Teaching and Learning of Hand Engineering Drawing in Tertiary Institutions for Large Classes

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Abstract
This study arises from the concern about pedagogy of engineering drawing at tertiary institutions in Kenya. Teaching hand drawing has become rare when engineering classes are becoming larger and online classes are a norm. The study used interpretive approach to explore perception of tertiary institutions to hand drawing and the best mode of delivery to enable students understand best. It's observed that delivery of the engineering drawing course was majorly done by powerpoints at 70.4%, and 87% of the students agreed that step by step illustration helped them understand best. The focus group established loading and timetabling to be biggest challenge in delivering. The focus groups proposed the maximum number of students per drawing class be limited to 70.
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1. Introduction

Engineering drawing and design is offered in all engineering units. Engineering drawing is the medium that engineers use to communicate. In Kenya, engineering drawing is commonly offered to engineering students in their first three years. The unit is offered in two sections. The first section, which acts as a prerequisite for the second section, is hand/manual engineering drawing. At this point, the design is done using pencil work. The second section involves using computers aided by Computer-Aided Design (CAD) software. This study will investigate the teaching of the first section namely, hand drawing.

Hand drawing is of interest in this paper since it is a prerequisite. Prensky (2001) noted that Digital immigrant instructors, who speak an outdated language, are struggling to teach a population that speaks an entirely new language. Also, as hypothesized by Prensky (2001) the digital natives may not be ready to receive the knowledge packed in the traditional/legacy fashion. For the digital natives to be receptive, the legacy curriculum should be taught in the language of digital natives. This change in teaching strategy is happening where debates are rife on whether to retain hand drawing in the curriculum. It is so common that even during the oral interview of the grant that funded this research, a similar question was posed, "Is hand drawing relevant in this digital world?" Engineers still agree that instruction in hand technical drawing remains a central component of the Graphical Communication courses (Field, 2004; McLaren, 2008). Field (2004) argues that knowledge of hand drafting develops thinking in three dimensions (3D) and communicating in two dimensions (2D) and thus aid in learning CAD. Leopold et al. (2001) observe that CAD users who have had hands-on problem solving through hand engineering drawing taught using 3D physical models have improved understanding of CAD compared to those who have learned CAD systems only.

Some engineering education teachers feel that they are involved in teaching a redundant subject and thus this may affect their preparedness during lectures. Others are adamant that school students need to know the basics of technical drawing before working in a CAD environment (McLaren, 2008) In Kenya, hand engineering drawing is still included in the engineering education curriculum. This debate is not restricted to Kenya but also documented in other countries like Scotland and USA (McLaren, 2008).

For learning to be effective, the learner should be the center of focus. This efficacy will only be achieved when appropriate didactics strategies are adopted. Dale (1969) established that learning occurs when more than one sense or stimuli is used in the classroom to explain a concept. These are the hearing, seeing, touching, tasting, and even smelling senses if applicable. This concept agrees with the old Chinese saying that "*I hear I forget, I see I remember, I do I understand*". In the digital error, the stimuli could be varied by using multimedia to deliver engineering lessons.

Developing competence in engineering drawing involves having spatial abilities to visualize and formulate 2D drawings to 3D and vice versa (Leopold et al., 2001). To develop such spatial abilities in students, teaching has to go beyond the lecture method, in which, the predominant educational resources are drawing tools, drawing boards, handouts, textbooks, and lecturer voice to the use of multimedia. Such an approach will include usage of 3D realia, CAD softwares to enhance visualization of 2D and 3D, augmented reality to enhance texts, and virtual reality to enhance imagination and abstraction.

From this background, this paper anchors itself in Edgar Dale cone of experience model/theory of media and teaching strategy selection. Dales (1969) theory, as influenced by Dewey ideologies of the importance of the continuity of learning experiences from schools into the real world, argued for a greater focus on higher-order outcomes and meaningful learning. Based on this, Dale developed the "Cone of Experience," which relates concrete to abstract continuum to audiovisual media options. This cone showed the progression of learning experiences from the concrete to the abstract as shown in Figure 1.

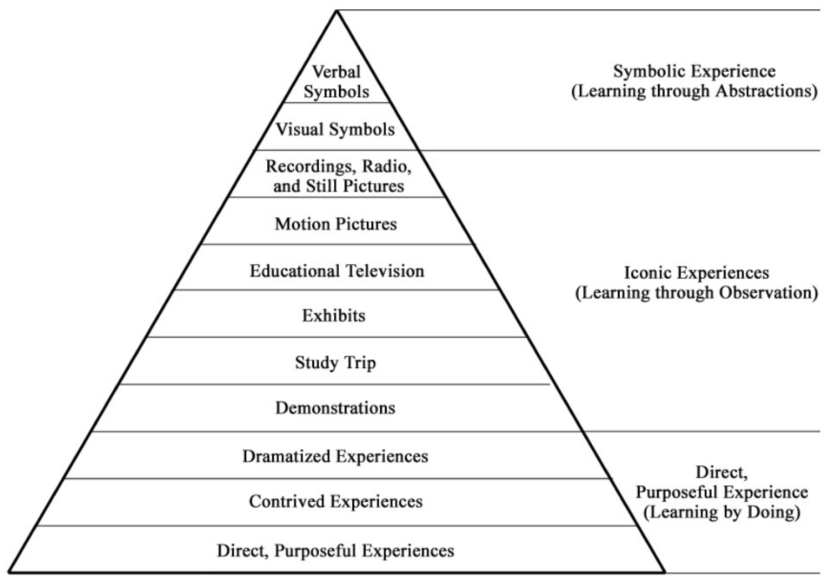


Figure 1: Dale's Cone of Experience (Lee & Reeves, 2017)

