of the Fourth Industrial Revolution (4IR) has intensified the need for schools to prepare learners with digital competencies that extend beyond subject-specific knowledge [4, 6]. The engineering profession increasingly requires graduates who are capable of working with artificial intelligence, automation, cloud computing, additive manufacturing, digital twins, robotics, and advanced modelling software [4, 9]. Consequently, integrating technology into EGD is no longer optional but has become an educational necessity to ensure learners remain globally competitive [4, 6].

This study therefore investigates the challenges faced by teachers and students in digital classrooms and assesses the impact of technology-integrated lessons on students' academic achievement, technical drawing competencies, spatial visualization skills, and future professional opportunities [1, 2]. The study also contributes to the growing body of literature on technology integration in EGD by examining how digital pedagogies can improve teaching effectiveness while preparing learners for higher education and the rapidly changing world of work [6, 8, 9].

2. Aim of the Study

This study aims to assist newly qualified EGD educators and contribute positively to ongoing discussions about the evolution of Information and Communication Technology (ICT) in classrooms. The findings will be particularly beneficial to EGD educators in their first year of teaching Grades 10 to 12, emphasizing the importance of acquiring versatile ICT skills. These skills are essential for creating an effective and conducive learning environment for both educators and students, ensuring students are equipped with the necessary competencies to thrive in workplaces and enter the job market confidently.

The study further seeks to explore how the integration of technology can enhance the teaching and learning of Engineering Graphics and Design by improving learners' spatial visualisation, graphical communication, problem-solving, and technical drawing skills [1, 2]. It also aims to examine the role of technology in promoting learner-centred teaching practices, encouraging collaboration, creativity, and independent learning while supporting diverse learning needs within EGD classrooms [4, 6]. As educational institutions continue to embrace digital transformation, it is important to understand how technological tools can be effectively integrated into teaching without compromising curriculum objectives or learning outcomes [4].

Furthermore, the study aims to identify the challenges that educators experience when integrating technology into EGD classrooms, including limited technological knowledge, inadequate professional development opportunities, insufficient infrastructure, and unequal access to digital resources [2, 3]. Understanding these barriers will provide valuable insights into how schools, teacher education institutions, and policymakers can better support educators in implementing technology-enhanced teaching practices [3, 6].

The study also intends to contribute to the growing body of literature on technology integration in technical education by providing recommendations that can inform curriculum development, teacher training programmes, and educational policy [6, 8]. Ultimately, the research seeks to demonstrate that effective technology integration can improve teaching quality, increase learner engagement, strengthen academic performance, and better prepare learners for higher education and careers within the rapidly evolving digital economy associated with the Fourth Industrial Revolution (4IR) [4, 6, 9].

3. Method

The study adopts an interpretivist paradigm, positing that truth is contingent on context and socially constructed [10]. This paradigm focuses on understanding individuals lived experiences. In this qualitative inquiry, meaning arises from the interaction between researchers and social phenomena [11]. Interpretivism acknowledges that reality is subjective and shaped by individuals' experiences, beliefs, and interactions within their social environments. This paradigm was considered appropriate because the study sought to gain an in-depth understanding of how EGD educators perceive and experience the integration of technology in their teaching practices rather than measuring these experiences quantitatively [10, 11].

The aim is to explore the integration of technology in EGD classrooms and understand how digital mediums enhance students' design skills. A qualitative research approach was adopted because it allows researchers to explore participants' experiences, perceptions, and opinions in greater depth while providing a richer understanding of educational phenomena [11]. Through this approach, the researcher was able to examine how educators incorporate technology into their lessons,

the challenges they encounter during implementation, and the perceived influence of digital technologies on learners' technical drawing and spatial visualization skills.

While teachers' technological proficiency may vary, continuous training can foster a deeper understanding of subject matter, in contrast to sporadic training sessions [12]. Continuous professional development is particularly important because technological innovations continue to evolve rapidly, requiring educators to update both their technological knowledge and pedagogical approaches. Ongoing training enables teachers to develop confidence in using digital technologies while ensuring that technology supports curriculum delivery rather than functioning as an isolated classroom resource [3, 6, 12].

