The Teaching and Learning of Technology: Spotlight on Sectional Drawing among Student Teachers in an Eastern Cape University, South Africa

Moses Makgato, Tshwane University of Technology

Abstract

Sectional drawing is part of graphical communication in technological subjects to reveal the hidden details in a drawing. This paper seeks to provide a better way in the teaching and learning of sectional drawing to student teachers at an Eastern Cape university. Purposive sampling was used to select 40 students in 2nd and 3rd year, both female and male of varying ages of 17- 27 years, enrolled in the Bachelor of Education: Technical Education studying Engineering Graphics and Design. Fifteen (15) of the students were in their third years whereas 25 of them were in their second years. Both quantitative and qualitative research approaches were used to obtain data from students and lecturers. Questionnaires and classroom observation were used as data collection instruments. Classroom observation was analyzed as a report on what was observed and interviews were first transcribed and patterns and quotes were transcribed verbatim identify the themes of the interview result. The results of this study found that students have poor EGD background; have difficulties in understanding sectional drawing; lack of understanding of sectional drawing principles, lack of knowledge on 2D/3D of sectional drawing. It was also found that students performed poor in the spatial visualization test, which the basis for understanding doing well in sectional drawing of EGD course. Observation results showed that lecturers lack adequate pedagogic practices to effect efficient understanding of sectional drawing to student teachers. It is recommended that more attention on line-work and spatial visualization exercises should be emphasized during teaching, using Piaget perception and imagery theories. Specific subject didactics of technology subjects should be strengthened with these topics in order to prepare efficient and quality teachers of EGD and related subjects.

Key words: *Sectional drawing, Engineering Graphics and Design, spatial visualization, student teachers*

Introduction

In the engineering world, Engineering Graphics and Design (EGD) is the medium of communication through drawings. It relates between theory and the picture of reality, the same way as Technical drawing does. EGD provides an accurate and complete picture for every object in terms of shape and size in the technology related fields (Widad & Adnan, 2000). The EGD emphasis is 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, Rio & Lee, 2006). EGD is one of the elective courses taken by student teachers in the technology teacher education programmes at a university in South Africa. Student teachers in 2nd and 3rd years of study in an Eastern Cape university 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 utterance by students and lectures prompted this study to investigate factors associated with difficulties student teachers have in sectional drawing in EGD course at Eastern Cape university because students' poor performance hamper them from progressing to the next level and eventually completing their degree on time.

According to Brink, Gibbons and Theron (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 Engineering Graphics and Design (EGD) at a Grade 9 level of the National Curriculum Statement (NCS) curriculum, where graphic communication is studied (Brink et al., 2003). On the other hand, the main purpose of sectional drawing is to reveal the hidden details in a drawing (Moolman & Brink, 2010). The revelation of the hidden details in a drawing will assist the students/draughtsmen/engineers to identify underlying components in a drawing when designing technical projects. This will enable an engineer to be able to assemble or dismantle components in a model for further machining purposes in industries.

The revelation of underlying or hidden components in a drawing is done through reading and understanding various line-types that are used in EGD. According to Moolman and Brink (2010), there are ten different types of lines that are used in the entire EGD curriculum that also applies in schools. Out of these ten line-types, seven of them are the main ones in EGD concepts, with the other three mainly being the applications of some of the other types. A sectional drawing question could contain all seven line-types depending on its degree of complexity. This require the availability of drawing instruments from students in order to make sense of the sketches that they draw and assist the teaching activity. When students do not have drawing instruments it will be difficult for both teaching and learning to happen because Wells (2000) says when the teacher and students do not work together optimally to come up with an intrinsic product, then there is no learning.

