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Model-Based Teaching and Learning: An Experiential Research of Teaching Engineering Drawing for First Year Engineering Students

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Abstract: *Technology plays a major role in the easement of teaching and learning in engineering education. Novel techniques adopted in the recent days, have resulted in a huge success on the part of educators. These techniques create a great difference in the instructional delivery, with real-time impact on the understanding and learning of students. In this context, Model Based Teaching and Learning (MBTL) is identified as one such resourceful method to teach certain educational concepts which require imagination. Use of models within the pedagogy of engineering education promotes meta cognitive thinking skills of students. The purpose of this research was to examine the advantages of adopting model – based teaching and learning for the course, Engineering Drawing for first year engineering students. A class of 120 Engineering students during the second semester participated in the research. The students were randomly grouped into two groups of each 60 in order to receive different treatments. The first group was identified as the Control group (CG) which was taught concepts of Engineering Drawing using traditional lecture method, while the second group, the Experimental Group (EG) was facilitated with models related to projection of lines and orthographic projections. The results revealed that using models had a significant impact on the academic achievement of the students. Based on their performance in the continuous assessment, it was concluded that models were very helpful in improving the marks, and also played an effective role in the comprehension of concepts.*

Keywords: *Model-based Teaching and Learning (MBTL), Engineering Drawing, Control Group, Experimental group, continuous assessment.*

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I. INTRODUCTION

Engineering Drawing is an essential part of the curriculum of engineering education. It lays the foundation for engineering design for many engineering disciplines. Though most of the application of Engineering Drawing is used in Mechanical and Civil engineering, it is important that basic engineering designs have to be learnt by engineering graduates who belong to other disciplines. Today, industries demand high level of visualization of equipment and products during designing and manufacturing. Hence, lack of knowledge in engineering drawing will prove to be a great disadvantage for engineering graduates. Over a period of time, the teaching of engineering drawing has evolved from traditional lecture method to creating technology-based learning environments. Though design software like AutoCad exists, the traditional hand drawing still remains to be the most challenging and demanding method of teaching Engineering Drawing. The rapid change in teaching Engineering courses over the last few years, had led to the changing trends in the teaching of Engineering Drawing.

Drawing is a perfect means by which engineers communicate their ideas. It is a universal graphic language that helps impart knowledge on various aspects of engineering. The broader objectives of teaching Engineering Drawing include:

- To teach students to communicate using graphic techniques
- To learn the principles and standards of mechanical drawing and dimensioning
- To interpret the information in 2D mechanical drawing
- To understand the application of industry techniques applied in Engineering Drawing

Engineering Drawing as a graphical language helps visualize a concept drawn on paper. It is similar to the form of spoken or written format of a language where specific rules and standards have been developed to retain consistency in industry. Many industries create their own internal standards; therefore, it is important to communicate their requirements in one form. Hence, the relevance of one standard graphic form is increasing day by day.

Every engineer is expected to create drawing as per the requirements of the industry. The genesis of an idea will start from drawing the model in his/her mind, on paper.

Therefore, Engineering Drawing is considered to be the language of engineers.

In order to increase the efficiency of teaching Engineering Drawing, a lot of innovative methods have been adopted by teachers. One such way is incorporating technology into the mainstream of teaching – learning. Since, it demands high level imaginative, analytical and creative skills the gap between visualizing a concept and expressing it on paper does exist. Hence, teachers adopt inventive practices of teaching this unique course to the students. One such method is Model Based Teaching and Learning (MBTL) where students are introduced to 3D models and given opportunities to create their own models using a variety of materials. This experiential way of learning has induced active learning skills on the part of the students. This paper is an exploration into the adoption of Model based teaching and learning and it also focuses on testing the effectiveness of this technique in the classroom.

II. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

First, it is important to arrive at the general definition of models as put forth by Ingham and Gilbert (1991)[1]: a model is a simplified representation of a system, which concentrates attention on specific aspects of the system. Further, models enable aspects of the system, i.e., objects, events, or ideas which are either complex, or on a different scale to that which is normally perceived, or abstract to be rendered either visible or more readily visible (Gilbert, J. 1995). The value of models and modeling to traditional scientific research is well documented (Black 1962)[2]. Models are important in engineering research both in formulating hypotheses to be tested and in describing scientific phenomena (Gilbert, J. 1995). The value of models and modeling to engineering education has been increasingly recognized over a period of time among educators At present, models and modeling are considered integral parts of scientific literacy (Gilbert and Boulter, 1998)[3]. With the gaining importance of introducing models into the learning environment comes the need for model based teaching and learning.