The study further recognizes that successful technology integration depends on more than access to technological resources. It requires educators to possess appropriate pedagogical strategies, curriculum knowledge, and the ability to select technologies that support meaningful learning experiences [6, 8]. Consequently, understanding educators' lived experiences provides valuable insight into the practical realities of implementing technology within EGD classrooms and contributes to identifying strategies that can strengthen digital teaching practices in South African schools [2, 6].

4. Results and Discussion

The rapid proliferation of technological tools has enhanced teaching and learning processes in EGD [13]. However, challenges remain, including issues related to instructional design, technology integration, development of online learning materials, accessibility, and computer competency [13, 14]. Restructuring integration processes depends on the needs of teachers and curriculum requirements.

The findings indicate that technology has significantly transformed the EGD is taught, enabling educators to present complex engineering concepts using interactive and visual learning resources that improve learner engagement and understanding [4, 9, 13]. Participants reported that technologies such as CAD software, Learning Management Systems (LMS), interactive whiteboards, simulation software, and online learning platforms provide learners with opportunities to visualise engineering drawings more effectively than traditional teaching approaches [6, 9]. These digital tools encourage active participation and support collaborative learning, allowing learners to interact with technical concepts in more meaningful ways [6, 7].

Educational quality requires teachers to possess curriculum knowledge focused on experiential harmony [13]. Technological tools and computer competencies are essential in facilitating EGD, inability to integrate such tools compromises educational quality [13]. Many schools have heavily invested in technology, expecting teachers to seamlessly integrate it into lessons [1, 13].

Despite these investments, the findings suggest that access to technological resources alone does not guarantee successful technology integration. Many educators indicated that limited professional development opportunities and inadequate technological confidence prevented them from using available resources to their full potential [2, 3]. Participants emphasized that continuous training is necessary to improve educators' confidence in selecting appropriate technologies, designing learner-centered activities, and integrating digital resources effectively into EGD lessons [3, 6, 12].

Technologically integrated education systems tend to be learner-centered, inclusive of diverse teaching methodologies [1]. Learning Management Systems prioritize students' interests by valuing input and recognizing their role in knowledge construction [1]. The COVID-19 pandemic highlighted the need for adaptable and emancipatory educational approaches, such as flipped classrooms [1]. However, students with limited computer literacy may struggle to benefit from these approaches [1].

The COVID-19 pandemic accelerated the adoption of online and blended learning across many educational institutions, demonstrating both the potential and limitations of digital education [1, 4]. While technology enabled learning to continue during school closures, many learners experienced difficulties due to unreliable internet connectivity, limited access to digital devices, inadequate technical support, and varying levels of digital literacy [1, 6]. These findings reinforce previous studies suggesting that successful technology integration depends not only on infrastructure but also on equitable access to digital resources, teacher preparedness, and institutional support [3, 4].

Furthermore, participants reported that learner-centered digital pedagogies increased learner motivation and encouraged greater independence during learning activities. Technologies such as recorded demonstrations, instructional videos, online discussion forums, and digital assessments enabled learners to revisit difficult concepts outside the classroom, promoting self-directed learning and improving conceptual understanding [6, 7]. These findings suggest that blended learning approaches have the potential to improve learner achievement by combining traditional teaching methods with technology-enhanced instructional practices [1, 4].

Many EGD students face challenges understanding sectional drawings due to their complexity [2, 15]. Teachers often struggle to break down concepts into digestible components. Mastery of sectional drawings requires reasoning and spatial skills [15].

The findings indicate that digital visualization tools have the potential to reduce these learning challenges by enabling learners to manipulate three-dimensional models and observe sectional views from multiple perspectives [9, 15]. Participants noted that learners demonstrated improved understanding when CAD software and virtual simulations were incorporated into classroom instruction, as these technologies helped bridge the gap between abstract theoretical concepts

and practical application [9]. Interactive modelling also enhanced learners' spatial reasoning abilities, allowing them to visualize internal structures that are often difficult to interpret using static two-dimensional drawings alone [15].