Further, the Cone categorized learning experiences into three modes: enactive (learning by doing), iconic (learning through observation), and symbolic experience (learning through abstraction). These categorizations were borrowed from Bruner's (1966) three learning modes. Dale's theory informed the research on the importance of selecting media and teaching strategies that concentrated on iconic experiences and direct, purposeful experiences.

As stated by Dale, the bottom of the Cone represents "purposeful experience that is seen, handled, tasted, touched, felt, and smelled" (Dale, 1954, p. 42). These experiences develops spatial abilities (Leopold et al., 2001). By contrast, verbal symbols (i.e., words) and messages are highly abstract at the top of the cone. As Dale (1969) explained, "The word *horse* as we write it does not look like a horse or sound like a horse or feel like a horse" (p. 127). The words do not have a physical resemblance of the real object.

In most cases, this symbolic experience is what is used by technical drawing (TD) teachers (Leopold et al., 2001). Manual TD being a prerequisite of CAD learning, gives real and concrete experiences that are necessary to provide the foundation of permanent learning. The use of 'Dale cone of experience' to select multimedia is augmented by "Bogus Cone of Remembering" which claims that learners will generally remember 10 percent of what they read, 20 percent of what they hear, 30 percent of what they see, 50 percent of what they hear and see, 70 percent of what they say, and 90 percent of what they both say and do. Therefore, this paper will investigate the common simulations and audio-visual media and teaching strategies employed to facilitate hand engineering drawing teaching and learning in Kenya's tertiary institutions.

2. Interpretive approach

An interpretive approach was adopted for this research because we ascribe that reality is socially constructed or made meaningful through actors' understanding of events. The researchers were alive to the limitations that different individuals may construct different meanings about the same phenomenon (Crotty, 1998). To counter this limitation, meaning was constructed through the prism of Dale cone of experience model/theory of media and teaching strategy selection and the remembering cone, which facilitated the integration of human interest into a study within educational technology theories. Within the interpretive approach, we used the Phenomenology perspective because it provided us with information from a rich amount of data experienced from the first-person point of view using induction and human interests and stakeholder perspective having their reflection on the study (Smith, 2003). Phenomenology is the study of "phenomena": the way we experience things, or things as they appear in our experience, thus the meaning things have in our experience (Smith, 2003).

Our study sought to explore how teaching and learning of hand engineering drawing in tertiary institutions is perceived and interpreted. Their perceptions of their meanings to their experiences are central to this research.

3. Methods and methodology

The cross-sectional survey that this study reports on was conducted in August 2020. The study was conducted among engineering drawing lecturers from six universities, namely, Dedan Kimathi University of Technology (DeKUT), alumni and fifth-year students of Bachelors of Science Degree in Engineering (Mechanical, Mechatronics, Civil and Electrical Engineering options). The central research question was framed as: *In your perspective, how is teaching and learning of hand engineering drawing done, and how do you best teach or learn the subject*? Once the research received ethical clearance from the University, piloting of the online questionnaire was done, and once subjected to Cronbach's test, internal reliability of 0.83 was realized. While this is good enough, issues that affected reliability were addressed satisfactorily. These mostly were confusing statements and terminologies that made the questions vague.

A sampling frame of thirty-two (32) public universities was prepared and a representative sample of eight (8) universities was purposively made to the sample. The selection criterion was that the University had to be offering a Bachelor of Science in engineering. In the case of engineering students, the entire population of 198 students was involved in the study. The whole population was taken since most researchers reported a response rate of between 20-25% in the online questionnaire. Eight (8) alumni were purposively selected for telephone interviews for triangulation purposes. The Bachelor of Science in Engineering is a five-year undergraduate degree program used to prepare engineers in mechanical, mechatronics, electrical and civil engineering.

A cross-sectional survey collects data at a single point in time from a specific population. For this reason, a cross-sectional survey design was selected as the appropriate research strategy to gather information. The information gathered was used to design an experimental piloted intervention, and the results were reported on a different paper. An online questionnaire was created to obtain feedback from the students. Mobile phone interviews were used to get data from the alumni. A virtual Focus Group Discussion (FDG) was used to obtain data from engineering drawing university lecturers. The data collection techniques were consistent with phenomenology (Smith, 2003)

At first, FGD was held virtually using the University's online platform. From the eight universities that were sampled, five universities participated in the FGD. One University had two discussants, and thus, the total numbers of discussants were six (6) and two (2) moderators. McLafferty mentions this as a sufficient number for FGD (McLafferty,2004). The FGD adopted a semi-structured group session to make members freely participate in the discussions (Carey, 1994). When the discussant freely participated in FGD the participant validated their contributions (Carey, 1994). This method improves the validity of the gathered data. The discussion was recorded, and transcribed notes included verbatim to emphasize individual voices (Yin, 2011) and paraphrased recordings of their responses. The FGD and desk review notes were considered in developing the student questionnaire.

