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# Difficulties Experienced by Pre-service Teachers and Lecturers in Engineering Graphics and Design Course at a University in South Africa

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**ABSTRACT** Engineering Graphics and Design is the medium of communication in technical field. EGD is one of the electives taken by students in their degree course in South African Universities. This paper investigated difficulties students and lecturers have in sectional drawing. Purposive sampling was used to select 40 female and male students in 2nd and 3rd year of varying ages. Data was collected through questionnaires, focus group interviews and classroom observations. Questionnaire data was analyzed statistically using figures and percentages whereas classroom observations were analyzed as a report on what was observed in class. Interviews were analyzed thematically. The results found that students have difficulties in understanding sectional drawing and have poor spatial skill. Lecturers lacked adequate pedagogic practices of sectional drawing. The paper recommends that students' spatial skills should be developed before the commencement of the academic year and sectional drawing resources be made available for effective teaching of EGD.

## INTRODUCTION

Engineering Graphics and Design (EGD) teaches internationally acknowledged principles that have both academic and technical applications. The emphasis in EGD is on teaching specific basic knowledge and various drawing techniques and skills so that the EGD learners will be able to interpret and produce drawings within the contexts of Mechanical Technology, Civil Technology and Electrical Technology (Department of Basic Education, (DoBE) 2011). The EGD emphasis is also focused on the correct use of tools and equipment, drafting media, sketching, lettering, alphabet of lines, geometric construction, fundamentals of Computer Aided Draughting (CAD) and multi-view drawings (Widad et al. 2006). EGD is one of the elective courses taken by pre-service teachers in the technology teacher education programmes at a university in South Africa. Pre-service teachers in 2nd and 3rd years of study in a university in South Africa who have enrolled in the Bachelor of Education: Technical Education course find sectional drawing difficult to learn and battle to pass it. They cited various reasons for the difficulties that they experience in sectional drawing. Their lecturers also mentioned difficulties in facilitating sectional drawing. These comments by pre-service teachers and lecturers prompted this study to investigate factors associated with their difficulties in sectional drawing in the EGD course at a University in South Africa because pre-service teachers' poor performance hamper them from progressing to the next level and they eventually fail to complete their degree on time.

According to Brink et al. (2003), a sectional view in drawing subjects is a view where you imagine that part of the object has been removed to reveal hidden detail, while in reality nothing has been removed. They also state that a sectional drawing demands the basic knowledge and skills of (EGD) at a Grade 9 level of the National Curriculum Statement (NCS) curriculum, where graphic communication is studied (Brink et al. 2003). The revelation of the hidden details in a drawing will assist the students/draughtsman/engineers to identify underlying components in a drawing when designing technical projects. This will enable an engineer to assemble or dismantle components in a model for further machining purposes in industries.

Sorby (2009) suggests that those who enroll in the EGD course need to have attended some courses related to spatial visualization skills. Spatial visualization ability has been recognized as a predictor of success in many technology related fields, EGD included (Strong and Smith 2002). Spatial visualization is a fundamental skill for those working and studying in the field of engineering, as well as those individuals in technology professions that work with a diversity of vector graphic tools designing in three-dimensional space and virtual environments (Yue 2006). For this reason, spatial visualization has long been considered an essential component toward careers using and interpreting graphics technologies (Yue 2006). Yet, despite the importance of this skill, large sections of the general populace do not perform well when confronted with spatial-visual relations tasks, especially in Science, Technology, Engineering and Mathematics (STEM) subjects (Wai et al. 2010). Garmendia et al. (2007) contend that visualization is important not only in a professional engineering practice but also in terms of teaching Graphic Expression. If a student is not capable of visualizing, they are going to find it difficult to follow and understand the rest of the content in the course.

