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An Experiential Learning Approach for Enhancing Performance of First Year Engineering Students in Engineering Graphics Course

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***Abstract*— Engineering Drawing is a crucial and mandatory course for first-year engineering students. This subject plays a vital role in enhancing students' ability to visualize, imagine, and effectively illustrate concepts. It aids them in expressing their ideas clearly and swiftly, comprehending drawings produced by others, and devising effective designs. The curriculum covers essential topics like projection, sectioning, and the development of solids such as prism, pyramid, cylinder, cone, cube, and tetrahedron. These topics help students develop the ability to conceptualize, visualize, and create drawings according to specific requirements. The achievement of learning outcomes related to these subjects is hindered by the challenges faced by first-year engineering students, including their lack of fundamental knowledge in technical drawing and limited abilities in imagination and visualization. As a result, their performance in these areas tends to be subpar. To address this issue, a practical "learning by doing" approach is introduced alongside traditional classroom instruction. This strategy aims to boost the visualization, imagination, and technical drawing proficiency of first-year engineering students. This article outlines the author's endeavors to enhance students' visualization, imagination, and drawing skills. The focus is on involving students actively in both classroom and extracurricular learning. By methodically incorporating a "learning by doing" approach, there has been a notable enhancement in student engagement, achievement of course objectives, and overall performance in the course assessments.**

The topic of development of solids was completely taught with this method. This activity resulted increase in the CO attainment, active participation and engagement of the students in the class room as well as outside of the classroom. Following the implementation of this activity, there was a substantial rise of 17.30% in the accomplishment of course outcome, coupled with a notable increase of 25.34% in the students' learning index.

***Keywords*— Course Learning Outcome, Engineering Graphics, learning by doing**

***JEET Category*—Pedagogy in teaching learning**

I. INTRODUCTION

In modern engineering design processes, 2D drawings, encompassing plans, elevations, and sections, continue to hold a paramount position as foundational documents. While three-dimensional models offer a comprehensive portrayal of structures, they have not supplanted the significance of 2D drawings in engineering communication and practice. Over time, the practicality of architectural and as-built drawings in capturing a building's current state and functional modifications has diminished. This underscores the imperative of employing drawings that faithfully depict the existing conditions and furnish comprehensive insights for renovation, conservation, and design endeavors(Li et al., 2023)

Engineering drawing functions as a universally accepted technical language for engineers, providing a standardized mode of communication across the global engineering community. Proficiency in engineering drawing empowers engineers to conceive designs, depict them on drawing sheets, and ultimately create blueprints as a precursor to the manufacturing process(Murthy et al., 2015).

In the realm of production processes, a workpiece model stands as a fundamental input requirement. Conventionally, these models are crafted through the utilization of computer-aided design (CAD) software, which could encompass tools like AutoCAD or SolidWorks. This model subsequently undergoes a metamorphosis into a numerical control (NC) program, facilitated by computer-aided manufacturing (CAM) tools like CATIA or ESPRIT. The NC program, in its turn, is employed by a machining tool to actualize the manufacturing of the workpiece. The design and production phases can be perceived as distinct stages or, conversely, harmoniously evolved through an integrated CAD-CAM system(Scheibel et al., 2021).

Perumaal (2018) presented a novel approach to enhancing the learning environment of the Engineering Graphics course for first-year engineering students, with a focus on improving spatial visualization skills. It discusses a range of blended learning activities that aim to bolster students' confidence and address challenges. The study outlines strategies for effective learning, including student engagement, suitable approaches, content alignment, time and resource management, and evaluating activity success, while showing that well-structured activities, supported by appropriate learning resources, lead to significantly improved learning experiences through active learning strategies.

Traditional engineering paper drawings have historically served as graphical representations of products. Presently, numerous

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enterprises continue to rely on these drawings to streamline their production processes. However, with the widespread adoption of CAD/CAM technologies, a multitude of sophisticated approaches such as digital manufacturing, rapid prototyping, enterprise resource planning, computer-integrated manufacturing, concurrent engineering, virtual reality, and mass customization have emerged and gained traction. The effectiveness of these advanced technologies hinges on the availability of comprehensive three-dimensional (3D) solid models of products. The reliance on two-dimensional paper drawings presents challenges when attempting to implement these cutting-edge methodologies. Consequently, the conversion of engineering paper drawings into 3D solid models has emerged as a necessity, facilitating the seamless application of these advanced technologies(Chen & Feng, 2003).

