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Scaffolding Preservice Engineering Graphics and Design Teachers' Interpretation Ability of Assembly Drawing

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Abstract
This study focuses on first-year Pre-service Engineering Graphics and Design teachers (PSEGDTs), as studies on the spatial-visual abilities of PSEGDTs is absent in mainstream spatial-visual literature. This paper reports on a teaching resource designed to support PSEDGTs' reading and interpreting AD. Data is presented in response to the following research questions, Does the comprehension of Assembly Drawing by PSEGDTs, alter after exposure to the teaching resource, if so how and, what contributed to the change? Twenty-one first-year PSEDGTs who participated in the authors' more extensive study were deliberately chosen to partake in this research. Individual interviews and focus group interviews were employed to develop data. Content analysis was embraced to elicit meaning from the data. The results highlight a significant improvement in most first-year PSEGDTs ability to read and interpret assembly drawings after the teaching resource. The research proposes an innovative strategy for teaching and learning of assembly drawing.

Keywords: Assembly drawing, Interpreting, Reading, Spatial-visual skills, Teaching.

1.0 INTRODUCTION

Spatial-visual skills play an essential role in reading and interpreting engineering drawings (1 and; 2). Studies by Authors [3, 4,5 and 6] confirm that engineering students emerge from the schooling system with poorly developed spatial-visual ability. Possible reasons for poorly developed spatial-visual ability is assessments and examinations at school value written text, which facilitates the expansion of verbal, written and numerical skills instead of spatial-visual skills. Poorly developed spatial-visual skills and high failure rates among learners have been explicitly linked to the learning environment and traditional teaching methods in engineering graphics and design (EGD) classrooms [7 and 8]. Concerning the learning environment Branoff *et al*, [8] explains it ought to be conducive for learners to engage in hands-on experiences of drawing activities, application of drafting standards and conventions, creating and modelling 3D images from 2D blueprints to hone in their spatial skills. These scholars also elaborated that traditional teaching methods do not link drawing activities and the design process conspicuously [7 and 8]. It is suggested that the best pedagogy ought to be selected for effective teaching and learning of assembly drawing. Moreover, the teacher should have explicit content knowledge and relevant teaching strategies to make the subject matter accessible to students. In other words, teachers ought to know how to adapt the content and use the appropriate teaching methods so that students understand and can engage with the content. Thus, in this paper, we put forth the notion that teacher practice and students experiences of learning are invaluable "resources" within the teaching and learning context that can be used as a potential for student participation and engagement. Therefore, the argument advanced in this research is that spatial-visual skills are not innate but can be developed over time by scaffolding. Scaffolding is a teaching method, which can be used to direct students to complete the activity independently [9]. It is also worth noting that studies on the spatial-visual ability of PSEGDTs have not been studied in mainstream spatial-visual ability literature. This study responded to the following question: Does the comprehension of Assembly Drawing by PSEGDTs, alter after exposure to the teaching resource, if so, how and what contributed to the change?

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2.0 LITERATURE REVIEW

Engineering drawing is a form of visual communication where lines and symbols are used to communicate thoughts rather than verbal descriptions [10].

To be able to read and interpret engineering drawings and solve problems requires students to apply rules and conventions and, more importantly, to have a well-developed sense of spatial thinking to represent and manipulate information [10]. Sotsaka [11] asserts to engage in the aforementioned activities and to represent spatial information students need support and scaffolding.

Meneghetti, Borella, and Pazzaglia (12] elaborate that learners need to acquire appropriate tools to process, read and interpret engineering drawings. Similarly, Metraglia *et a*l, [13] argue that visualisation skills can be improved by appropriate training. Therefore, students ought to gain practical hands-on drawing and designing skills to visualise how different components fit and work as a unit via appropriate teaching.