Several studies agree that first year students at universities in EGD courses experience difficulties in spatial visualization abilities in drawing sections (Garmendia et al. 2007; Nagy-Kondor 2007; Upadhye et al. 2013). Despite having studied drawing subjects at schools, Garmendia et al. (2007) found that students have not developed their spatial ability sufficiently and they have serious difficulties with mentally manipulating figures in space. The major difficulties of students are to visualize and draw two dimensional (2D) projections and three dimensional (3D) views of objects (Akasah and Alias 2010). Knowledge of students' difficulties in spatial visualization of objects in drawing courses will enable teachers and academics to design teaching strategies which solve these difficulties so that students can perform well in EGD courses (Garmendia et al. 2007). So far there are no studies that have found exact difficulties of students and solutions that can be used in all contexts to address the performance of students in EGD courses. Potter et al. (2006) found that there are relationships between cognitive, social factors and students' performance in Engineering Graphics. It is on the basis of gaps identified from other studies that this study investigated the difficulties experienced by students in the first year of their technology teacher education programme in the EGD course. Although the findings of this study may not be generalized, in similar contexts the results will be valuable.

The EGD course in a University in South Africa, where this study was undertaken, consists of several topics and concepts, one of which was sectional drawing. The study therefore investigated factors that pre-service teachers and lecturers perceived as difficulties in the learning and teaching of the EGD course, particularly the sectional drawing concept.

## Objectives of the Study

The main objective of this paper was to investigate both the lecturers' and pre-service teachers' difficulties in teaching and learning sectional drawing at a University in South Africa.

## Theoretical Framework

This paper was informed by Vygotsky's theory of the Zone of Proximal Development as well as the Pedagogical Content Knowledge (PCK) notion. Vygotsky's theory focuses on the influence of external stimulation on development (Cole et al. 1978). He asserts that higher mental functions are integrally tied to social interaction. The importance of social interactions is also illustrated in what he terms the "zone of proximal development" (ZPD). This is the zone between the level of problem solving an individual can do in isolation and the level of problem solving an individual can do in social situations involving other more knowledgeable individuals (Cole et al. 1978). This type of zone would be found among students studying together in study groups, in which they had the opportunity to work with more knowledgeable students. This theory was employed to ascertain how pre-service teachers learn in the classroom.

The Pedagogical Content Knowledge (PCK) notion was used in this paper to ascertain how knowledge is transferred to others (Shulman 1987). This was done by assessing how learning occurred in the EGD classroom through teaching. PCK assisted the researchers in understanding how illustrations, examples, explanations, and demonstrations were formulated in

an EGD classroom particularly in the facilitation of sectional drawing. Rollnick et al. (2008) say that, combined together, the knowledge domains integrate to form the teachers' PCK that results in classroom manifestations that can be seen. These knowledge domains are: "knowledge of subject matter, knowledge of students, general pedagogical knowledge and knowledge of context" (Rollnick et al. 2008). Manifestations refer to observable teaching practices in the classroom.

**Purpose of the Study and Research Questions**

The pre-service teachers' performance in sectional drawing at a University in South Africa had been poor for years, thus not allowing students to complete the EGD course on time. The study sought to investigate difficulties in the teaching and learning of sectional drawing and devise with a better way to teach and learn sectional drawing. This is reflected in the two research questions:

*RQ 1:* What difficulties are experienced by lecturers and pre-service teachers in teaching and learning sectional drawing in the EGD course?

*RQ 2:* What are the spatial visualization competences of student teachers in learning sectional drawing in the EGD course?

## MATERIAL AND METHODS

The study made use of both the qualitative and quantitative research approaches. The purpose of using mixed methods was to obtain sufficient data that would augment each other in order to fully understand the difficulties in the EGD course and spatial visualization skills of pre-service teachers in the EGD course. Therefore the data collection instruments used included pre-service teachers' questionnaire, classroom observation during the teaching and learning of sectional drawing as well as a semi-structered interview with lecturers and focus group interviews with pre-service teachers. The interview was audiotaped with the permission of participants to allow adequate transcription and coding.