Secondly, four research assistants were recruited and trained to administer the online questionnaire. Training of research assistance increases the research validity and the response rates (Noble & Heale, 2019). Each research assistant was allocated one group: Mechatronics, Mechanical, Civil and Electrical engineering. The research assistants were to call each student through the mobile call to introduce the study and seek consent. After consent was obtained, a link was shared with them and requested feedback within a day. Sharing the link through social media groups was discouraged since the respondents could have discussed how to respond to the questionnaire. Such a way could have greatly affected the validity of the collected data. Follow-up calls were made to remind participants to respond to the questionnaire. Data collection exercise was done within five days as a survey was to be implemented within a short period.

The questionnaire structure was that, closed questions were designed to measure student preference and perception of certain teaching media and strategies. The open questions were less specific and aimed to get individual student voices Yin (2011) opinions and suggestions. Their views on the nature of improvement to be done were also sought to deepen understanding of the student experience (Allen & Wright, 2014).

Of the 198 questionnaires issued out, 110 were duly filled and returned, representing a 55.56% response rate. This rate is higher than the typically expected response rate of 20 to 25%, mostly experienced on online surveys (Fincham, 2008).

Lastly, all the eight alumni were engaged in one-on-one telephone interviews. The interviews were semi-structured to facilitate the free expression of the participants' thoughts (Cohen et al., 2011) and were conducted by the study. This method was to get a deeper understating Yin (2011) of the filling on how technical drawing was offered and its application in the actual industry. The notes included both verbatim and paraphrased recordings of their responses.

The data analysis occurred concurrently with the FGD, and interview data were thematically analyzed to support the numerical data.

4. Result and findings

While several themes emerged, our attention in this section was on themes that most directly addressed the central research question, namely:

In the view of participating students and lecturers, what factors influenced the teaching and learning of hand engineering drawing in universities?

The factors that this study sought to investigate were the demographical information of the students, the teaching and learning materials being used to teach hand engineering drawing, and challenges that negatively influence the teaching and learning of hand engineering drawing.

Framed within the interpretive phenomenological perspective, the research question was created to elicit responses about how they made meaning around their lived experiences during teaching and learning of manual engineering drawing. Therefore, the results and findings reflect participants' reported perceptions of how they constructed, perceived, and interpreted the teaching and learning of manual engineering drawing.

Throughout our discussion, manual engineering drawing will also be referred to as manual technical drawing or hand engineering drawing. The results are as displayed below;

4.1 Target respondents

The online student questionnaire survey targeted respondents from four engineering specialties at the Dedan Kimathi University of Technology. The four engineering specialties are commonly offered in Kenyan universities. From 198 targeted students, 110 respondents were filled up and received. The distribution of the responses are shown in Figure 2.

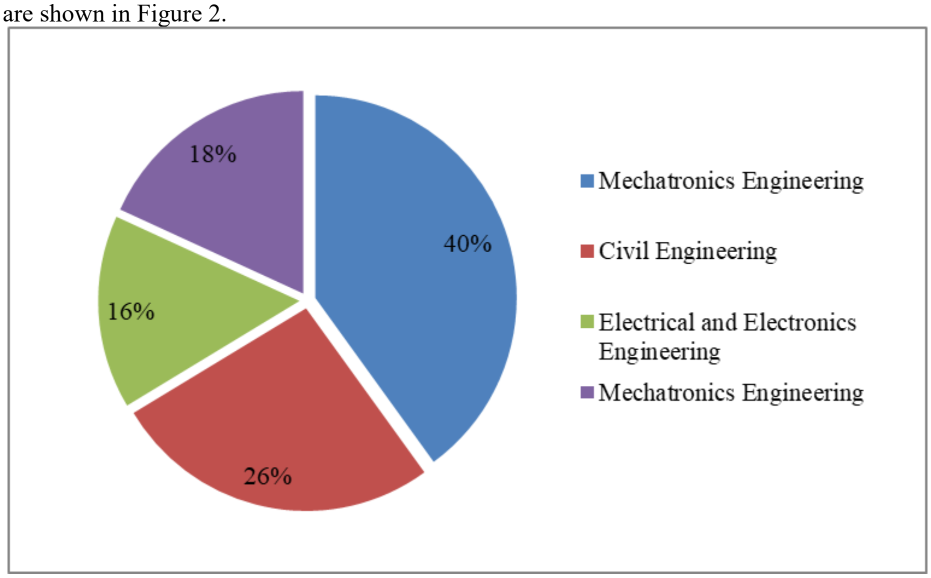


Figure 2: *Course Studied by the Respondents*

The respondent stratified by sex, 77% were male while 23% were female. Studies have indicated that male and female students have different spatial abilities in learning engineering drawing. However, available data are not explicit on whether male and female students and teachers have different learning and teaching styles.