In planning the teaching resource to promote PSEGDTs' comprehension of Assembly Drawing, we were guided by the scholars mentioned above and the challenges identified among PSEDGTs when they were given tasks on AD [14]. According to Sotsaka [14] the challenges include: the lack of ability to process information in the title block; inability to understand EGD nomenclature, failure to make a distinction between orthographic and isometric projections, incompetence to discern spatial relations between objects, helplessness to mentally manipulate objects, distinguish between different types of lines and apply SANS code of practice.

3.0 THEORETICAL FRAMEWORK

This study is framed by Balaban, [15] notion of scaffolding. According to Balaban [15], scaffolding is an instructional resource through which the teacher guides and supports student learning via focused activities/tasks and provides students with the tools they need to learn. Tools are essential to effective learning. Tools can be designed to support learning specifically. For example, specific disciplines have specialised symbolic representation and nomenclature as part of their discourse that students need to learn to engage with the subject matter [16]. Every well-developed area of human activity has evolved its own set of specific symbolic tools to support thinking and communication. Children are not born with these tools–they have to be developed in them over time. The teacher uses what Vygotsky recognised as crucial tools (words/ symbols) to convey ideas, reinforce learning, and support the development of desired links between concepts. Krajcik and Blumenfeld [17] assert that the use of supportive scaffold resources helps and accelerates the student's task of learning. Scaffolding thus emphasises the collaboration between the teacher and the learner in constructing knowledge and skill. In other words, it is a two-way process rather than a unidirectional process from teacher to student. There are various techniques of scaffolding learning such as demonstration, dividing a task into more uncomplicated steps, providing guidelines, keeping attention focused, as well as providing examples and questioning [18 and 19].

4.0 METHODOLOGY

This qualitative case study embraced a transformative paradigm as the intention was to change how PSEGDTs comprehend AD. Twenty-one first-year PSEGDTs who enrolled in training as teachers of EGD at the University of Technology were purposively selected for this study. Permission to conduct research was obtained from the relevant offices and the participants. Pseudonyms were used to protect the identity of the participants. Each participant was referred to as P1 etc.

Data were generated in four stages in the original research project. For this paper purpose, attention is paid to data generated via interviews and focus group interviews, which occurred after the four weeks of the exposure to the teaching resource, in response to the challenges PSEGDTs encountered when comprehending AD.

The interview questions paid attention to does their interpretation ability of AD change due to the teaching resources, if so, how. The focus group interview focused on their account of the teaching resource they experienced. The video recordings from the interviews were a precise word for word transcription. All transcripts were sent to participants to verify their accuracy.

Content analysis was used to interpret the data collated. This means that transcripts were read many times to identify what was said. After that, keywords and phrases were noted and regrouped into codes and themes. Finally, data obtained from the interviews and focus group interviews were juxtaposed to note how their reading and interpreting of AD was scaffolded.

5.0 RESULTS AND DISCUSSION

The findings in response to the research questions: Does the comprehension of Assembly Drawing by PSEGDTs, alter after exposure to the teaching resource, if so, how and what contributed to the change are presented next.

Does the comprehension of assembly drawing, by PSEGDTs alter after exposure to a teaching resource, if so how and what contributed to this change?

Our findings reveal that PSEDGTs comprehension of AD altered after exposure to the teaching resource in the following three ways: the nomenclature of EGD, processing details in the title block, ability to measure, visualise, manipulate objects and assemble parts. In the section that follows, each of these categories will be discussed and the

factors that contribute to the change in PSEGDTs comprehension.

5.1 Understand the nomenclature of EDG

EGD has specific terminology associated with it, and if students do not understand these key terminologies, they cannot read and interpret information from visual texts. The excerpts below depict how the teaching resources made available to first-year PSEGDTs the "tools" required to cope with EGD and transformed their understanding of the nomenclature of EGD.

> *we were introduced to the terms, that we ought to have learnt at school, terms that prevented us from responding to the questions in the exams and tasks expected of us, but now that I understand these terms like oblique view, top view, isometric drawing, orthographic drawings, I can access the information in the tasks. Interview*, P7- interview

> *He has spent a lot of time equipping us with the basic terms in EGD, which we did not understand in high school, gave us many chances to work with the different views individually and in a group he has even provided us with pencils and equipment that we need for EGD*" P13 (individual interview)

Comparable testimonies arose from the focus group interviews.