Sorby (2009) states that students who learn EGD need spatial visualization skills to understand its concepts. Sorby (2003) 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 & 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; Branoff, 1998; Gorska, Leopold & Sorby, 2001). 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 segments of the general populace do not perform well when confronted with spatial-visual relations tasks (Ben-Chaim, Orion & Yael, 1997). The traditional teaching methods and approaches are not emphasizing the students' visualization skills (Widad, Rio & Lee, 2006). The EGD course in an Eastern Cape university, where this study was undertaken, consists of several topics and concepts, of which sectional drawing, with its related spatial visualization abilities made students to perform poor in sectional drawing of EGD course. The study therefore investigated factors students teachers and lecturers perceived as difficulties in the teaching and learning of EGD course, particularly focusing at sectional drawing.

The content knowledge of Engineering Graphics Design as a school subject

Engineering Graphics and Design (EGD) subject include technological knowledge, concepts 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. The main topics of EGD are General drawing principles for all technological drawings ; 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. CAD (Computer-Aided Drawing/Design) (DBE, 2012). The prescribed content for the EGD subject is shown in table 1 below.

Table 1 *Prescribed Content for the EGD Subject*

Topic	**Prescribed content**
Drawing principles relevant to all types of drawing	A-type line (darkest line): Border & title/name block/ panel; outlines & visible parts; answers of e.g. loci; projection symbol; tables B-type line (medium line): All writing & numbering; dimensions; projection planes; auxiliary views; hatching; screw threads; folding lines, break lines C-type line (lightest line): Constructions; planning; projections; guidelines (for writing) Medium chain-line (B-type): Centre points of circles; centre lines (centre axis); section planes; assembly diagrams; building lines/ boundaries (servitudes) Dark chain-line (A-type): Plumbing, water pipes, drainage, services, irrigation systems Short broken-line (B-type): Hidden detail; items to be removed on civil drawings Long broken-line (B--type): Contour lines on civil site plan
Free-hand drawing	The basic hand movements needed to draw proportional single, multiview and pictorial drawings on plain paper and/or grid sheets
Geometrical Construction	Geometrical constructions: bisecting lines and angles, perpendicular lines, angles, dividing a line, a circle through three points, circle divisions, inscribed and circumscribed circle to triangles, fillets, tangents, convex and concave tangential arcs • Regular polygons with 3, 4, 5, 6 & 8 sides • Ellipse
Mechanical drawing	3rd angle orthographic working drawings with non-sectional and sectional views of mechanical castings and objects from industry. Include the following: Title, scale, hidden detail, dimensioning, cutting planes, hatching detail, notes and symbol of projection

Isometric drawing	Simple isometric drawings with isometric and non-isometric lines as well as auxiliary views
Solid geometry	1st angle orthographic views of right-regular prisms and pyramids with 3, 4, 5, 6 and 8 sides only, as well as cylinders and cones. The axis of the solids may be perpendicular, parallel or inclined to one principal projection plane only. Include the following: • Sectional views • The true shape of the cut surface.
Descriptive geometry	1st angle orthographic views of points and line segments that are perpendicular, inclined or oblique to the projection planes. • The true length and the true inclination of line segments to the horizontal plane(HP) or vertical plane (VP) using different methods, e.g. projection or construction • The true shapes of surfaces from given edge (side) views
Civil drawing	Limited to single-storey dwellings, 1st angle orthographic working drawings with floor plans, basic single line elevations and sectional elevations showing the detail of the foundation to the slab. Include the following: • Annotations, labels, dimensioning and scales • Relevant abbreviations and conventions • On the floor plan only: windows and doors • Hatching detail • Perimeters and floor areas

Purpose of the study and research questions

The students' performance in sectional drawing had been poor for years, thus not allowing them to complete the EGD course on time. The aim of the study was to investigate difficulties in the teaching and learning of sectional drawing of student teachers in the teacher education programme and come up with a better way to teach and learn sectional drawing.

Theoretical framework

This study was underpinned by two theories, namely Piaget's perception and imagery theory, and Pedagogical Content Knowledge. Piaget's cognitive theories of learning are also relevant and enhancing the spatial visualization of sectional drawing in the teaching and learning of EGD course. Pedagogical Content Knowledge has to do with the teaching practices in the classroom, and assisted the study in observing the appropriate teaching attributes of teachers of EGD course.