This study investigated the impact of attitude on the learning of engineering drawing among engineering students. The research was conducted at the Federal University of Agriculture Abeokuta, Nigeria, involving 152 participants from all four engineering departments. A self-administered questionnaire, utilizing a 5-point Likert attitude scale, was employed as the research instrument. Data analysis using SPSS 16.0 software revealed that the students displayed a favorable attitude towards engineering drawing both as a subject and in terms of teaching methodology. Their sentiments were uncertain regarding classroom environment and background information, but exhibited negativity towards instructional and educational aspects (Azodo, 2017). (Pando Cerra et al., 2014) investigated the effectiveness of using Web-based CAD tools with self-correction features for teaching engineering drawing, a subject requiring graphical problem-solving. 121 students were divided into experimental and control groups, with experimental groups using the online tools and control groups employing traditional methods. Statistical analysis revealed that a higher proportion of students in the experimental groups not only passed the test but also demonstrated improved scores, suggesting that Web-based interactive CAD tools constitute a valuable enhancement in teaching engineering drawing and related disciplines. This research explored the scope of studying web-based 3D interactive concept maps, incorporating interactive images to aid in comprehending challenging concepts in engineering drawing. It assesses the impact of two learning strategies—2D concept mapping and web-based 3D interactive concept mapping—on learning outcomes and spatial ability. The findings demonstrate that the latter strategy helps mitigate spatial ability limitations, particularly benefiting students with lower spatial skills in constructing robust mental models(Violante & Vezzetti, 2015). This study aimed to investigate the benefits of implementing model-based teaching and learning for the subject of Engineering Drawing among first-year engineering students. A group of 120 students participated, divided into a Control Group taught through traditional methods and an Experimental Group using models for line projection and orthographic projections. The results indicated that the use of models had a notable positive effect on students' academic achievements, as evidenced by improved marks and enhanced concept comprehension based on continuous assessment performance(Selvi et al., 2019). This study utilized Unity development tools to create an augmented reality (AR) application for mobile smartphones. The application showcases 3D structural models corresponding to distinct views of geometric objects, aiding engineering drawing learning. Through scanning and matching views, students experience a merged virtual-real environment, effectively enhancing their understanding of 3D objects in engineering drawing based on positive survey outcome(Yan et al., 2019). Ramatsetse et al. (2023)demonstrated its ability to produce precise 2D curve drawings, outperforming the efficiency of manual drawing methods utilized in software like AutoCAD. Notably, the traditionally time-intensive process of adding dimensions to drawings, which could take hours through manual efforts, was completed in just 2 minutes using computer algorithms. Ramatsetse et al. (2023) revealed a progression of Engineering Graphics and Design (EGD) applications, starting from basic traditional drawing creation and extending to advanced techniques involving three-dimensional drafting, such as computer-aided design (CAD).

II. Methodology and Implementation

The authors introduced a model building activity as part of the solid surface development process in Engineering Drawing. This initiative was aimed at engaging students beyond the confines of the classroom, fostering learning, and enhancing students' imaginative and visualization skills. After covering the basic concepts of the development of solids topics, the individual students were given the various solids with different dimensions. The instructions were given to the students as shown in the Fig. 1.

Course Name: - Engineering Graphics (SH1134) Issue date: - 27th Jan 2023

Submission Date: - 7th Feb 2023

ISE -2 (F Y B Tech)

Title: - Case study on section of development of surfaces

Instructions: -

1. Students are instructed to find their roll no. in appended below list and note down the solid mentioned against their roll no. (for Ex- **2203016**- Pentagonal Prism).
2. Prepare an example/problem of above solid, which includes the projections of section and development separately or combine. Assume suitable height of the object, if required.
3. Physically prepare the section of solid (cut it as per above example/problem) and also prepare its development. (use cardboard like material to make it)
4. Write on it, Title: ISE-II [Case study on development of surfaces], your roll no., name, batch, date.
5. Submit above model to me on or before 7th Feb 2023
6. **Also prepare pdf image of above model and upload it on Moodle, under tab the assignment (upload here ISE-II).**
7. **Name of the pdf file must be as – 2203016_Pentagonal Prism**

Fig. 1. Instruction for Students

The students need to prepare the card sheet model of the given solid. After preparing the model each student was instructed to select the problem from the text book. The students were instructed to take the sectional cut of the model as per the conditions given in the problem from text book. Then the model of solid was developed parallel or radially. After that student need to solve the same problem on the drawing sheet. In the solved problem student need to paste the development of the model on the solution of the development.

