

Exploring the Practical Application of Course Drawing Among High School Engineering and Graphics and Design Learner

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Abstract: The aim of this paper is to analyse the practical application of course drawing in Engineering Graphics and Drawing in education. Various data bases and scholarly search engines were used to use relevant literature. In the review of the literature the focus was based the discussion on Engineering Graphics and Drawing (EGD) curriculum. This was followed by the explanation of EGD aims. In addition, the examples of various drawings in EGD were provided. The assessments used in EGD were identified and discussed in line with the purpose and type of assessment as well as how assessments were conducted in this subject. The explanation of the subject knowledge of EGD is presented. Furthermore, the description of the Pedagogical Content Knowledge of EGD is also provided. Finally, the description of the challenges encountered with teaching and learning of EGD are presented. It was found from the literature that the importance of Engineering Graphics and Drawing (EGD) curriculum is to teach specific fundamental knowledge, various drawing techniques and skills. It was also, mentioned that several challenges were encountered with the delivery of the subject relating to learner's academic performance in Assembly Drawing (AD) is usually poor. Literature shows that the reason for a low performance is because most teachers failed to develop visual, spatial skills in the learners, and that teachers apply the traditional method of teaching in course drawing which hinders the learner's active involvement in the drawing.

Keywords: Assembly drawing, Course drawing, Engineering Graphics and Design, Pedagogical Content Knowledge

1. Introduction

Engineering Graphics and Design presents the basic knowledge and drawing skills needed for career opportunities relating to architecture such as: Civil, Mechanical, Aviation, Maritime, Agricultural, Mining, etc. It has been a trend that engineering educators are challenged by the need to keep their curricula relevant and current with the populations they serve (Moody, 2009; Dym et al., 2005). The course drawing was then introduced to be fully conducted in the classroom under the supervision of the teacher (models/projects). These authors (Okolie, 2014; Okorie, 2001) further argue that the high failure rate of school learners in their exit examinations in EGD is associated with traditional teaching methods, which do not sufficiently develop learners' spatial ability. This conceptual paper reports about exploring the practical application of course drawing among high school engineering and graphics and design learner. Therefore, course drawing is the method use in EGD practical application to check the theory taught (DBE, 2011). Course drawing can be offered in two methods, which is randomly selection

of drawing from the pool and directly instructed drawing. In course drawing it is expected of the teachers to adopt the learner-centred approach. As for Sotsaka (2017) in learner centred approach, the teacher needs to be facilitators, their duty is to monitor and supervise the learners to ensure that the theory learnt in class can be applied during the Practical assessment task (PAT). In the 21st century drawing is versatile and useful for conveying information (Makowska, 2019). It is critical that learners apply good drawing techniques with good spatial organization (Priya, 2016). In the following sections, the subject knowledge of EGD will be explained, and furthermore the pedagogical content knowledge (PCK) of EGD will be described. Finally, this chapter will also describe the challenges encountered in the teaching and learning of EGD.

2. Literature Review

In this section existing literature is synthesised and evaluated to gain an insight into the practical application of course drawing among high school engineering and graphics and design. According

to Cohen, Manion, and Morrison (2007), the acquisition of data can be done in two different ways. Firstly, it could be a pre-existing information, waiting to be accessed, such as past years' matric results. Secondly, data can be collected directly and first-hand from the source, such as interviewing and/or observing people or collecting questionnaire responses, are referred to as primary data. For the purposes of this paper, literature is reviewed on the practical application of course drawing in Engineering Graphics and Drawing in education. Firstly, Engineering Graphics and Drawing (EGD) curriculum will be discussed. Secondly, the explanation of EGD aims and examples of various drawings in EGD are provided. Thirdly, assessments used in EGD are identified and discussed concerning the purpose and type of assessment as well as how assessments are conducted in this subject. Furthermore, the subject knowledge of EGD is explained and the Pedagogical Content Knowledge of EGD is described. In addition, Learners' motivation to study EGD is discussed. Finally, this also describe the challenges encountered with teaching and learning of EGD.