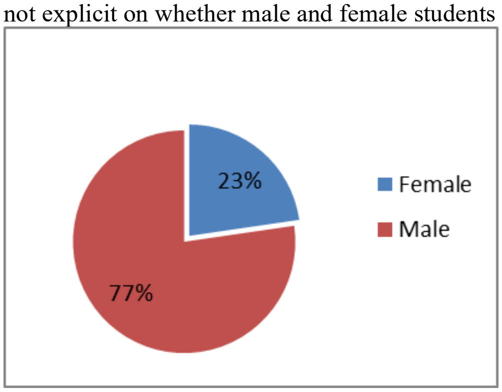


Figure 3: *Gender of the Respondents*

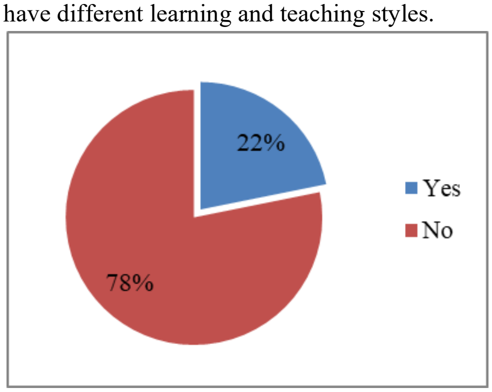


Figure 4: *Prerequisite Knowledge of the Respondents*

Also, the respondents were stratified based on prior knowledge. It was established that 78% have no previous knowledge of engineering drawing from a random sampling of students taking engineering. In comparison, 22% had a basic understanding of engineering drawing acquired from high school. This predisposed knowledge was vital as it influences students' learning styles, speed, and the adopted teaching strategy.

The study established that curriculum for all engineering degrees had a unit on manual engineering drawing, which was offered in the first and second years of study. Subsequently, CAD programs were offered to enhance students' design skills.

To establish the usefulness of manual engineering drawing, the study asked students whether they had applied manual engineering drawing concepts and skills in real life. This question was essential as its perceived usefulness influences' the student's learning attitude. Figure 5 shows that 76% had applied ED skills in the real-life situation while 24% were yet to use ED skills in a real-life situation.

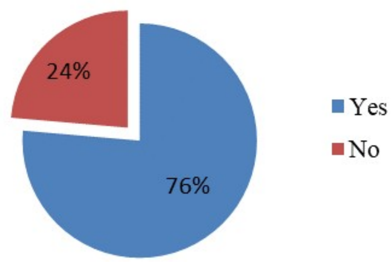


Figure 5: *Application of Engineering Drawing skills in Real Life*

4.2 Student views on frequently used teaching medium in engineering drawing.

The students were asked to indicate the frequently used mediums while teaching engineering drawing. The feedback determined that lecturer notes on power point slides were the most commonly used media at 70.4% while the list preferred method was radio at 0% followed by podcasts at 0.9%. 62% of the respondents cited smartphones, computers, and the internet, while 49.1% cited print texts. Augmented reality, which involves using CAD programs, was quoted by only 5.6% of the students as being used in class. This data only indicates medium used but did not indicate the frequency of use. The frequency is as shown in Table 1.