Although technology substantially improved learner engagement and conceptual understanding, participants emphasized that effective technology integration depends largely on educators' technological pedagogical competence. Teachers who possessed stronger TPACK demonstrated greater confidence in integrating digital technologies into their lessons, resulting in more engaging learning experiences and improved learner participation [6, 8]. Conversely, educators with limited technological competence often reverted to traditional teaching methods despite having access to technological resources [2, 3].

Overall, the findings demonstrate that technology has considerable potential to transform EGD education by improving learner engagement, strengthening spatial visualization skills, enhancing technical drawing competencies, and supporting learner-centered pedagogical practices. However, these benefits can only be fully realized through sustained investment in teacher professional development, reliable technological infrastructure, curriculum support, and equitable access to digital resources [3, 4, 6].

5. Conclusion

The study highlights the importance of integrating technological tools into EGD classrooms to enhance teaching and learning. Teachers often treat technological tools in isolation rather than integrating them with content knowledge and appropriate pedagogical practices, limiting their potential to improve learner outcomes [4, 5]. The findings demonstrate that effective technology integration extends beyond the availability of digital resources and requires educators to possess the knowledge and confidence to use technology purposefully within the curriculum [3, 6, 8]. When technology is meaningfully integrated into teaching, it enhances learners' spatial visualisation, graphical communication, technical drawing competencies, and problem-solving abilities, all of which are fundamental skills in Engineering Graphics and Design [1, 9].

The COVID-19 pandemic accelerated the adoption of online learning, presenting both challenges and opportunities for students to engage independently with content knowledge [1]. Although many schools experienced difficulties related to internet connectivity, access to digital devices, and varying levels of digital literacy, the pandemic demonstrated that technology has become an indispensable component of modern education rather than an optional teaching resource [1, 4]. It also highlighted the need for schools to develop resilient and flexible teaching approaches capable of supporting learning during periods of disruption while promoting continuous learner engagement [4, 6].

A blended teaching and learning approach is recognized as one of the most effective methods for supporting the needs of 21st-century learners because it combines the strengths of face-to-face instruction with the flexibility and accessibility of digital learning environments [1, 3]. Blended learning provides learners with opportunities to collaborate, learn independently, revisit instructional content, and receive immediate feedback, thereby promoting deeper conceptual understanding and increased learner autonomy [6, 7]. Within EGD classrooms, technologies such as Computer-Aided Design (CAD) software, Learning Management Systems, simulation software, and interactive digital resources create authentic learning experiences that better prepare learners for tertiary education and the engineering profession [4, 9].

Teachers' lack of confidence in teaching CAD underscores the necessity for innovative teaching approaches and sustained professional development to empower educators and foster creativity in using complex CAD programs effectively [3]. The study therefore recommends that teacher education institutions integrate technology-related modules throughout pre-service teacher training programmes and that schools provide continuous professional development opportunities focusing on digital pedagogy, TPACK, and emerging educational technologies [3, 6, 8]. Such initiatives would strengthen educators' technological competence while improving their ability to integrate digital tools into meaningful learning experiences.

Furthermore, investment in technological infrastructure should be accompanied by ongoing technical support, equitable access to digital resources, and institutional leadership that promotes innovation and collaboration within schools [3, 4]. Addressing these challenges will contribute to reducing inequalities in technology access and ensure that all learners benefit from high-quality technology-enhanced education regardless of their educational context [1, 4].

In conclusion, the integration of technology into EGD has the potential to transform teaching and learning by creating learner-centred classrooms that encourage critical thinking, creativity, collaboration, and innovation. As education continues to evolve within the context of the (4IR), educators, policymakers, and teacher education institutions must work collaboratively to ensure that technology is effectively integrated into EGD curricula. Through sustained investment in teacher development, curriculum innovation, and digital infrastructure, schools can better prepare learners with the knowledge, skills, and technological competencies required to succeed in higher education, professional engineering environments, and an increasingly digital global economy [4, 6, 9].

Abbreviations

EGD	Engineering Graphics and Design
TPACK	Technological Pedagogical Content Knowledge
PCK	Pedagogical Content Knowledge
ICT	Information and Communication Technology
4IR	Fourth Industrial Revolution

Author Contributions

Nonhlanhla Angel Miya is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no co conflicts of interest.

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