2.1 Engineering Graphics and Drawing (EGD) Curriculum

The importance of Engineering Graphics and Drawing (EGD) curriculum is to teach specific fundamental knowledge, various drawing techniques and skills (CAPS, 2011). The EGD consists of several concepts taught yearly for Annual Teaching Plan (ATP) and general drawing principles for all technological drawings. These concepts are as follows: Free-hand drawing, instrument drawing, first and third angle orthographic projections, descriptive and solid geometry, mechanical working drawing, civil working drawing, isometric drawing, perspective drawing, electrical diagrams, interpenetrations and developments, loci of helixes, cams and mechanisms, the design process and Computer-Aided Drawing/Design (CAPS, 2011) These concepts aim to assist the learners to be innovative, think critically, be creative, reason visually, solve problems as well as work value and nurture teamwork and collaborative skills (Makhubele et al., 2019).

2.2 EGD Aims

As stated in CAPS (2011), the specific aims of EGD are to teach learners graphical drawings as the primary means of communication in the technological world. Furthermore, learners need to understand

and apply the specific basic content and concepts within the contexts of Mechanical Technology, Civil Technology and Electrical Technology (CAPS, 2011). This could be accomplished with the use of the various instrument and freehand drawing techniques and skills to solve technological problems through graphical drawings. This implies that learners will be required to apply the design process to achieve these aims (CAPS, 2011). Furthermore, it is also required that learners use advance technological drawing methods with the use of Computer-Aided Drawings/Design (CAD) to be relevant in the 21st century and the era of the Fourth Industrial Revolution (CAPS, 2011). It may be argued that EGD gives expression to the knowledge, skills and values worth learning in schools. In this case, the curriculum ensures that learners acquire and apply knowledge and skills in ways that are meaningful to their own lives (CAPS, 2014). This statement is supported by Elom (2014), who argues that drawing subjects particularly EGD, are the factory to produce the needed technologists, technicians and craftsmen as well as skilled artisans required to turn the nation's economy positively,

For learners to develop the skills, EGD teachers should expose learners to hands-on experience of drafting techniques, drafting standards and conventions (Singh-Pillay & Sotsaka, 2017). These authors further argue that rote learning or memorization does not provide the opportunity to develop these skills. Literature shows the most effective approaches of teaching practical skills relate to enquiry, demonstration, project, and assignment methods (Makhubele et al., 2019). To promote conceptual deeper forms of learning, teachers need to understand how students approach learning (Simelane-Mnisi & Mji, 2017). To enhance learners' skills, abilities as well as competence in EGD, the teacher need to guide learners with positive attitudes and values (Priya, 2016). These authors further emphasize the EGD quality of learning as it is considered critical factor for producing competent professionals. To build a strong nation and to bring out the best way to get along with global competition (Priya, 2016).

2.3 Drawings in EGD

According to Żychowska (2019) drawing serves the purpose of information and becomes a tool for conveying messages. Quillin & Thomas (2015) supports Żychowska's view by further indicating that architectural drawings in the 21st century has become a versatile and complex medium for conveying

information (Quillin & Thomas, 2015). In architecture the process of drawing teaches students about architecture as a profession (Żychowska, 2019). Quillin & Thomas (2015) argue that the drawing of visual representations is critical for learners as well as scientists alike to enable visual model-based reasoning.

In the current era, research shows that technological disruption in the traditional process of design impact on the architect's way of thinking (Kowalczewski et al., 2019) This implies that modern technology allows the combination of freehand drawing, software and other tools (Kowalczewski et al., 2019) In the South African EGD context particularly in high school matriculation examination, literature revealed that learners' academic performance in Assembly Drawing is usually poor (Singh-Pillay, 2017). This author further states that the reason for a low performance is due to the fact that the majority of teachers failed to develop visual, spatial skills in learners. In this study to understand the practical application of course drawing it is important to present the different types of drawings that learners are expected to draw. According to DBE (2011), EGD has various types of drawing on it curriculum which include free-hand, instrument drawing First and third angle orthographic projections, descriptive and solid geometry, mechanical working drawing, civil working drawing, isometric drawing, perspective drawing, electrical diagrams, interpenetrations and developments, loci of helixes, cams and mechanisms, design process as well as Computer-Aided Drawing.