Questionnaires were of a Likert type where pre-service teachers put a tick on a 1- 4 rating scale where 1 was strongly agree (SA) and 4 strongly disagree (SD). The questionnaire contains 8 indicators which measures the variable of difficulties the preservice teachers experience in EGD courses. The questionnaire data was analyzed statistically with the aid of SPSS statistical software. The reliability of the questionnaires in this paper was 0.7 using Cronbach's alpha reliability coefficient (Santos 1999). The data was also collected using Purdue Spatial Visualization Test (PSVT: R) (Guay 1977), which consists of three topics, each with twelve questions. The three topics were (1) Developments (2) Rotations and (3) Isometric views. For the purpose of this study Rotation and Isometric views were administered to students because they are specifically relevant to spatial visualization abilities for sectional drawing.

Classroom observations were video recorded so that the researcher could watch them many times and also consult other expects who have extensive experience in research and EGD to determine its reliability and trustworthiness. The classroom observation schedule was adopted from Staffordshire University's "Guidelines for the Observation of Teaching (Hammersley-Fletcher and Orsmond 2004). A purposive and convenient sampling was used to select forty (40) 2nd and 3rd year EGD pre-service teachers enrolled in the teacher education course to take part in the study. Fifteen pre-service teachers in third year and twenty-five in second year, both male and female aged between seventeen and twenty-seven, took part in the study. There were a total of six female and nine male pre-service teachers in the 3rd year and ten female and fifteen male pre-service teachers in 2nd year doing EGD. Structured Focus group interviews that were structured were conducted with pre-service teachers (5 groups consisting of 8 members each). The interviews were transcribed and themes were developed based on the questions asked, and classroom observations were analyzed descriptively per item.

## RESULTS

**Questionnaire Results on Students' Difficulties in the EGD Course**

For the purpose of answering RQ 1 of this paper, pre-service teachers were requested to respond to item statements measuring difficulties in the EGD course, particularly sectional drawing. Table 1 provides results of the descriptive analysis (frequency, percentage, means and

standard deviations) about items considered to cause difficulties in learning sectional drawing in the EGD course. The mean and standard deviation in each of the frequency responses is a measure of central tendencies on each question/ statement to provide further information on the responses. Standard Deviation provides an indication of how far the individual responses to a question vary or "deviate" from the mean. For example, on item/indicator 6 of 'Relevant previous topics of sectional drawing and the mean response by participants is 2.88, which means that the participants strongly disagreed that they had done relevant previous topics on sectional drawing. The SD on this response is 0.69, which means that there was little deviation from the mean, implying that they had one voice of disgreement on this item.

According to Table 1 the item with the highest score is item 4 (where 93% of the participants answered that they "do not" have EGD instruments), with a mean score of (M of 3.38) and standard deviation (SD of 0.89); 88 percent of the participants answered that they "do not have" EGD background from school with (M= 3.40) and standard deviation (SD = 0.50). Eighty-three percent of the participants agreed that they do have difficulties with sectional drawing with a mean score of 1.95) and a standard deviation of 0.85). The table also shows that most pre-service teachers (77% of the sample) do have a lack of understanding of sectional drawing principles, this is supported by the mean score of 2.40) and a standard deviation of 0.73). On a lack of knowledge on 2D/3D of sectional drawing 60 percent of the participants agreed that they lack knowledge on 2D/3D of sectional drawing, with M= 1.65 and SD = 0.83. Most participants (65% of the sample, with a mean of 1.70 and a SD 0.72 agreed that they are familiar with EGD line-types which form the basics of EGD courses.

### Test Scores on Students' Visualization and Spatial Questions

In response to RQ 2 of the study the pre-service teachers were given a test on spatial visualization in order to assess their EGD knowledge, as shown in Table 2. The test consisted of twenty-four questions on rotation and isometric sections (twelve in each section) taken from the Purdue Spatial Visualisation Test (PSVT) (Guay 1977). The orthogonal rotations of 3D objects are designed to help visualize the rotation of a three dimensional (3D) object (Guay 1977). The isometric views show what 3D objects look like from different views, and they test the spatial visualization skills in engineering graphic courses (Yue 2000). The table shows the summary of test scores in the form of pre-service teachers' frequency scores, means and standard deviations.