The CO addressed through this activity is shown in Table I

TABLE I
COURSE OUTCOMES (CO)

CO	Statement	Activity
CO2	Generate sectional view, true shape of sections and development of lateral surfaces of regular solids	Learning by Doing

The aim of this activity is to enhance the visualization, creativity, and technical drawing skills of first year engineering students. The assessment of the activity is carried out with rubrics as shown in Fig. 2

Rubrics for the assessment of ISE-II (Engineering Graphics course –SH1134)

Criteria			Roll No.
Level 5 (Completely Attained) (6-8)	Level 3 (Somewhat Attained) (3-5)	Level 1 (Not Attained) (0-2)	
Model has prepared with cutting plane and has innovation to present the model	Model has prepared with cutting plane but neatness is missing	Model has prepared but cutting plane and neatness is missing	
Applies the knowledge of trigonometry to find the angles, areas, etc.	Applies the knowledge of trigonometry with some error.	Difficult to Apply the knowledge of trigonometry.	
Correctly visualize and interpret the data given in illustration.	Minor errors visualize and interpret the data given in illustration.	Does not able to visualize and interpret the data given in illustration.	
		Total out of 24	
		Total out of 8	

Fig. 2. Rubrics sheet for assessment of the activity

The students were directed to bring the models with them to the classroom. The students were organized into groups of five, categorized based on the type of solids, which included prism, pyramid, cone, cylinder, tetrahedron, and cube. Each group of students was asked to explain the one problem along with solution. The Fig. 4. depicted the students explaining the problems in groups.

The students were guided to present the sheet with the affixed model to the instructor upon the conclusion of the class activity.

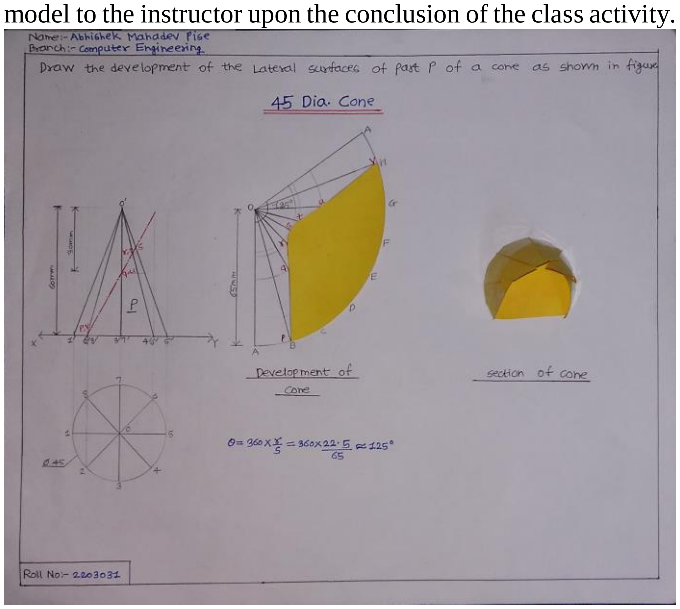

Fig. 3. Sheet Prepared by Students

III. Result and Discussion

This section documents and deliberates upon the observations made during the activity.

After introducing the activity in the class, ample time was allocated to the students. Subsequently, the students' drawing sheets were collected for grading through a google form. A total of 59 students took part in the activity and submitted their drawing sheets along with the attached models. The samples of the drawing sheet along development of card sheet paper depicted in the Fig. 3.

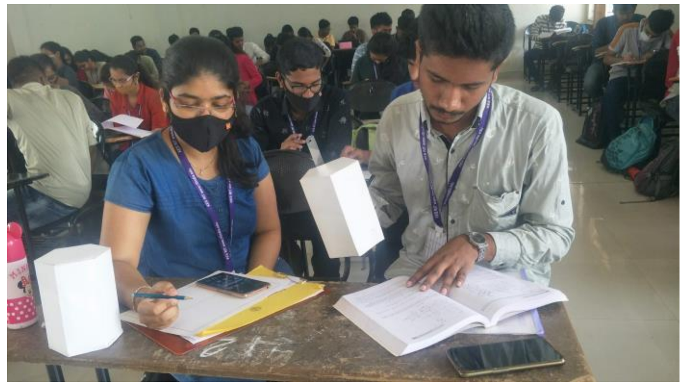

Fig. 4. Students Discussion

The drawing sheets are evaluated, and the students' scores are conveyed, along with general recommendations, during the class. The outcomes of the activity were analyzed and categorized into four clusters, as detailed in Table III. The influence of the activity was noted in both the Unit Test Exam (UT) and the End Semester Exam (ESE). The problems related to solid surface development were included in the Unit Test II (UT II) and the ESE, carrying weights of 13 and 15 marks respectively. During the examination, a noteworthy enhancement in students' scores was noticeable for questions related to the development of solid surfaces. The scores achieved in UT II and ESE for the respective topics were contrasted with the results from the past two years, as depicted in Table III.