2.4 Assessment in EGD

Assessment is the most powerful instrument for teachers as it influences the way students respond to a subject (Gibbs, 1999). Additionally, Mnisi (2015) describes assessment as a fundamental part of teaching and learning as it makes a judgment about how students' tasks meet appropriate standards. Assessment is the process of identifying, gathering, and interpreting information about the performance of learners using continuous planned various forms (CAPS, 2011). Four steps involved in the assessment process include generating and collecting evidence of achievement; evaluating this evidence; recording the findings and using this information to understand. These steps contribute to the learner's development to enhance the learning and teaching process (CAPS, 2011). The purpose of assessment is to assist students to learning how to identify their

strengths and weaknesses (Simelane-Mnisi & Mji, 2014). Assessment of students' competency should be measured in a way that provides students with an opportunity to demonstrate knowledge and skills acquired. Several studies have been conducted on the assessment and marking of student work in engineering graphics course (Elrod & Stewart, 2005).

2.5 Type of Assessments in EGD

The type of assessments mostly used in EGD as identified in the curriculum should be both informal (Assessment for Learning) and formal (Assessment of Learning) (CAPS, 2011). This section briefly discusses beneath.

2.5.1 Assessment for Learning

Assessment for learning is the assessment designed to inform teaching it is a way to see what the students can do and a way to see what the teachers should do in response, Mnisi (2015), Brown & Glasner (1999) state that assessment for learning focuses on classroom strategies and techniques related to classroom learning. In this regard, assessment for learning is mostly referred to as continuous assessment and formative assessment (Mnisi, 2015). The EGD assessment strategies associated with assessment for learning include observations, discussions, practical demonstrations; student-teacher discussions, and informal classroom interactions (DBE, 2011). In most cases, formative assessment promotes students to obtain answers to difficult questions they encounter, and practice in the environment where they receive constructive feedback to enhance the learning process (Beatty & Gerace, 2009). The purpose of assessment for learning is to constantly gather information on a students' achievement that could be used to improve their learning (DBE, 2011). Assessment for learning assists in monitoring of students' progress.

2.5.2 Assessment of Learning

Assessment of learning is a summative assessment used primarily to compare students and report progress (DBE, 2011). Assessment of learning are all assessment tasks, which make up a formal program of assessment for the year (DBE, 2011). It is the strategy designed to confirm what students know, usually demonstrating whether they have met curriculum outcomes of their individualized programs, or to certify proficiency and make decisions about students' future programs or placements (Mobara, 2018). The assessment strategies used

for assessment of learning include projects, oral presentations, demonstrations, performances, tests, examinations, practical tasks, etcetera. These assessment tasks are used for progression and certification purposes because they are marked and formally recorded (CAPS, 2011). In this case, assessment of learning becomes public and results in statements or symbols about how well students are learning (Mobara, 2018).

These forms part of a year-long formal programs of assessment in each grade and subject (CAPS, 2011). Assessment of learning tasks ensures proper standards as well as maintains quality assurance through moderation (CAPS, 2011). The policy states that moderation for the purpose of quality assurance as well as for ensuring proper standards are maintained in all formal assessment tasks (CAPS, 2011). The formal assessment offers teachers with a systematic technique of evaluating learners' progress in a grade and in a particular subject. Since EGD teaches both the knowledge and application or skill-based subject, the policy emphasizes at least formative or summative assessment tasks be conducted on weekly basis (CAPS, 2011). Thus, the minimum formal assessment requirements for Engineering Graphics and Design in Grade 10 is two tests, 12 course drawings, mid-year examination and one Practical Application (PAT).

2.6 Implementation of EGD Assessments

In EGD, assessments are conducted in two approaches, which is formal and informal (CAPS, 2011). The EGD assessment for learning priorities the purpose of continuously collecting information on a learner's achievement that can be used to improve their skill in their figure tips. Informal assessment is a daily monitoring of learners' progress (CAPS, 2011). This is done through observations, discussions, practical demonstrations; learner-teacher conferences, informal classroom interactions, etc. Informal assessment may be as simple as stopping during the lesson to observe learners or to discuss with learners how learning is progressing (CAPS, 2011).