On the rotation section which had twelve questions, out of forty pre-service teachers, only one pre-service teacher answered all twelve questions correctly, five pre-service teachers got eleven questions correct, while two of them scored ten out of twelve questions correctly. The mean score was 7 and the standard deviation was 3.32). The average score on the rotations' section was seven or 58 percent, which is not an excellent performance. This is not surprising when looking at the indicators of difficulties reported in Table 1. The standard deviation of 3.32 shows a considerable spread of the scores by participants from the mean, as can be

**Table 1: Pre-service teachers' indications of difficulties in the EGD course (**N=40)

| *Statement/indicators* | *Agree* | | *Disagree* | | **Mean* | *SD* |
|---|---|---|---|---|---|---|
| | *Frequency* | *%* | *Frequency* | *%* | | |
| 1.I have difficulties in understanding sectional drawing | 33 | 83 | 7 | 17 | 1.95 | 0.85 |
| 2. Show lack of understanding of sectional drawing principles | 31 | 77 | 9 | 23 | 2.40 | 0.73 |
| 3. Have drawing models | 21 | 53 | 19 | 47 | 3.38 | 0.74 |
| 4. Have EGD instruments | 3 | 7 | 37 | 93 | 3.38 | 0.89 |
| 5. Students are familiar with EGD line-types | 26 | 65 | 14 | 35 | 1.70 | 0.72 |
| 6. Relevant previous topics of sectional drawing | 20 | 50 | 20 | 50 | 2.88 | 0.69 |
| 7. Students have EGD background | 5 | 12 | 35 | 88 | 3.40 | 0.50 |
| 8. Lack of knowledge on 2D/3D of sectional drawing | 24 | 60 | 16 | 40 | 1.65 | 0.83 |

*Strongly Agree (1), Agree (2), strongly Disagree (3), Disagree (4), I do not know (5)

seen in Table 2. There is a better performance on isometric views with a mean score of 8 or 67 percent and a standard deviation of 2.74). The results of isometric views also show that there was not much deviation of scores of most students from the average score, which indicates that most students were good at isometric views.

**Table 2: Summary of students' performance scores on spatial visualization abilities**

| *Rotation section* | | *Isometric views section* | |
|---|---|---|---|
| *Student frequency* | *Scores* | *Student frequency* | *Scores* |
| 1 | 2 | 1 | 4 |
| 1 | 3 | 3 | 5 |
| 4 | 4 | 6 | 6 |
| 6 | 5 | 7 | 7 |
| 4 | 6 | 4 | 8 |
| 8 | 7 | 5 | 9 |
| 3 | 8 | 6 | 10 |
| 5 | 9 | 6 | 11 |
| 2 | 10 | 2 | 12 |
| 5 | 11 | | |
| 1 | 12 | | |
| N = 40 | Mean = 7 SD = 3.32 | N = 40 | Mean = 8 SD = 2.74 |

## Results of Focus Group Interviews with Pre-service Teachers

Three themes, namely (1) insufficient time for EGD and sectional drawing; (2) lack of secondary schools' EGD background (3) knowing the importance of line-types emerged from the analysis of transcripts of focus group data. These results served as a response to RQ 1 *(What difficulties are experienced by lecturers and student teachers in teaching and learning sectional drawing in the EGD course?)*. These themes are presented and discussed below. The themes below were derived by (1) transcribing the interview data from the participants (2) reading the transcripts several times to obtain the common pattern of issues discussed (3) coding and categorizing the data into themes for narration and description.