Piaget's perception and imagery theory

Piaget's perception and imagery theory assisted the study in ascertaining how the students developed cognitively in understanding EGD concepts. Adopted from Piaget's four periods of perception, namely the sensori-motor period, pre-operations, concrete operations and formal operations stages, these four periods helped the study determine how students' perception and visualization were used because the four periods form the fundamentals of mental growth (Nakin, 2003). At the initial stage (sensori-motor) the children in their samples exhibited a purely egocentric view of the world that continued to the second stage. At the third stage, the children could perform reversible mental actions but only on real, concrete objects (Cockroft, 2002). During the final stage of formal operations children not only classified, ordered and reversed mental operations, but could also take results of these concrete operations and generate hypotheses about their logical relations, resembling the kind of thinking called 'scientific method' and referred to as abstract reasoning (Campbell, 2006). Therefore the Piaget's perception and imagery theory assisted the study in observing how students developed in one EGD concept to the other right till to the learning of sectional drawing.

Methodology

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

Questionnaires contained two sections that are, students' biographical data and eight (8) closed ended-type questions. Closed questions served as a survey where the researchers were only interested in knowing figures (numbers) and percentages that respondents gave based on each question. These closed ended questions were of a Linkert type where respondents were putting a tick on either 1- 4 rating where 1 was strongly agree (SA) and 4 strongly disagree (SD). The quantitative data were analyzed statistically with the aid of SPSS statistical analysis. The reliability of the questionnaires in this study was 0.7 using Cronbach's alpha reliability coefficient (Santos, 1999). The data was also collected using Purdue Spatial Visualisation Test (PSVT), (Guay, 1977), which consist of three topics, each with 12 problems/questions. The tree topics are (1) Developments (2) Rotations and (3) Isometric views. For the purpose of this study Rotation and Isometric views were administered to students because they specifically relevant to spatial visualisation abilities for sectional drawing (ibid).

Classroom observations were video recorded so that the researcher could watch them over and over again and also send them to other expects who has extensive experience in research and EGD to determine its reliability. During observation field notes were also taken. The classroom observation schedule was adopted from Staffordshire University's "Guidelines for the Observation of Teaching (Hammersly-Fletcher & Orsmond, 2004).

A purposive sampling was used to select forty (40) 2nd and 3rd year EGD students enrolled in the teacher education course to take part in the study. There were 15 students in third year and 25 students in second year, of varying ages of 17- 27 years both male and female, who took part in the study. There was a total of 6 female and 9 male students in the 3rd year as well as10 female and 15 male students in 2nd years doing Engineering Graphics and Design. Focus group interviews that were structured were conducted with students (5 groups with 8 members). Both the classroom observations and interviews were video recorded so that listening to them all over again could help get a pattern of the responses. The interviews were transcribed and themes were developed based on the questions asked and classroom observations were analyzed descriptively per item.

Results and discussions

Questionnaire results on students difficulties in EGD course

Table 2 *Student Teachers Indications of Difficulties in EGD Course*

N =40

Statement/indicators	**Agree**		**Disagree**		**Mean**	**SD**
	F	**%**	**F**	**%**		
1.Difficulties in understanding of sectional drawing	33	83	7	17	*1.95	0.85
2. Lack of understanding 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