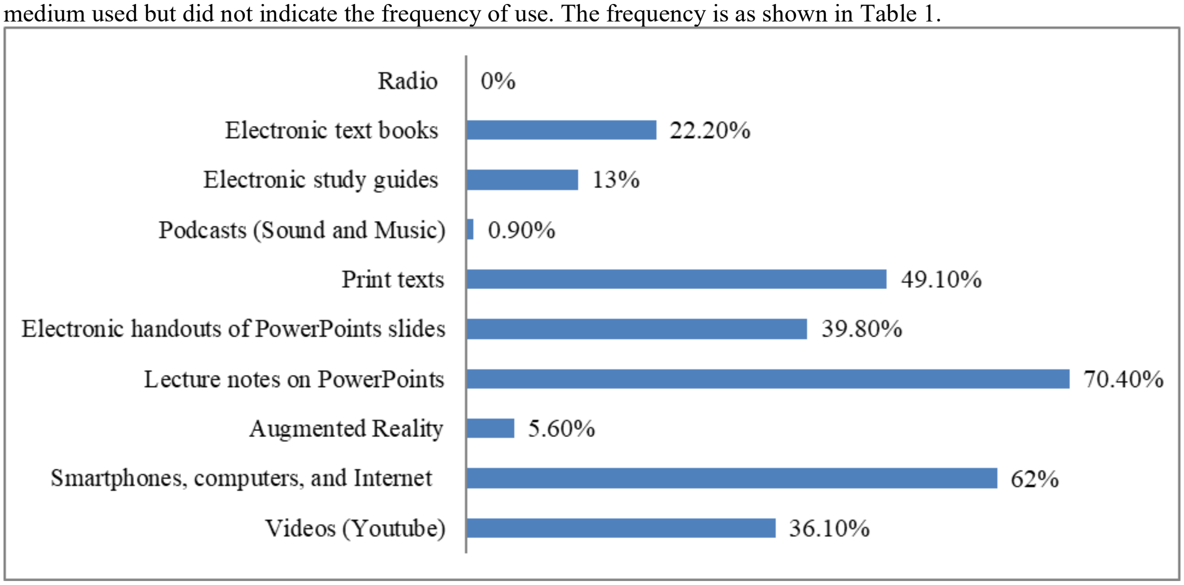


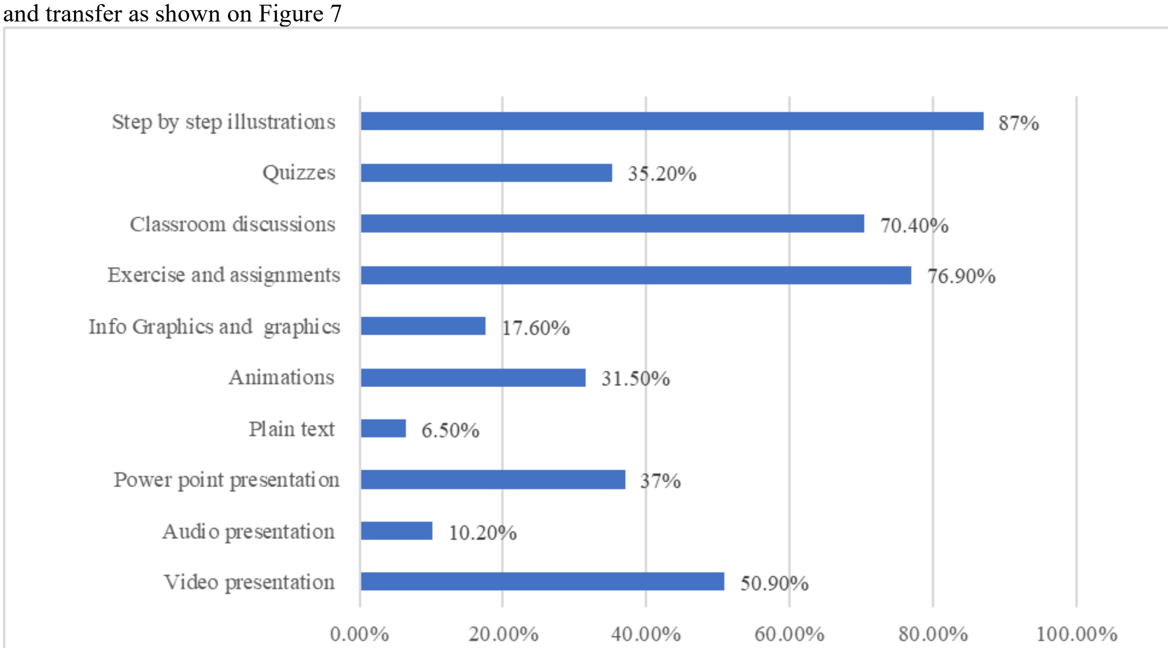
Figure 6: Multimedia used to Teach Engineering Drawing

Table 1: *Frequency of use of selected teaching media in Engineering Drawing lessons*

Teaching medium	Frequently used	Rarely used	Not used at all	Total(N)
Podcast (sound and music)	3	42	65	110
Wall charts	4	60	46	110
Augmented reality	18	38	54	110
Videos (YouTube)	21	50	39	110
Real design model	34	54	22	110
Smartphones and Internet	47	47	16	110
Electronic handouts of PowerPoints slides	49	44	17	110
CAD software	52	45	13	110
Lecture notes on PowerPoints	63	38	9	110
Print-text	65	32	13	110
Free hand sketching	71	36	3	110
Drawing sets and tools	73	34	3	110
chalk/whiteboards	94	10	6	110

The teaching media was frequently used when 50% +1 (56 respondents) of the students indicated the same. The remaining aids will be considered as not being used frequently. Media that is rarely used does not make much educational impact on learning outcome achievements. From Table 1, chalk/whiteboard is the most commonly used media. This finding is followed by drawing sets and tools, freehand sketching, print text, and lecture notes on PowerPoint.

At the same time, the study investigated what facets helped then students learn hands engineering drawing. The purpose was to get what the student perceived or found aiding much in enhancing competency acquisition and transfer as shown on Figure 7



Note. N=108

Figure 7*: Facets that Help Students Learn Engineering Drawing During Lessons*

Most of the students at 87% felt that step-by-step illustrations of a drawing procedure aided them much to gain the required competency. Also prominently mentioned were exercises and assignments at 76.9%, classroom discussions at 70.4%, and video presentations at 50.9%. The students felt that plain text at 6.5% and audio presentation at 10.2% were of least impact in aiding knowledge acquisition and transfer.

After learning a competence, one must remember and even apply the learnt skills in a new situation. The study sought the students' perception from their own learnt experience, which aided them most in recalling or remembering what they had learned. The results are presented in Figure 8.