2.7 Subject Knowledge of Engineering Graphics and Design Subject Challenges

Literature shows that poor performance in EGD is caused by lack of the importance of the drawings equipment (Khoza, 2004). Lack of the drawing equipment such as A3 drawing board with a T-square,

masking tape, drawing pencil: 2H, 3H or 4H, eraser, ruler, 30°/60° drawing set square, 45° drawing set square, drawing compass, divider, small protractor, dust cloth and calculator do contribute to poor performance (Singh-Pillay & Sotsaka, 2017). Furthermore, Khoza (2004) highlighted inadequate motivation concerning drawing, lack of necessary instruments and bad teaching and learning materials (textbooks) as other contributors to poor performance. It was further found that many learners perform poor in the technical subject outside their schooling years because they were not exposed to full effective practice (Mtshali, 2018). In addition, up to now the major challenge in educating prospective professional engineering students is the poor quality of school teaching in these subjects. These challenges lead to poor performance in Grade 12 (Singh-Pillay & Sotsaka, 2017).

Fleisch et al. (2007) argue that most South African EGD learners perform poorly on national examinations in EGD particularly in paper one. This brings a hunch about learners' performance on paper one since Civil Drawing is also examined in paper one. There is a range of complex reasons for this underachievement (Fleisch et al., 2007). One of usual reasons becomes the macro-societal level, where poverty, malnutrition, unemployment, and high HIV/AIDS rates in many communities have a very strong correlation with poor learner achievement (Fleisch et al., 2007). Khoza (2004) states that the society, too, must bear its share of the responsibility for the performance of learners at school. What occurs at school is an image of what is happening in our society (Khoza, 2004).

According to Aganga (1998) most secondary school laboratories fall short of this basic standard and therefore this has a negative impact on learners' performance in civil drawing task lessons. Aganga (1998) also found that schools with relevant instruments, decent furniture and laboratory equipment brings an effective practice of learners on EGD activities. In some instances, EGD teachers are teaching the outdated civil drawing task because they lack ICT tools and resources to implement the new programs (Mtshali, 2018). However, Mtshali (2018) further stresses that the challenging part in teaching the practical skills in technical subject is caused by teachers not having a sound knowledge of the subject, inadequacy of teaching materials, and inadequate skills in the subject possess poor result in the subject.

2.8 Classroom Requirements

Sufficient space for medium-to-large school desks or drawing tables, desks with a minimum top size of 700 mm x 450 mm or A2, or larger drawing tables that will sufficiently accommodate an A3 drawing board and drawing instruments. All the computer hardware and software required for CAD, large blackboard and/or whiteboard, with an eraser and chalk/pens, large set squares, ruler, protractor and compasses for the black/whiteboard. In addition, classroom requirements include overhead projector and large projector screen, large lockable cupboard for all the teacher's files and resource material, sufficient cupboards or storage space for all the learners' EGD files, approved EGD textbooks, with explanatory examples and exercises for each topic, and teachers' guides and sufficient A4 or A3 drawing sheets for all the drawing tasks and an approved EGD textbook with self-explanatory examples and exercises for each topic.

2.9 EGD Learning Requirements

The school should have adequate security in place to protect all the necessary resources and equipment. It should also have enough room for medium-to-large school desks or drawing tables, as well as adequate artificial fluorescent lighting, desks with a minimum top size of 700 mm x 450 mm or A2, and larger drawing tables that can hold an A3 drawing board and drawing instruments. All the computer hardware and software required for CAD must be available at the school. For a successful presentation of the subject, equipment such as a large blackboard and/or whiteboard with an eraser and chalk/pens, large set squares, ruler, protractor, and compasses for the blackboard, overhead projector and large projector screen, huge lockable cupboard for all of the teacher's files and resource material should be in place. There should also be storage space, such as cabinets and shelves, as well as space for all of the learners' EGD files. The certified EGD textbook, which includes explanatory examples and exercises for each topic, as well as teachers' instructions and enough A4 or A3 drawing sheets for all the drawing tasks, is also necessary. Learners need to have an approved EGD textbook with self-explanatory examples and exercises for each topic, workbook/work file may only be used in conjunction with a textbook and not as a substitution for a textbook. The learner is required to bring a large file, A3 drawing board with a T-square, masking tape and drawing pencil: 2H, 3H or 4H.