> *The lecturer has an expectational understanding of EGD, explained what each term meant, then showed us in drawing, he also used a you-tube video, it all makes sense, I can identify different view, projection, lines. I can complete the task that I could not do previously*" P12 – focus group interview

The excerpts above highlight that once PSEGDTs were empowered to understand the terminology associated with the visual text of AD, they could process information in the text provided, differentiate between the projections and sections information. The lecturers' mindfulness of PSEGDTs' background knowledge of AD (or lack thereof) was used to structure the teaching resource and activities for the best possible learning. In being taught the nomenclature of EGD and how to distinguish between different views, the first-year PSEGDTs were equipped with the "tools" required to make sense of AD. The strategy mentioned above to teach reading and interpretation of visual text is supported by Pearson *et al*, [20]. In other words, teaching PSEGDTs to understand the nomenclature of EGD is a vital tool that undergirds their ability to process graphical information.

5.2 Making sense of information from the title block

Initially, most (18) PSEGDTs could not figure out the information contained in the title block and apply it appropriately when constructing diagrams. However, after engaging with the teaching and learning resources provided, PSEDGTs could access the information contained in the title block as is indicated in the excerpts below:

> *After paying attention during the lecture and engaging in all the short tasks during the lecture, I can list and recognise the information found in the title, the description of the object in the AD; the type of projection; the drafting standard used; and the scale of drawing and dimension. and know how to use in to construct my drawing, this lecturer is easy going and approachable, you can ask questions.* P5- interview

> *Understanding the information about the description of the object, type of projection, drafting standard, scale and dimension in the title box has improved my drawing, the feedback I got from the lecturer is encouraging and I am now confident of the content in EGD*. P2- interview

> *The lecturer is easy going, he knows his content and the curriculum, you can ask as many questions about the lesson, and he takes the time to explain, I'm starting to enjoy it, he gives feedback to show where you are wrong EGD, In school, you could not ask questions, the teacher just taught and left, he was not bothered if we understood.* P1 (individual interview)

> *Previously I would not respond to visual texts-now with the help from this lecturer, and him explaining and giving up many short tasks, I have had many opportunities to apply what I learnt I can do this as I can read and make sense of the information and then start my drawing.* P15 Focus group interview

The data revealed that first-year PSEGDTs could use the pedagogical resources available to them to read, make sense, decode and deconstruct that data from the title block. They could link the details provided in the title block to the visual text provided and engage with the task. It is visible that processing the details contained in the title block gave PSEGDTs the confidence to discern the relationship amongst the text in the title block, the visual text and the task. The data confirms that understanding the details within the title block forms the platform for accessing and interpreting information provided and linking it to the visual text. This finding aligns with Azodo [21] and Akasah *et al*,

[22] studies, which confirm that students need to be taught to read and interpret information.

Additionally, it is evident in the above excerpts that first-year PSEGDTs encountered a favourable learning environment that contrasts with the one they had in high school. Learning in this instance is viewed as a symbiotic relationship, where both first-year PSEGDTs and the lecturer tried to value, recognise, and converse with each other to create a safe, trusting learning space where students feel encouraged and motivated [23]. Furthermore, the testimonies show that students feel safe, respected and confident in a conducive relaxed classroom environment, where they are warmly welcomed and can ask questions to advance their ability to make sense of assembly drawings. Thus, fostering an atmosphere conducive to learning will boost intellectual activities, enhance learning, encourage cooperation, promote growth and development among students. A study conducted by Darling-Hammond et al. [24] reported that learners' learning is sculpted by the learning environment, the rapport between students and teachers and opportunities to learn.