### *Theme 1: Insufficient practising of EGD and sectional drawing*

A group member from 2nd year (Siphokazi) said: "I only practice when we are about to write a test because I don't have a drawing board and our EGD laboratory is open during lecturing hours and not in the evening for us to use it." However, another pre-service teacher from 3rd year (Ndiphiwe) said the following: "I practice a day or two before the test because in our class there are four guys who understand sectional drawing from school so they help me and others and they are not always available." The above responses are triggered by the fact that lecturers of EGD never get to use models, simulations, and examples to enhance learning as outlined by Bucat (2004). This, on its own, is a difficulty in learning sectional drawing.

### *Theme 2: Lack of secondary schools' EGD background*

A pre-service teacher from the 2nd year (Lindelwa) said the following in isiXhosa (translated into English): "Er sir, I did Graphics at school but we never did this kind of sectioning and that's why I struggle big time." Similarly, a 3rd year student teacher (Xolile) said: "I did Civil technology and Mathematics at secondary level and that's what I planned to do here in tertiary, but when I was given EGD I never knew I will come across sectioning and it is not for us in Civil technology."

This means that if pre-service teachers do not have a full foundational background when doing sectional drawing, they are likely to experience difficulties. According to Brink et al. (2003), as mentioned earlier in the study, a sectional drawing demands the basic knowledge and skills of EGD at Grade 9 level of the NCS curriculum, where graphic communication is taught.

### *Theme 3: Knowing the importance of various line-types*

A 2nd year pre-service teacher (Abongile) who also studies Mechanical technology as a second major subject said: "I know that linework is the basis of drawing but I really don't know why other lines are so important in sectioning." On the other hand, a 3rd year student teacher (Amyolie) said the following: "I do know the importance of various line-types because they help me in differentiating the features in the object."

## Results from Classroom Observation

The results from observation provided responses to RQ 1 which sought to understand the difficulties lecturers and pre-service teach-

ers have in teaching and in the learning of the EGD course. The results are presented and discussed focusing on pre-service teachers' academic EGD level, that is, 2nd and or 3rd years of study as well as the lecturers' teaching practices.

### *Second Year Classroom Observations*

EGD for the 2nd years was offered twice a week for two hours ten minutes each, thus totaling four hours twenty minutes (4 hrs: 20 minutes), on Wednesdays from 8: 00 till 10:10 and Thursdays at 10:30 till 12:40. For the two observation sessions pre-service teachers' punctuality was satisfactory with most of them arriving on time and simultaneously. Even though most pre-service teachers had their own drawing boards, they often shared instruments like set-squares, compasses and most of them did not have erasers. Drawing was more innovative because there were no drawing models that they referred back to. After the day's topic was laid down, some pre-service teachers got together in a group and watched as one of them drew. At the same time the lecturer attended to the ones that were working out their given tasks on their own. During the pre-service teachers' interaction the noise level went up due to discussions and information sharing. This interaction resulted in some pre-service teachers not having completed the given tasks because of having spent most of the period at their fellow classmates' desks.

The application of line-work and its uses was not easily observed as most of the pre-service teachers spent most of their time at other classmates' desks. However, the classmates who understood what had been taught had a good insight into the application of line-work but the errors that they committed after assessment of the given work were more on the application of line-types. What was also observed is that those who were engaged in drawing knew how to utilize drawing instruments. What was found to be a trend was that few of them used a clutch pencil to draw, with the majority using an ordinary HB pencil (the one that needs a pencil sharpener to sharpen when blunt). Also what was observed was that most tasks that were issued during the observation period were group work tasks.

### *Third Year Classroom Observations*

In the 3rd year EGD class, the facilitation was twice a week for four hours twenty minutes (4 hrs 20 minutes) in total on Tuesdays from 10:30 until 12:40 and Fridays from 08:00 until 10:10. There were fifteen 3rd year pre-service teachers consisting of female and male students. For the two observation sessions pre-service teachers' punctuality was excellent, with all of them being in class on time. Their lecturer was also punctual and the lessons started smoothly.