From the results it was observed that average marks for the development of solid topic is increased from 8.73 to 10.23 showing 17.18% increment in the marks. Similarly in the ESE average marks for the topic showed an increment of 18.98% for the students.

TABLE III
COMPARISON OF AVERAGE MARKS OF THE STUDENTS IN UT II AND ESE

Test	Max Marks	Average Marks		
		2021-22	2022-23	% Increase
UT II	13	8.73	10.23	17.18
ESE	15	9.64	11.47	18.98

Table IV displays the percentage attainment of the course outcome associated with the solid development topic. It is evident that the level of attainment for CO2 has demonstrated a marked improvement when compared to the preceding year, which followed conventional teaching methods. In the academic year 2022-2023, the attainment of CO2 witnessed a notable enhancement of 5.41% compared to the academic year 2021-22.

TABLE IV
ATTAINMENT OF CO2

CO	% Attainment		
	2021-22	2022-23	% Increment
CO2	74.31	79.72	5.41

At the end of the topic the feedback is taken from the students to measure the students learning index (SLI) using google form. The feedback SLI from the students depicted in the Fig. 5

As depicted in Figure 4, it is evident that 79.2% of students strongly agree, 17.3% agree, and 3.5% fairly agree that they are capable of developing the provided solid in accordance with the given conditions. Notably, there are no students in the "not agree" category. This underscores the complete engagement of all students in the learning process.

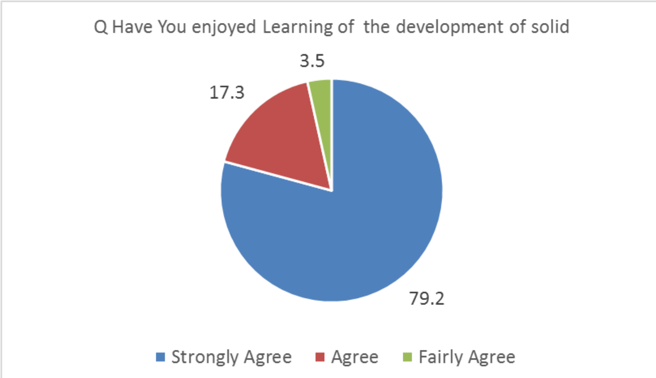

Fig. 5. SLI feedback of students

The course end survey taken at the end of the course depicted in Fig. 6. It is clear that from Fig. 6, more than 90% students are able to develop the given solids in given conditions.

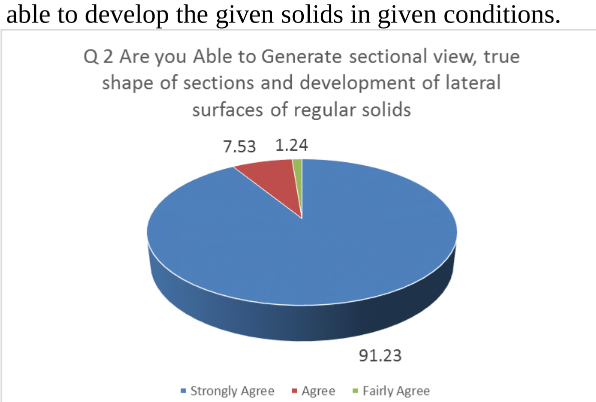

Fig. 6. Course end survey feedback

IV. Conclusions

The implementation of the activity proved to be a successful component of active learning within the engineering graphics course, effectively enhancing the technical drawing, visualization, and imaginative capabilities of first-year engineering students. The attainment of CO and results of the test are analyzed and compared with previous attainment and results.

Based on the observations following conclusion are drawn.

1. The activity implemented led to an increased engagement of students beyond the classroom, enhancing their learning experience in solid development.
2. As a result of this activity, the instructor was able to classify students based on their levels of imagination and visualization skills. Those students falling into the lower skill category were provided with targeted encouragement and training to enhance their visualization abilities.
3. The average scores for solid surface development in both UT II and ESE exhibited significant improvement compared to the previous year, thereby playing a role in enhancing the final grades of the students.
4. The attainment of CO related to development of solid improved by 5.41% compared to previous year.
5. The student learning index for the development of solid topic also improved significantly.
6. There was a notable enhancement in the technical drawing skill, imaginative capability, and level of student engagement in the learning process.

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