Moreover, these scholars argue that emotions have the ability to enable or inhibit learning: positive emotions facilitate learning and negative emotions inhibit learning. This in-depth insight of PSEGDTs' proficiency or lack of ability to read AD is the key to espousing teaching methods that facilitate and scaffold student learning. In the above example, teaching and learning are not understood as separate entities but rather as an interdependent and connected activity, in which the way of teaching sculpts the way of learning and the level of learning flows back into the way of teaching. The above finding are aligned with that of Coe, et al, [25] on the effectiveness of teachers, who identified content knowledge, learner knowledge and familiarity with the curriculum as the three most important factors affecting students' progress.

5.3 Ability to measure, visualise, manipulate objects and assemble parts

All 21 first-year PSEGDTs initially struggled to measure, visualise, mentally rotate objects, observe the relationship between parts of an object, and group the parts on a drawing. Spatial visualisation is an essential skill in EGD, needed for the creation of mental images. Visualisation is a mental comprehension of virtual information. Thus, for PSEGDTs to visualise objects, they must be able to see objects from different perspectives.

> *The lecture used models, illustration, videos to help us understand the different views and projections, we also had the opportunity to engage in sketching objects so we can imagine, mentally move objects around and put them together, I also learnt to measure accurately my confidence is high.* P11 interview.

> *The multiple short tasks, clear explanations, step by step guidance to demonstrate what needs to be done or how to deconstruct the text and respond to the question posed, opportunity to sketch assembled object, parts, models have helped improve my ability to visualise parts not drawn, manipulate objects and assemble them and to apply the rules, conventions and standards, I learnt how to use a ruler correctly.* P4 Focus group interview

> *He compliments and encourages us and our performance of the task at hand- constantly gave us feedback, he asked many questions to redirect and guide us whenever he saw gaps in our solutions.*

The increase in PSEGDTs proficiency to measure, visualise, mentally rotate objects and assemble parts of the object is evident in the above testimonies. Furthermore, these excerpts highlight the multiple ways in which the lecturer scaffolded the PSEGDTs ability to visualise, manipulate objects and assemble parts such as sketching, demonstrations, video, illustrations, demonstrations, explanations and guided discovery. PSEDGTs were also introduced to a systematic way to analyse visual information and use a ruler correctly to measure. Models were used to help PSEGDTs to visualise and thus nurture their spatial ability. The finding from this study in terms of teaching strategies used to promote visualisation, measure accurately, manipulate objects and assemble them is in contrast to Garmendia *et al* study [26]. According to Garmendia et al, [26] poor teaching methods contribute to lack of visualizing ability. PSEGDTs were provided with opportunities to sketch models from different views. Sorby, *et al*, [27] noted that that spatial ability can be enhanced by sketching and drawing. According to Delahunty *et al* [28] and McDevitt *et al*, [29] students who engage in hand-drawing activities are the capable to "see" ideas mentally and convert them into drawings [30 and 31]. This means that sketching aids abstract concept representation and allows students to refine their cognitive processes and explore new concepts [28]. By engaging in manual drawing, students acquire skills in seeing and manipulating 2D and 3D drawings and transposing images in mind before that on paper [32]. Likewise, McDevitt *et al*, [29] have argued that drawing objects correctly from different views requires an understanding of the relationship between shape and form. By engaging in sketching, PSEGDTs were required to develop accuracy skills, expanded their knowledge of the

fundamentals of constructing a drawing, applying rules, conventions and standards.

It is also worth noting that the lecturer broke down the learning activities into smaller or shorter tasks. According to Darling-Hammond *et al*, [24] many short activities permit teachers to give each student additional feedback and engage in more in-depth teaching practices. By providing feedback and making recommendations for improvement, students are motivated to improve the efforts in AD. There are similarities between these results and that of Hattie *et al* [34], who noted that detailed and timeous feedback create opportunities for self-assessment to improve skills and competencies and allow reflection on learning [34]. The lecturer also used questioning as a strategy to guide students during AD. These results concur with the findings of previous studies conducted in professional design and assembly settings and school settings, which show that assembly is supported through dialogic questioning [35 and 36]. These results highlight how this lecturer uses questioning as an excellent strategy to scaffold and guide students during EGD. These results correlate with the research conducted by Stables *et al*, [36], who noted that questioning can guide learners' next steps and help teachers establish what the learner is doing or thinking.