3. Pedagogical Knowledge Content of Engineering Graphics and Design Engineering

Educational researchers, particularly Ingersoll (2001) noted the lack of attention given to the needs and concerns learners become a hitting stone at the end. Likewise, these seasoned specialists are able to offer unique and valuable contributions to their work situations. The obligation to educate children requires the nation to invest in all teachers. In a laboratory teacher must be in a position of the Association of Supervision and Curriculum Development. Ingersoll (2001) holds the belief that teachers who have been teaching a few years simply go along as always. In short, course drawing tasks which are given to learners at the end of any topic covered in a week to check their level of understanding, course drawing are used to measure the speed and standard of learner's ability individually. Bjurulf & Kirlbrink (2012) stipulate that in Sweden more emphasis of EGD courses is given to undergraduate learners (Grade 10-12) for engineering purposes. Learning should be more conceptual than the current traditional way of teaching (Bjurulf & Kirlbrink, 2012). Based on a review of the distinction between conceptual and procedural knowledge, an analysis of student solutions to tasks designed to be solved with a conceptual approach but 'proceduralized' by the learners sheds some new light on this classical distinction.

According to Lunetta et al. (2007), in a study conducted in Sweden by Ingersoll (2001), for course drawing to be effective in their laboratory learners are compulsory to organize and deploy cognitive ideas in the school's laboratory as part of skills acquire. In support of Lunetta et al. (2007) who state that failure of correct integration may cause the teaching of EGD to lose its value and set standards. This further stipulate that for Swedish learners to fully understand EGD lesson lies with school furniture, meaning all EGD classes are fully furniture with all necessary instruments: Laptops, Tablets, Models, and Charts (Lunetta et al., 2007).

Literature further reveals that learners are able to pass and perform in their course drawing task due to concurrently learning taking place in their school (Millar, 2002). Computation is an important part to EGD lesson as it goes with understanding the scale. Skills in computation have long been one of the main objectives of engineering teaching and learning in school and university (Millar, 2002).

These authors argue that learners who, for example, solve complex drawing correctly sometimes do not know what to do if the task is given in different angle (Haolader et al., 2017). Such behavior indicates a poor conceptual understanding and become a hit stone in a long process understanding.

In a study conducted in Germany, it is common that learners use a handbook as engineers' data reference book in the classroom and also in the examination to ensure that they do well in their given course drawing (Bjurulf & Kirlbrink, 2013). However, in Bangladesh a learner must recall all the information he/she requires to solve a problem in the examination, if not supplied as data sheet together with a question paper (Bjurulf & Kirlbrink, 2013). Furthermore, in Bangladesh questions/examinations are designed in such a way that learners can answer the questions without a reference book because the necessary data sheets are supplied (Bjurulf & Kirlbrink, 2013).

4. Learners' Motivates to Study EGD

Motivation, as Rubenstein, Pohl et al. (2017) point out, is a complicated phenomenon. Motivation, according to behaviorists, is merely the anticipation of a reward (Brown & Glasner, 2000). However, cognitivists consider motivation to be more closely tied to the learner's decisions, as stated by Brown & Glasner (1999), the choices people make about what experiences or goals they will pursue or avoid, and the degree of effort they put forth in doing so. Overall, a greater understanding of students' motivation and attitudes may aid engineering curriculum and teachers in developing EGD teaching programs that generate the attitudes and motivation most conducive to the development of more effective architecture, quantity survey, and other engineering products (Rubenstein, Pohl et al., 2017). The motivation of the learners to study EGD is critical in this study.

Since the 1990s there has been considerable growth in the adoption of technical subject and Engineering Graphics and Design has been part of those adopted subject within higher education (Adrian, 1991). Despite the widespread growth in practice of EGD, concerns continue to be expressed about the extent to which effective use is being made for all the EGD learners (Cuban et al., 2001). The sharing of 'good practice' and 'lessons learned' among EGD learners can help learners to gain interest in

the subject and that also lead in great inspiration to pass (Zychowska, 2019).

5. EGD Teaching and Learning Challenges

DoE (2012) stressed that in South Africa, technical subjects aim to construct and improve the built environment to enhance the quality of life of the individuals and society. In support of this view Maeko and Makgato (2017) state that the aim of practical task is to equip learners with first-hand experience in preparation to trade industries. In addition, technical subjects strive to produce learners that are equipped with both knowledge and skills to solve problems that will improve the built environment and enhance the quality of life of the individual and society (Kennedy, 2011). However, Khoza (2004), state that challenges discovered relates to classroom discipline classroom management can also be the main cause of EGD poor academic performance. Khoza (2004) further stressed that the way teaching takes place has implications for classroom control and that learners' behavior can also have an influence on the teaching style.