***Agree (1), Strongly agree (2), Disagree (3), Strongly disagree (4)**

For the purpose of answering to RQ1 stated above student teachers were requested to respond to item statements measuring difficulties in EGD course. Table 2 above provide results of descriptive analysis (frequency, percentage, means and standard deviations) about items considered to be difficulties in EGD course. According to table 2 the item with highest score is “having EGD instruments ” (where 93% participants answered that they “Disagree” that they have EGD instruments), with mean score (M= 3.38) and standard deviation (SD = 0.89); have EGD background (88% participants answered that they “Disagree” that they have EGD background), with mean score (M= 3.40) and standard deviation (SD = 0.50); have difficulties in understanding sectional drawing (83% participants answered that they “Agree” that they have difficulties in understanding sectional drawing), with mean score (M= 1.95) and standard deviation (SD = 0.85); lack of understanding sectional drawing principles (77% participants answered that they "Agree" that they lack understanding of sectional drawing principles), with mean score (M= 2.40) and standard deviation (SD = 0.73). According to Abrahams (2003) principles on sectional drawing enable students to produce good sectional drawing in step by step process. On lack of knowledge on 2D/3D of sectional drawing (60% participants answered that they "Agree" that they lack knowledge on 2D/3D of sectional drawing), with mean score (M= 1.65) and standard deviation (SD = 0.83). Chan (2007) argues that students with lack of knowledge on 2D/3D concepts will experience difficulties to imagine how objects would appear when rotated in 2D and 3D space. Most (65% , M= 1.70, SD = 0.72) of participants agreed that they are familiar with EGD line-types which forms the basics of EGD courses. According to Moolman and Brink (2010) drawing is a graphic language used by engineers and draughtsman to communicate their design using symbols, dimensions, and different types of lines.

Test scores on students visualisation and spatial questions

Table 3 *Summary of Students Performance Scores on Spatial Visualization Abilities*

Rotation		**Isometric views**	
Students 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

In response to RQ2 of the study the students were given test on visualisation and spatial section of sectional drawing of EGD. The test consisted of 12 questions or problems on 'rotation' and 'isometric views' respectively taken from Purdue Spatial Visualisation Test (PSVT) (Guay,1977). The orthogonal rotations of 3D objects are designed to help visualise the rotation of a three dimensional (3D) objects (Guay, 1976). The isometric views is about what the 3D objects looks like from different views, and it test the spatial visualisation skills in engineering graphic courses (Yue, 2000). Table 3 above shows the summary of test scores in the form of students frequency scores, means and standard deviation. On 'rotation' table 3 shows that out of 40 students and 12 problems, one student scored correct in all 12 problems, 5 students scored 11 problems, 2 students scored 10 problems, with means (M = 7) and standard deviation (SD = 3.32). The average score on 'rotation' is 7 or 58%, which is relatively not an excellent performance. This is not very much surprising when looking at the indicators of difficulties reported in table 2 above. The standard deviation of 3.32 is a consideration spread of the scores by participants from the mean, as it can be seen on table 3. There is a better performance on isometric views with a mean (M = 8) or 67% and standard deviation (SD = 2.74). The results on isometric views also shows that there is no much deviation of scores of most students from the average score, which indicate that most students were good in isometric views.

Results from classroom observation

The results from observation serves as answer to RQ1 which sought to understand the difficulties lecturers and students have in teaching and learning EGD course. The results are presented and discussed focusing on levels of students (2nd and 3rd years classrooms) as well as on the lecturer teaching facilitations.

Second year classroom observations

EGD for the 2nd year students was offered twice a week for two hours ten minutes each, thus totaling four hours twenty minutes (4hrs: 20 minutes), on Wednesdays from 8: 00 am till 10: 10 am and Thursdays at 10: 30 am till 12: 40 pm. There were a total of 30 2nd year students with fewer females than males. For the two observation sessions students' punctuality was satisfactory with most of the students arriving on time and simultaneously. Their lecturer was the first to arrive in class and before any lesson could start an attendance register was circulated for students to sign. Students were getting ready for learning because most of them did not use the institution's t-squares but their own drawing boards that made their readiness faster and less disruptive. A few of them though used t-squares that the institution provided.

Even though most students have their own drawing boards, they often share instruments like set-squares, compasses and most of them do 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 students got together in a group and watched as one of them drew. At that moment the lecturer attended to the ones that were working out their given tasks on their own. During the students' interaction the noise level went up due to discussions and information sharing. This interaction resulted in some students 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 students spent most of their time at other classmates' desks. However, the classmates who understood what had been taught had a good insight in the application of line work but the errors that they committed after assessment of the given work was 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. Students were grouped into four groups of 5 for the tasks given to be submitted for assessment. Three sectional drawing questions were given a time frame of a week to be completed and submitted.