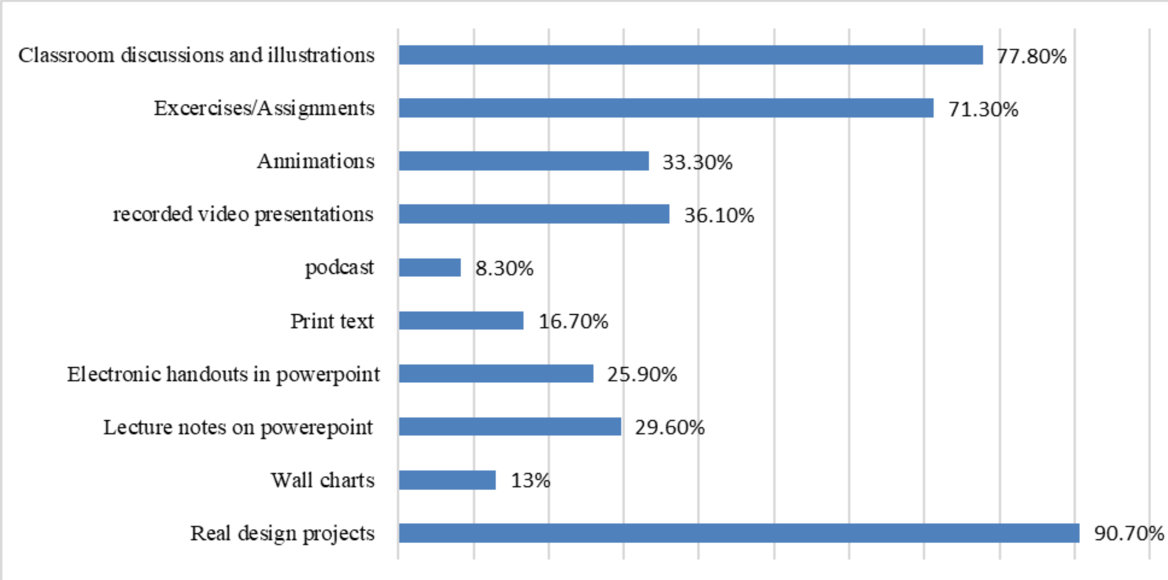


Figure 8: *Mediums that Increase Remembrance of Engineering Drawing knowledge*

A majority of the students at 90.7%, felt that when the teaching involves designing real projects, they remembered much of what they learned. Also, at 77.80% and 71.3% of the students indicated that classroom discussions involving step-by-step illustrations and take-home/classroom exercises/assignments aided remembrance, respectively. The list metioned was podcast at 8.3%, wall charts at 13%, and print text at 16.7%.

To triangulate the data in figure 7 and Table 1 students were asked to select mediums that assisted them in gaining most of their engineering drawing and design skills. Prominently selected in helping students to achieve much of the engineering drawing skills is the internet having 79 (71.8%) respondents. What appeared revolutionary is that more respondent at 61(55.5%) and 52(47.3%) indicated that they gained much from self-study/discovery and friend through discussions, respectively, than from lecturers at 37(33.6%) respondents. From the data, 36 respondents felt that they gained very little from textbooks, which was the highest.

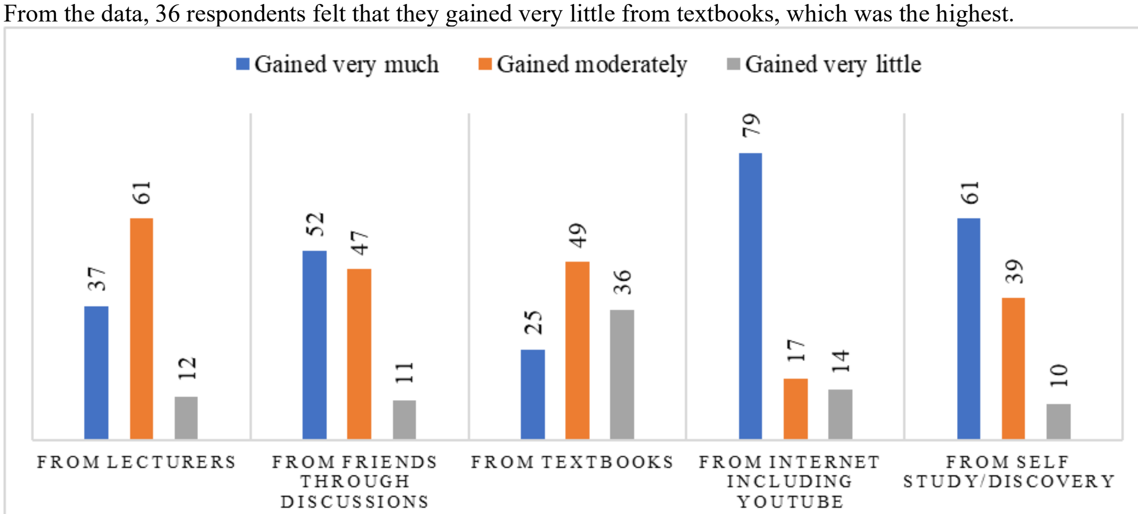


Figure 9*: Medium that Assisted Students to Gain Much of their Engineering Drawing Skills*

5. Discussions

This section aims to discuss some of the factors that, in the view of the student, teachers, and alumni, enhance the teaching and learning of hand engineering drawing in tertiary institutions. Written comments from the survey and transcribed spoken interview comments are included.