South African's learners mostly perform poorly on national examinations in EGD particularly in paper one (Fleisch et al., 2007). There is a range of complex reasons for this underachievement. One of the usual reasons becomes the macro-societal level, where poverty, malnutrition, unemployment and high HIV/AIDS rates in many communities have a very strong correlation with poor learner achievement (Fleisch et al., 2007). In addition, Khoza (2004) states that the society too, must bear its share of the responsibility for the performance of learners at school. What occurs at school is an image of what is happening in our society (Khoza, 2004).

Aganga (1998) also found that schools with relevant instruments and decent furniture laboratory brings an effective practice of learners on EGD activities. In some instances, EGD teachers are teaching the outdated civil drawing task because they lack ICT tools and resources to implement the new programs (Mtshali, 2018). In proceeding with Mtshali (2018), this author highlights the challenging part in teaching the practical skills in technical subject is caused by teachers by not having a sound knowledge of the subject, inadequacy of teaching materials, and inadequate skills in the subject possess poor result in the subject.

6. Results and Discussion

The aim of this conceptual paper was to analyse literature relating to practical application of course drawing in Engineering Graphics and Drawing in education. It further outlined challenges encountered when teachers apply the traditional method of teaching EGD course drawing which hinders the learner's active involvement in the drawing. The outcome of this conceptual paper was limited to the literature scope. Various data bases and scholarly search engines were used to get relevant literature. In the review of the literature the focus was based on the discussion on Engineering Graphics and Drawing (EGD) curriculum. Existing literature, indeed, indicates that teachers are trapped in using the traditional method when teaching and assessing EGD learners which we find it as a step back in current days. The assessments used in EGD were identified and discussed concerning the purpose and type of assessment as well as how assessments were conducted in this subject.

References

- Aganga, R. 1998. An investigation into the use of improvisation of biology teaching in some Ogun State Secondary Schools. *Journal of Integrated Science*, (1):61-68.
- Andrian, R.J. 1991. Particle-imaging techniques for experimental fluid mechanics. *Annual Review of Fluid Mechanics*, 23(1): 261-304.
- Beatty, I.D. & Gerace, W.J. 2009. Technology-enhanced formative assessment: A research-based pedagogy for teaching science with classroom response technology. *Journal of Science Education and Technology*, 18(2):146-162. DOI 10.1007/s10956-008-9140-4.
- Bjurulf, V. & Kirlbrink, V. 2013. Transfer of knowledge in technical vocational education: A narrative study in Swedish upper secondary schools. *International Journal for Technology and Design Education*, 23(3):519-535.
- Brown, S. & Glasner, A. 1999. *Assessment Matters in Higher Education*. Buckingham: Open University Press.
- Cohen, L., Manion, L. & Morrison, K. 2002. *Research Methods in Education*. London: Routledge Falmer, Taylor and Francis Group.
- Cuban, L., Kirkpatrick, H. & Peck, C. 2001. High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal*, 38(4):813-834.
- Department of Basic Education. 2011. Curriculum Assessment Policy Statements (CAPS): Civil Technology. Available at: www.thutong.doe.gov.za/Resourcedownload.aspx
- Department of Basic Education, DBE. 2012. Curriculum Assessment Policy Statements (CAPS). Civil Technology. Available at: www.thutong.doe.gov.za/Resourcedownload.aspx
- Elom, N. 2014. Effective teaching and learning in technical colleges: Challenges of technical drawing in the Department of Technology and Vocational Education, Ebonyi State University, Nigeria: *Journal of Educational Policy and Entrepreneurial Research*, 76-86.
- Elrod, D. & Stewart, M.D. 2005. Assessing student work in engineering graphics and visualization course: *The Engineering Design Graphics Journal*, 69(2):78.
- Fleisch, M.C., Newton, J., Steinmetz, I., Whitehair, J., Hallum, A. & Hatch, K.D. 2007. Learning and teaching advanced laparoscopic procedures: Do alternating trainees impair a laparoscopic surgeon's learning curve? *Journal of Minimally Invasive Gynecology*, 14(3):293-299.
- Gibbs, G. 1999. Using assessment strategically to change the way students learn.
- Haolader, F.A., Cicioglu, D. & Kassim, K. 2017. A model of technical and vocational teacher education at bachelor's degree level and its relevance to the occupational tasks of TVET teachers in the OIC Member States. *TVET@ Asia*, (8):1-19.
- Ingersoll, R. 2001. A different approach to solving the teacher shortage problem. *CPRE Policy Briefs*. Available at: <https://repository.upenn.edu/cprepolicybriefs/21>.
- Kennedy, O.O. 2011. Re-appraising the work skill requirements for building technology education in senior secondary school for optimum performance in Nigeria: *European Journal of Applied Sciences*, 3(2):46-52.
- Khoshoo, V., Thoppil, D., Landry, L., Brown, S. & Ross, G. 2003. Propofol versus midazolam plus meperidine for sedation during ambulatory esophagogastroduodenoscopy. *Journal of Pediatric Gastroenterology and Nutrition*, 37(2):146-149.
- Khoza, S.D. 2004. Academic performance of Engineering Drawing N2 students of Ekurhuleni West College in 2003. Unpublished Masters' Thesis. Tshwane University of Technology: Pretoria.
- Lunetta, V.N., Hofstein, A. & Clough, M.P. 2007. Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. *Handbook of Research on Science Education*, (2):393-441.
- Maeko, M.S.A. & Makgato, M. 2017. The transfer of requisite civil technology hands-on practical skills to student teachers in South African civil technology teacher training universities: *International Journal of Educational Sciences*, 18(1-3):147-157.
- Makhubele, D.M., Simelane-Mnisi, S. & Makgato, M. 2019. Exploring technology teaching and learning approaches used in South African high schools: *World Transactions on Engineering and Technology Education*, 17(3):295-301.
- Millar, R., Tiberghien, A. & Le Maréchal, J.F. 2002. Varieties of lab work: A way of profiling lab work tasks. In *Teaching and Learning in the Science Laboratory*. Dordrecht: Kluwer.
- Mji, A. & Makgato, M. 2006. Factors associated with high school learners' poor performance: A spotlight on mathematics