Just like with the 2nd years, most pre-service teachers had their own drawing boards with all four female pre-service teachers having drawing boards as compared to their 2nd year female counterparts. Although not all of them had drawing instruments like compasses, erasers, French and flexi curves etc., the 3rd year learning organization was a bit different to that of the 2nd years with the noise level being a bit lower. There was no model for what the lecturer introduced and learning and drawing was abstract as well. After the lesson was introduced, two male pre-service teachers began the work with all the others gathering around them for observations and questions. The lecturer too was amongst them trying to see and assist while they were drawing. Female pre-service teachers happened to be the ones posing a lot of questions, showing more curiosity to understand in-depth what was drawn. By the end of the lesson not all of the pre-service teachers had finished drawing what had been given to them.

The second round of classroom observations led to the announcement of a test and the lecturer stated that he did not believe in assignments, but in tests. Completed sectional drawing tasks had irregularities like hidden details still showing, sectional lines being overlapped over bold lines and sectional lines going in the wrong direction. However, the display of quality lines was of a high standard as compared to the 2nd years. Eighty percent of the pre-service teachers did not have clutch pencils and used ordinary pencils that required a sharpener when blunt. The 3rd year pre-service teachers' curiosity in learning sectional drawing was higher than that of their 2nd year counterparts. They showed a lot more interest in finding out how and why a drawing should look a specific way. At the end of the lesson, the lecturer was the first to leave and student teachers remained behind to carry on with their drawings until the other class came to use the only EGD laboratory venue.

From the results of classroom observation it can be deduced that the teaching and learning

of sectional drawing is not sufficiently monitored to support pre-service teachers to develop because a lecturer in one class left his class on their own after presenting an abstract sectional drawing lesson. This made it difficult for students to learn and master sectional drawing. Another lecturer opted for an exercise along with its memorandum for students to work it out. This was also a difficult for the students because they were never given a proper explanation on how line-types are denoted, what the dimensions are and what is happening in the entire drawing. Another difficulty was that students grouped themselves around the desk of a brighter classmate who drew on his own drawing sheet while others watched. At the end of the lesson, it was only that bright student who drew something while otherwise been just spectators.

**Classroom Observations on Lecturers' Teaching Activities**

The observation protocol used for this paper was adapted from Peer Observation of Teaching (PoT), which is commonly applied at the British higher education sector as a means of enhancing the quality of teaching and learning.

During the classroom observations, it was noted that the common representations used by lecturers included explanations and illustrations. Illustrations were done through diagrams that were either drawn on the board or taken from the printouts that pre-service teachers had to clarify some concepts. Explanations were aided by drawing models that were mainly relevant to isometric drawing; however there were no models for sectional drawing. Differences between the two lecturers' approaches were revealed through the representations they used to teach sectional drawing. Lecturer A made extensive use of practical explanations and a demonstration while these were not observed in lecturer B's lessons. Lecturer A's sectional drawing introduction required the knowledge of previous EGD concepts, hence pre-service teachers with poor EGD background found it difficult to draw a sectional drawing sketch. It can be interpreted that lecturer B lacked some content and pedagogic knowledge as described by Shulman Pedagogical Content Knowledge (PCK) framework (Shulman 1987).

Lecturer A used his EGD experience by bringing in practical examples that EGD has in the curriculum and that enabled his class to perform sectional drawing exercises from those given in their pamphlets. Lecturer B gave his class the tasks with memos so that they could reproduce the solutions from the memorandum given to them. This made pre-service teachers struggle to (1) interpret the drawing, (2) read the line-types that were used, (3) analyze dimensions of the drawing and (4) they also did not know some of the terminologies used in the questions. Even though lecturer B did not leave the classroom, the aim of the lesson was for the pre-service teachers to brainstorm, which they struggled to do because of their poor EGD background, as also revealed in questionnaire results and test performance (Tables 1 and 2).