Additionally, shorter assignments ensured that PSEGDTs had many chances to learn and master critical terminology, practice and develop the skills necessary to improve their spatial visualization skills development, and be successful in completing the assignments.

By building up the learning of PSEGDT with smaller tasks that gradually increase in difficulty, PSEGDT obtain the know-how and understanding of what they can do with assistance and tasks that they cannot do on their own. This "scaffolding" refers to the support provided that allows first-year PSEGDTs to become proficient at tasks outside of their cognitive ability quickly. Scaffolding in this study embraced affective and cognitive aspects. The cognitive aspects include giving academic support and feedback timeously. The affective aspects entail providing compliments, motivation, encouragement and assisting students to recognise the habits of mind needed to become skilful in understanding the importance of the task and how their competence could unfold [37]. The above findings align with Schut *et al*, [34] notion of praise as scaffolding learning. When praise is directed at the student, it may be effective for building a trusting relationship between the student and lecturer.

6.0 CONCLUDING THOUGHTS

The findings indicate that the comprehension of assembly drawing by first-year PSEGDTs improved following their exposure to the teaching resource. The advancement observed in PSEGDTs ability to make sense of the nomenclature of EGD, details from the title block, their ability to distinguish the orthographic and isometric projections and visualise different views, mentally manipulate objects, to measure accurately, recall the SANS code of practice, assemble parts and draw different lines types. The above changes in their ability to comprehend AD could be attributed to their experience of the teaching resource used. Our findings resonate with our argument that spatial-visual skills are not innate but can be developed over time by scaffolding. Based on the finding of this study, a model for connecting the teaching and learning of assembly drawing in engineering graphics and design is suggested.

6.1 Model for connecting teaching and learning of AD in EGD.

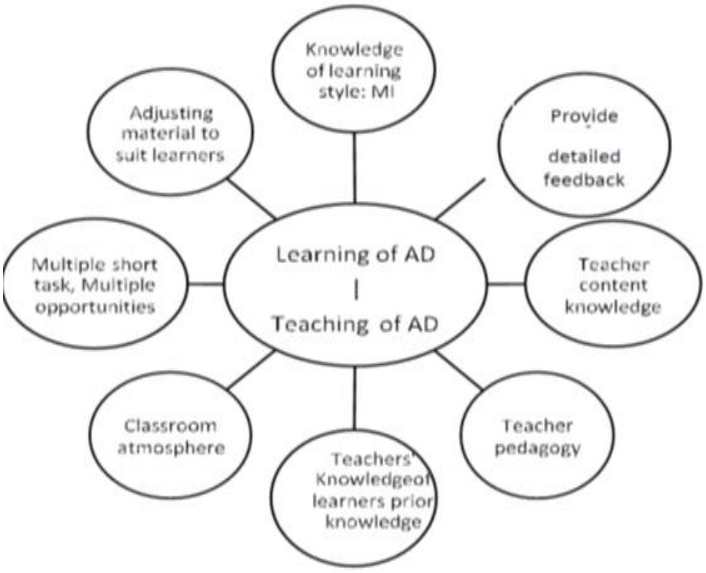

Figure 1: Model for connecting teaching and learning of AD in EGD.

The model above saw teaching and learning as an intrinsically interconnected process. The teacher's role is central to the process of teaching and learning, as the planner and mediator of learning. Thus, the teacher must have the in-depth content knowledge to plan learning and appropriate pedagogical skills to facilitate learning. This means that the teacher needs to know which information or skills students will require to engage with specific content, use multiple strategies to scaffold learning, be cognisant of learners learning style and prior knowledge (or lack of knowledge) that is carried with them, create an environment that supports learning by providing detailed feedback to student (on how they can improve their drawing/design), multiple opportunities to learn and practice skill required and acquired.

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