

Difficulties Experienced by Student Teachers and Lecturers in Engineering Graphics and Design Course at a University in South Africa

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ABSTRACT 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 is one of the elective courses taken by student teachers in the technology teacher education programmes at a university in South Africa. This paper reports on a study undertaken to investigate factors associated with difficulties student teachers have in sectional drawing in EGD course. 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. Questionnaires served as quantitative method administered to student teachers whereas classroom observation, students' focus group interviews were also carried out as qualitative approaches. Classroom observation was analyzed as a report on what was observed in response to the research question. Interviews were first transcribed and patterns and categories identified to determine themes the interview data. 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 is the basis for understanding and performing well in 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. Specific subject didactics of technological subjects should be strengthened in order to prepare efficient and quality teachers of EGD and related subjects.

INTRODUCTION

Engineering Graphics and Design is a course which 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 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 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 and 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.

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 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; Branoff 1998; Gorska et al. 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 et al. 1997). The traditional teaching methods and approaches are not emphasizing the students' visualization skills (Widad et al. 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.

PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

The students teachers' performance in sectional drawing had been poor for years at a university in the Eastern Cape of South Africa , 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. This is reflected in these two research questions:

1. What difficulties are experienced by lecturers and student teachers in teaching and learning sectional drawing in the EGD course.

2. What are the spatial visualization competence of student teachers in learning sectional drawing in EGD course

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 understand 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-structured 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 were of a Linkert type where respondents were putting a tick on a scale of 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 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 visualisation abilities for sectional drawing.

Classroom observations were video recorded so that the researcher could watch them over and over again and also send them to other experts who has 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 (Hammersly-Fletcher and 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 as 10 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). 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 1: Student teachers indications of difficulties in EGD course

N =40

***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 1 above provide results of descriptive analysis (frequency, percentage, means and standard deviations) about items considered to be difficulties in EGD course. According to table 1 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 2: Summary of students performance scores on spatial visualization abilities

In response to RQ2 of the study the students were given test on visualisation and spatial section of sectional drawing of EGD ,as shown in Table 2 above. 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 2 above shows the summary of test scores in the form of students frequency scores, means and standard deviation. On ‘rotation’ table 2 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 1 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 2. 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 of focus group interviews with students

Three themes, namely (1) insufficient practicing of 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 response to RQ1 (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.

Theme 1: Insufficient practicing 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, a group member from 3rd year (Ndiphiwe) said the following: “I practice a day or two before the test because in our class,

sir, 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 metaphors 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 student 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 (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 students do not have a full foundational background when performing 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 done.

Theme 3: Knowing importance of various line-types

A 2nd year student (Abongile) a member of the Mechanical technology group said: “I know that line-work 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 (Amyolie) said the following: “I do know the importance of various line-types because they help me in differentiating the features in the object.”

Responses above show that students know line types, but what these line-types represent is still not clear to them. As mentioned in this study by Moolman and Brink (2010), line-work enables students to communicate ideas graphically in their Engineering career. This translates into line-work being the key factor in students’ understanding of any drawing concept as a foundation for drawing activities. Therefore, one cannot succeed or perform well in a concept if they do not play by the concepts’ rule.

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 and 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 and Inhelder 1971). According to Piaget and 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 and 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.

Classroom observations on lecturer teaching activities

Although the focus of this paper is not on lecturer it is proper to provide some data on teaching practices of EGD. The observation protocol used for this study was adapted from PoT (Peer Observation of Teaching), which is common place in the British higher education sector as a means of enhancing the quality of teaching and learning. The education system of the pre-1994 in this country was based on racial discrimination, and did not attempt to produce better equipped technical education teachers, particularly in the Black community (Makgato 2003). The lecturers observed also said that they had been involved in the programme re-curriculating process a long time ago and since then all of what they facilitate was still unchanged.

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 students had to clarify some concepts. Explanations were strengthened by the pre knowledge of isometric drawing because there were models that were mainly relevant to isometric drawing and none for sectional drawing (Treagust et al. 2003). 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 students with poor EGD background would find it difficult to draw a sectional drawing sketch. It can be interpreted that lecturer B lacked some content and pedagogic knowledge as prescribed by Shulman PCK framework (Shulman 1986).

Lecturer A used his EGD experience of bringing in practical examples that EGD has in the curriculum and that enabled students to perform sectional drawing exercises from those given in their pamphlets. Lecturer B gave students tasks with memos so that they could reproduce an answer from the memorandum given to them. Students struggled to (1) interpret the drawing, (2) read the lines, (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 students to brainstorm, which they struggled to do because of their poor EGD background, as also revealed in questionnaire results and test performance (table 1 and table 2).

Students with lecturer A did not struggle as much, compared in students of Lecturer B's class. Lecturer B was in the 3rd year group whereas lecturer A was facilitating the 2nd years. This shows a great difference between the strategies used by these two lecturers. Lecturer B relied too much on model answers or memorandums from the pamphlets that he distributed to students. Even after students did not complete their tasks on time and others never submitted their work, Lecturer B did not change his teaching approach when the researcher observed him for the second time. He did not change his approach to explain further even when some students asked how the solutions were found as they were drawing 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.

The above discussions imply that teachers' manifestations of their knowledge is not tested and gauged because they cannot provide simulations, models and metaphors that could assist in stimulating learning (Geddis and Wood 1997). If lecturers do not have textbooks and study guides for EGD, then they most likely lack curricular saliency as discussed by Geddis et al. (1997). Lecturers were unable to employ various assessment strategies because their knowledge of the subject matter is affected by the fact that they do not have current material and workbooks to 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 remain theoretical, with no simulations, practical observation and real visualization. Lecturers still lack experience of gauging students' spatial skills level of competence because their programme did not have a CAD component which is said to be software that assists students in learning 3D concepts which in turn provide spatial skills (Mackenzie and Jansen 1998, Bertoline 1991). Lecturers also spent most of the lesson presentations explaining in isiXhosa rather than in English because students struggle with English interpretation of questions. This also has a bearing on the reason why students fail to interpret a question because they end up being unfamiliar with English usage which is the language in which EGD and its concepts are asked.

It is concluded based on the presentation and discussion of observation results that the facilitations of EGD sectional drawing by the lecturers observation poses difficulties in understanding the content by students because lecturers lack appropriate content and pedagogic knowledge as prescribed by Shulman (1986) in PCK theoretical framework.

CONCLUSION

This study succeeded in shedding a light in identifying difficulties 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. The new revised teacher education programme at universities should strengthen the specific subject didactics of technology subjects 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 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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Table 1: Student teachers indications of difficulties in EGD course

N =40

Statement/indicators	Agree		Disagree		Mean	SD
	F	%	F	%		
1.Difficulties in	33	83	7	17	*1.95	0.85

understanding of sectional drawing						
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)

Table 2: 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