Pre-service teachers belonging to lecturer A did not struggle as much, compared in those belonging to lecturer B. Lecturer B was in the 3rd year group whereas lecturer A was facilitating the 2nd years. Lecturer B relied too much on model answers or memorandums from the pamphlets that he distributed to pre-service teachers. Even after the pre-service teachers failed to complete their tasks on time and others not submitting their work, lecturer B had not changed his teaching approach when the researcher observed him for the second time. However he did explain further when some of the pre-service teachers asked about solutions when producing sectional drawing. Lecturer A integrated his knowledge of subject matter, knowledge of students, knowledge of context and general pedagogical knowledge to select and vary the manifested representations in his teaching that resulted in his well-developed PCK which led to his students' understanding as alluded to by Rollnick et al. (2008).

The observations also revealed that lecturers were unable to employ various assessment strategies because their knowledge of the subject matter was affected because they do not have current material and workbooks to help them facilitate (Rollnick et al. 2008). This translates into the lack of useful strategies that assist students to learn successfully as mentioned by Magnusson et al. (1999). Therefore the facilitation of sectional drawing and other EGD concepts remained theoretical and abstract, with no simulations, practical observation and real visualization. Lecturers still lacked experience in assessing pre-service teachers' spatial skills level of competence because their programme did not have a spatial test that is said to be a good predictor for success in any technical subjects, EGD

included (Sorby 2003). It was therefore concluded, based on the presentation and discussion of observation results, that the facilitation of EGD sectional drawing by the lecturers' observation pose difficulties in understanding the content by pre-service teachers because lecturers lacked appropriate content and pedagogic knowledge as explained by Shulman (1986) in the PCK theoretical framework.

## DISCUSSION

In response to RQ 1 of the study, pre-service teachers were requested to respond to item statements measuring difficulties in the EGD course, particularly sectional drawing. It was clear that students lack understanding of sectional drawing principles; have no EGD instruments; and no EGD background. Most of these findings concur with findings from other studies regarding the challenges that students bring from secondary schools to higher education in EGD spatial visualization (Garmendia et al. 2007; Kaufman and Delacour 2006).

For instance, Chan (2007) argues that students with lack of knowledge on 2D/3D concepts will experience difficulty in imagining how objects would appear when rotated in 2D and 3D space. These findings are in consonance with the findings of Yadar (2007) and the report by UNESCO (2008) which opined that teaching/learning materials such as textbooks, classrooms, teaching aids (chalk, board, ruler and protractor), stationeries and laboratories affect academic performance of the learners. Also the result of the findings agreed with that of Mutai (2006) who asserts that learning is strengthened when there are enough reference materials such as textbooks, exercise books, teaching aids and classrooms. Thus, it is evident that the pre-service student teacher difficulties in learning sectional drawing were both instructional and contextual. The fact that pre-service teachers did not all have drawing instruments made it difficult for them to learn sectional drawing. Their lack of EGD background from secondary school level also added to the challenges that they had in learning sectional drawing. The lack of drawing models, particularly the ones that are relevant to sectional drawing, made the instructional practices abstract which made it difficult for them to learn.

Responding to RQ 2 of the study, the pre-service teachers were given a test on spatial visualization in order to assess their EGD knowledge, as shown in Table 2. The results in Table 2 support results from past research that having good spatial skills strongly predicts achievement and attainment in science, technology, engineering, and mathematics fields (for example, Shea et al. 2001; Wai et al. 2010). Therefore pre-service teachers' poor spatial skills also made it difficult for them to learn sectional drawing because it is said that for anyone to successfully learn the concept of sectional drawing and any other concept in a Technology field, spatial skills serve as a prerequisite (Sorby 2009). To address some of the spatial visualization deficiencies Kadam et al. (2012) used the Blender-MR training programme. This programme focuses on (1) Introduction to Blender User Interface, (2) Observing objects in multiple views including 3D space, (3) Rotation of views and rotation of 3D objects. The challenge with using this programme may be the assumptions that the problems faced by all students in EGD are the same, for example, context, socio-economic factors. Kadam et al. (2012) argue that although the multimedia are useful in improving spatial visualization skills, certain difficulties such as interpretation of engineering drawings required for 2D projections and 3D isometric drawings are still a challenge. Therefore, it is important to tailor-make the programme to suit the context of the students in order to obtain maximum benefit from the MR programme. Responses on line-types show that pre-service teachers know line-types, but what these line-types represent drawing object in 2D drawing is still not clear to them. According to Moolman and Brink (2010), line-work enables pre-service teachers to communicate ideas graphically in their Engineering career. This translates into line-work being the key factor in pre-service teachers' understanding of any drawing concept as a foundation for drawing activities. Therefore, one cannot succeed or perform well in a concept if one does not play by the concept's rules.