5.1 Demographical information of the engineering students

From 198 targeted students, 110 respondents filled up entirely and returned the survey questionnaire. The most significant percentage of 40% were drawn from mechatronic engineering, 26% from civil engineering, and 18%

and 16% from mechanical engineering and electrical engineering. The respondents were stratified by sex, 77% were male, while 23% were female. Studies have indicated that male and female students have different spatial abilities in learning engineering drawing. However, available data are not explicit on whether male and female students and teachers have other learning and teaching styles (Leopold et al., 2001).

For this reason, this study did not treat female and male students differently. All the study subjects were given equal treatment and were assumed to have uniform special abilities. Also, the responses were stratified based on prior knowledge. It was established that 78% had no previous knowledge of engineering drawing from a random number of students taking engineering. In comparison, 22% had basic prior knowledge of engineering drawing acquired from high school. This finding was significant as predisposed knowledge influences students' learning speed and the teaching strategy to be adopted. Prior knowledge helps to decrease cognitive load leading to good learning performance (Tong et al., 2020). This was controlled by testing on content that is not covered in the high school curriculum, thus having all learners at a consistent competence level.

5.2 The usefulness of manual engineering drawing

To establish the usefulness of manual engineering drawing, the study asked students whether they had applied manual engineering drawing (ED) concepts and skills in real life. This question is important as its perceived usefulness will influence the student's attitude while learning the subject. As shown in figure 4, it was established that 76% had applied ED skills in a real-life situation while 24% were yet to apply ED skills in a real-life situation. Also, even though the students involved in the study could easily be referred to as digital natives, they all believed that manual engineering drawing played a key role in enhancing their understanding of engineering drawing concepts. Thus, they appreciated being taught manual engineering drawing. Their observations agree with Dale; the bottom of the Cone represents "purposeful experience that is seen, handled, tasted, touched, felt, and smelled" (Dale, 1954, p. 42). These experiences develop spatial abilities (Leopold et al., 2001). Therefore, this study makes a case that manual engineering drawing should be retained in the engineering curriculum as its very relevant. Still, the approach to teaching it should be digitalized to improve the students' direct, purposeful experience. This is also adopted by (Leopold, 2005) in his paper geometry education for developing spatial visualization abilities of engineering students. From the lecturer's focus group discussion, the following quote summarizes the feeling of the discussants:

> *"We can reduce the number of traditional methods of drawing units in the curriculum and in favor of more emphasis on CAD-CAM or AutoCAD. However, we should not completely do away with the manual engineering drawing as it provides the foundations and basics of what they will use when learning CAD."*

5.3 Teaching medium used in engineering drawing

Lecturer notes on PowerPoint slides were the most commonly used media at 70.4%, while the list preferred method was radio at 0%, followed by podcasts at 0.9%. This approach to teaching engineering drawing will not lead to the effective acquisition of learning outcomes. This finding is supported by Dales cone of experience as it falls on the abstract delivery of content (Dale, 1969). From the Dale cone of experience, teaching activities of engineering drawing should aim to provide substantial knowledge based on a direct, purposeful experience or its absence; simulations could be adopted. This finding is contrary to what is assumed by engineering drawing lecturers, as they frequently wrote notes and sketches on the chalkboard and provided students with textbook handouts. This point came out explicitly during FGD as shown;

> *"teaching aids is very important and each lecturer should use them to deliver engineering drawing lessons .... getting software or a Multimedia to teach with is a toll order, you know what management is saying, "oh we don't have enough, don't have these .... We, therefore, do with textbook handouts only in most of the cases."*

The demonstration came a distant third in the frequency of use despite the students feeling that step-by-step illustration aided them to understand engineering drawing better. Step by step illustration could be best achieved by using direct, purposeful experience or simulations. Augmented reality is a good way of using simulations to teach. Despite easy accessibility of basic augmentation software built in CAD software, it was rarely used to teach manual engineering drawing. This view of manual engineering drawing and CAD engineering drawing as mutually exclusive bodies of knowledge has influenced the delivery of the two areas to be conducted in a mutually exclusive manner. This finding is captured from the FGD as narrated below;

> *"From the student's point of view, I would say it's more of the technology, because sometimes when you're, especially when you're doing the introduction parts of what, you have to use the T- square as the traditional way of doing it. They usually question whether this is the type of thing they will be doing when they go to work and then when you tell them. No, that at some point, you'll be taught how to use CAD. So, using your computers using the software as they tend to wonder, why do I need to know how to hold a T-square, how to do it manually, if there is a software that can make things easier for me. And*

given that we're living in a dynamic world and technology's changing and everything is changing. So although I don't have a specific case of a student saying that there is a challenge out, but that is the biggest question. Why do they have to use T-squares if eventually, they'll be using software's?"

From the FGD, no relationship is drawn between the two, so one is not considered a prerequisite. Augmented reality should be used to create a placebo effect of having a direct, purposeful experience. Thus, CAD software should be used as teaching and learning materials when teaching manual engineering drawing. This way, the delivery of manual engineering content will be digitalized. At the same time, students will be able to appreciate both manual and CAD engineering drawing as they will be able to see and experience the relationship between the two. Also, in a class of about 50 students, each will manipulate and interact with the digital aid individually. The use of digital media was mentioned, but in most instances, it was used to transmit textbook handouts and written assignments from lecturers to students. Rarely were they used as instruction vehicles in the classroom setup.