- and physical science: *South African Journal of Education*, 26(2):253-266.
- Mnisi, S. 2015. Exploring a teaching strategy using clicker mobile technology for active learning in undergraduate mathematics classes. Unpublished Doctoral Thesis. Tshwane University of Technology: Pretoria.
- Mtshali, T.I. 2018. Challenges faced by Civil Technology teachers in preparing and presenting theory and practical lesson in South African schools: A case of five schools in Ekurhuleni Districts. Unpublished Masters Dissertation. Tshwane University of Technology: Pretoria.
- Okolie, U.O. 2014. Analysis of Nigeria's National Electricity Demand Forecast (2013-2030): *International Journal of Scientific & Technology Research*, (3):25-28
- Okorie, J.U. 2001. Vocational industrial education league of researchers in Nigeria. Bauchi: Nigeria.
- Quillin, K. & Thomas, S. 2015. Drawing-to-learn: A framework for using drawings to promote model-based reasoning in biology. *CBE-Life Sciences Education*, 14(1):es2.
- Rubenstein, J.H., Pohl, H., Adams, M.A., Kerr, E., Holleman, R., Vijan, S., ... & Saini, S.D. 2017. Overuse of repeat upper endoscopy in the Veterans Health Administration: A retrospective analysis. *Official Journal of the American College of Gastroenterology | ACG*, 112(11):1678-1685.
- Simelane-Mnisi, S. & Mji, A. 2017. Establishing the reliability and validity of ASSIST questionnaire: A South African sample perspective. *Electronic Journal of Research in Educational Psychology*, 15(1): 201-223. Available at: <https://www.doi.org/10.14204/ejrep.41.16028>.
- Singh-Pillay, A. & Sotsaka, D.S. 2017. Engineering graphics and design teachers' understanding and teaching of assembly drawing. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(5):1213-1228. Available at: <https://doi.org/10.12973/eurasia.2017.00668a>.
- Żychowska, M.J. 2019. Teaching drawing to a new generation of engineers: *World Transactions on Engineering and Technology Education*, 17(1):60-65.