The results from interviews support the results from tests in that they reveal similar findings of (1) insufficient time for EGD and sectional drawing; (2) lack of secondary schools' EGD background (3) knowing the importance of line-types (Garmendia et al. 2007; Kaufman 2003 and Delacour 2004). Brink et al. (2003) asserted that spatial visualization in sectional drawing demands the basic knowledge and skills of EGD at Grade 9 level of the NCS curriculum, where graphic communication is studied.

The results from observations support what was earlier discussed by Yadar (2007) that the teaching/learning materials such as textbooks, classrooms, teaching aids (chalk, board, ruler and protractor), drawing instruments, stationeries and laboratories affect academic performance of the students in EGD courses. The observed practices in this study show that lecturer's inconsistent monitoring of classroom activities affect disciplinary issues and also have an increased effect on teacher's incompetence as alluded to by Smith and Smith (2006). There is a significant body of research attesting to the fact that classroom organization and behavior management competencies significantly influence the persistence of new teachers in their teaching careers (Ingersoll and Smith 2003). The ability of teachers to organize classrooms and manage the behavior of their students is critical to achieving both positive educational outcomes for students and teacher retention.

## CONCLUSION

This study has identified difficulties that pre-service teachers and lecturers face when learning and teaching sectional drawing. The results of spatial visualization tests also indicated that most pre-service teachers struggled with visualizing objects when rotated to different positions and this exposed the pre-service teachers' level of spatial skills from secondary school. The results showed those pre-service teachers' poor spatial skills made it difficult for them to perform well in EGD because for anyone to successfully learn the concept of sectional drawing, spatial skills are a pre-requisite. The observation results indicated that lecturers too have difficulties in teaching sectional drawing because of the resources that are made available to them and the teaching practices that they employ when facilitating sectional drawing. Observation of lecturers showed that the facilitations of EGD sectional drawing by the lecturers made it difficult for pre-service teachers to understand the content because lecturers lacked appropriate content and pedagogic knowledge.

## RECOMMENDATIONS

Since a lot of pre-service teachers come into the EGD course without enough content background, more attention should be put on linework and spatial visualization exercises before actual EGD and sectional drawing tasks. Drawing models for all EGD concepts need to be made available in order for learning to be concrete. To make these drawing models easily available, technology subjects that are normally paired with EGD at universities, which pre-service teachers take as their second major, should have a practical component that such models are made in the workshops. Pre-service teachers should be encouraged to buy drawing instruments in order to be kept busy during drawing lessons and practices. Assessment should be made frequently in sectional drawing so that the teaching and learning barriers can be easily identified. The use of a modern instruction method such as Blender-MR training should be encouraged. The qualitative analysis revealed that MR training was helpful to alleviate the difficulties that students typically face while solving EGD problems.

The limitation of the study is that it was based on a university in South Africa, and the result may not be generalized to all student teachers in EGD course countrywide. However, due to the limited number of universities offering this course, there is no doubt that the results will be much applicable to other universities. It will be interesting to pursue the same topic and conduct large-scale survey to include all student teachers in the EGD course across the universities offering B.Ed. programmes, with a view to understanding the challenges experienced by students in EGD courses.

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