5.4 Facets that Help Students Learn Engineering Drawing During Lessons

When designing engineering drawing teaching strategy, lecturers should consider using multiple intelligence theory concomitantly with dale cone of experience and remembrance cone based on this study results. Multiple intelligence theory advises that when designing teaching strategies, we should first consider the learner, the expected outcomes, and the different bits of intelligence that students process. To achieve this, Dale proposes that we design teaching strategies that employ as many senses as possible. From the results, students learned based on step-by-step illustration, classroom discussion, exercise and assignment, and video presentation. All the mentioned develops higher levels of skills in the cognitive domain. The psychomotor domain levels should be used to design the tasks when it comes to assignments. The lessons should start from imitation, which involves the teacher offering a step-by-step illustration as the student imitate what the lecturer is demonstrating. This should be followed by the students being given class exercises to work on as the lecturers offer assistance or follow a manual that provides step-by-step guidance. From the results in figure 7, the lecturer should provide more than three assignments to develop competence. Most students indicated that they remember most when discussing, doing assignments, and designing real projects. More than three assignments will aid the students to develop precision, articulation, and naturalization in that order. This can only be achieved through repetition. Interesting to consider is that students felt that they learned or gained more from self-study through mediums like the internet and from discussions with fellow students than from subject lecturers even though they found their teachers competent. The implication on strategy design is that more assignments should be provided, and learning materials should be provided using multimedia.

6. Challenges faced during engineering drawing delivery

During the focus group discussion, lecturers viewed loading and timetabling of engineering drawing as a significant challenge. This point is summarized by one of the FDG discussants as follows:

"when we were in GAMA (pseudonym) we had both the drawing office and we would give students portable drawing boards because the drawing room was very small. ……to use in their hostels to do assignments, because the workspace in the drawing room was not enough, and the drawing tables were not enough, …. On the lecture I talked about sometimes, we had to split the class as subject teachers without knowledge of the university management. So, if your allocation is like five hours a week, you see like you'd be undertaking like 10 hours since you have split the class into two. But you see the University doesn't recognize the second five hours. This so because we have an internal policy that when students exceed more than 120 is when you can split them into two groups. This is so regardless of whether the unit is technical, mathematical, design/practical or theoretical. ….. I think we need to come up with a policy, especially when it comes to drawing, that we have at most 50 students, per class? …"

This was the case as engineering drawing was classified a design unit, it was loaded and timetabled with regular hours just like all the subjects. In the universities that took part in the FGD, engineering drawing was loaded and timetabled for three hours instead of five hours which was recommended. Also, the timetable failed to indicate students' learning time. This is when students should be allowed access to the design rooms to complete assignments and do personal studies.

Also, prominently mentioned were the size of drawing classes and the availability of drawing facilities. Class size influences the types of cognitive skills a student is exposed to in any course (Raimondo et al., 1990). The large class size brings about pedagogical nightmares mainly when analyzed from blooms cognitive domain prism. Engineering drawing being a design and highly practical unit, it calls for lessons to be delivered in small class sizes. This will allow the course lecturer sufficient time to develop the middle-level skills of application and analysis and, most importantly, the high-level skills of evaluation and creation based on the cognitive domain. When the class size is large, the subject lecturer is restricted to only deliver the lower levels of knowledge and understanding (Raimondo et al., 1990). The effect of class size on cognitive skill development is the primary link between performance in Engineering drawing courses and engineering drawing class size. This was captured in the FGD as follows:

> *"I would say the big classes are quite a big challenge. The level of spatial visualization among the students is very low. Sometimes you'd find students who have completed all the engineering drawing units still have poor spatial visualization when it comes to interpretation of engineering 2D and 3D drawing".*
>
> *"The Room is quite big to hold upto 120 students but the students at the back cannot comprehend the drawing being illustrated on the white board. This has been the case for rooms having not integrated a display mechanism and curved rooms that are obstructed by columns what the lecturer is illustrating."*

The integration of digital media to deliver engineering drawing lessons can raise the number of students per class but not make it a large class size. This is because the technology just aids the lecturer in delivering a lesson, but it does not replace the lecturer. Therefore, with this aid, a particular factor could raise the number. More research needs to be done to establish the approximate exact number.

7. Conclusion

Large class sizes negatively affected the achievement of cognitive domain middle and high-level learning outcomes. Also, limitations in drawing rooms and facilities and improper loading and timetabling of the engineering drawing units negatively influenced learning outcomes. The engineering drawing lecturers felt that engineering drawing classes should be capped at a maximum of 70 students. The study proposes further research to establish the optimal number of students per lesson. On the teaching strategy, a learner-centered strategy that involves class step-by-step illustration, class exercises, and discussions, provision of more than three assignments per task and using multimedia should be adopted. To develop the best teaching strategies, lecturers should consider using multiple intelligence theory with the dale cone of experience and remembrance cone.

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