When a drawing lesson was presented the facilitator was too abstract because he did not have any drawing models to show illustrations, simulations and analogies to stimulate learning as required by PCK theoretical framework (Shulman, 1986). The technique that the facilitator used was abstract too, leaving students to rely on the uses of line-types on the given drawing to make sense of it.

Third year classroom observations

EGD in the 3rd year students was also offered twice a week for four hours twenty minutes (4hrs 20 minutes), in total on Tuesdays from 10: 30 am until 12: 40 pm and Fridays from 08: 00 am until 10: 10 am. There were 15 3rd year students consisting of female and male. For the two observation sessions students' punctuality was excellent, with all of them being in class on time. Their lecturer was also punctual and the lessons started smoothly. The attendance register was circulated for students to sign while the lecturer was busy with other duties like white board cleaning and other lecturing preparations in an attempt to get the classroom ready for learning.

Just like with the 2nd years, most students had their own drawing boards with all four female students 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 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 students began the work with all the students gathering around them for observations and questions. The lecturer too was amongst them trying to see and assist while they were drawing. Female students happened to be the ones posing a lot of questions, showing more curiosity to understand in-depth what was drawn. After the end of the lesson, not all of the students had finished drawing what was 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 (80%) of the students did not have clutch pencils and used ordinary pencils that required a sharpener when blunt. The 3rd year students' 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 in a specific way. At the end of the lesson, the lecturer was the first to leave and students remained behind to carry on with their drawings until the other class came to use the only EGD laboratory venue. This happened to be the time when a much brighter student/ (s) would go in front and give a clearer picture on what was earlier taught in class.

The other major observation made was that what Piaget describes as the mechanism by which the mind processes new information. Piaget, & Inhelder, (1971) says that a person understands whatever information fits into his or her established view of the world, starting from early developmental stages which is also supported by Nakin (2003). The concepts of sectional drawing and its drawing exercise requires special attention, in that students should possess appropriate spatial visualization abilities, which is mostly identifiable at an early developmental stages (Piaget, & Inhelder, 1971). According to Piaget & Inhelder, (1971 spatial skills are developed in three stages namely, (1) topological skills, (2) visualizing 3D objects and (3) visualizing the concept area. These skills are acquired according to the way a child matures. The age difference of the participants ranges between 17 and 28, and it does not seem like age or maturity of an individual brings about spatial skills development. Spatial skills need a good SMK and PCK for all of those to be infused in an individual.

From the results of classroom observation it can be deduced that the teaching and learning of sectional drawing is not monitored to support students developmental stages (Piaget, & Inhelder, 1971), because a lecturer in one class left students on their own after presenting an abstract sectional drawing lesson. This is a difficulty on its own for students to learn and master sectional drawing. Another lecturer opted for an exercise along with its memorandum for students to figure it out. This also a difficulty for the students because they were never given a proper explanation on how line-types are denoted, what the dimensions are and what is it that 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. And after the lesson, it was only that bright student who drew something and the rest were just spectators.

Conclusion

This study succeeded in sheding a light in identifying difficulties lecturers and student teachers experience in the teaching and learning of sectional drawing topic in EGD course, using mixed methods of data collection to enrich the results obtained. The results of spatial visualization tests also indicated that most students struggle with visualizing and object when rotated in different forms. Since students come into the EGD course without enough content background, more attention on line-work and spatial visualization exercises should be emphasized during teaching using Piaget perception and imagery theories as well as PCK theoretical framework. This implies that technology teacher education programme should capacitate and empower both professional continuing and beginner teachers with these theories. The new revised teacher education programme at universities should strengthen the specific subject didactics of technology subjects with these topics in order to prepare efficient and quality teachers of EGD and related subjects. Drawing models for all EGD concepts need to be made available in order for learning to be concrete. Students should be encouraged to buy drawing instruments in order to be kept busy during drawing lessons and practices. Assessment should be made frequent in sectional drawing so that students teaching and learning barriers can be easily identified.

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

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