Making the students visualize concepts still happens to be one of the challenging tasks for teachers in the classroom. A finding by Shawn Strong from Southwest Missouri State University and Roger A. Smith from Iowa State University Visualization skills have been found to correlate highly with successes in engineering, and mathematics in general. (Strong & Smith, 2001)[4]. Whereas in most of the educational institutions in India, Engineering Drawing is taught by traditional lecture, chalk and talk methods. Units like, projection of points, projection of lines, projection of planes, projection of solids are taught by using black board. Explaining these concepts of Engineering Drawing to students is a herculean task for the teachers. Especially the three dimensional concepts of orthographic projection, isometric projection and perspective projection require lot of imaginative quotient. Students with less visualization ability find great difficulty in understanding the three dimensional concepts, hence, this research focuses on recreating a Model-based teaching and learning environment. Every model is constructed in accordance with specific intentions in order to simplify its original in several respects.

With today's challenge of engaging the student actively in the classroom, a teacher plays a dynamic role in the process of teaching and learning. There is no doubt that the powerful visual aid still remains to be the black board in the classroom. However, courses like Engineering Drawing requires high imaginative skills, hence an appropriate teaching methodology is sought after. The theory employed in this paper is Model-Based Teaching and Learning (MBTL) set forth in a special issue of the International Journal of Science Education (Gobert &Buckley, 2000)[5]. Various topics in the syllabus were fabricated into models as shown in Fig.1.b and 2.b Students were taught the methods of fabricating these models to sensitize their learning. Learning occurs when people actively construct meaningful representations from presented information, such as coherent mental models that represent and communicate subjective experiences, ideas, thoughts, and feelings (Mayer et al., 1999)[6]. Engineering education has undergone a lot of evolutions. Educators constantly re-examine the content of engineering curricula to cope with emerging technologies. Therefore, it is indispensable to devise, apply and assess innovative pedagogical approaches into teaching without compromising on the traditional skills promoted in the curriculum.

Model-based reasoning occurs during situations when an individual mentally visualizes an environment in order to simulate (in the sense of a thought experiment) specific transformations of the system which may occur in real-life situations. These mental models readily produce inferences with respect to the situation to be cognitively mastered (Forbus & Gentner, 1995)[7]. In recent times, model-based instruction has gained popularity among educators and is now being applied in a wide range of engineering disciplines. It plays a crucial role in enhancing the graphical communication skills of engineering graduates since, ability to produce, read and correctly interpret engineering documentation is the most wanted skill for engineering graduates working in industries. With this as the backdrop of this research the following hypotheses have been formulated.

III. HYPOTHESIS

H1: The control Group which adopted traditional teaching method after the period (post test) has not improved. i.e. there is no historic effect of Pre test on the post test results.

H2: The performance of the experimental group after the administration of models (post test) has improved than the control groups**.**

IV. METHODOLOGY

The broader objective of this paper is to experiment in the process of teaching and learning, the application of models pertaining to the course *Engineering Drawing*.

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In order to carry out this research, 120 students doing their first year engineering programme were considered as participants. The participants were divided into two groups. One group was considered as the control group (N=60) for which traditional method of Engineering Drawing using black board was taught. The other group identified as the experimental group (N=60) which was taught concepts from *Engineering Drawing* using Model-based teaching. The model-based teaching and learning method component consisted of various learning cycles.

Firstly, each unit begins with the introduction of a concept followed by drawing. The major challenges faced in Engineering Drawing in conventional method is to explain the three dimensional concepts of projections by drawing on the board or in paper. Hence, in model – based learning, topics in which the concept is more relevant to promote experiential learning, students create their own models to induce visualization of images. For example, Fig.2.a represents the drawing of projection of lines. After drawing this on paper, students were given assignments to create models using materials like chart paper, sticks and foam sheets. Fig.2.b represents the model of projection of lines created by students. Similarly, Fig.3.a is the drawing of orthographic projection of an object and consequently the model created by students is represented in Fig.3.b. The students were given the development of the model as given in Fig.1 to construct the model.

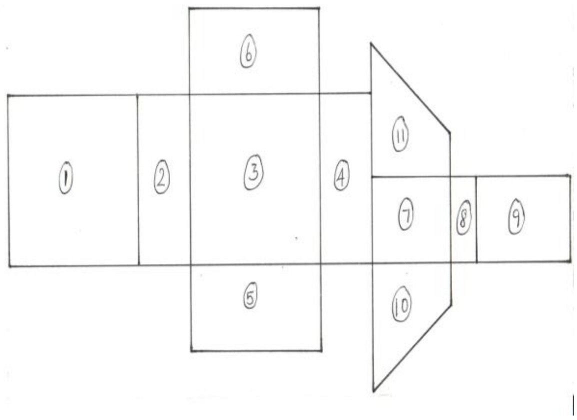

Fig. 1. Development of the model

Meanwhile the students in the control group were taught concepts using traditional lecture method. The process of any teaching and learning is not complete without assessment. Hence, assessment of the course *Engineering Drawing* was analyzed to observe the impact of control and experimental groups. Here, the marks of pretests and post tests of both groups were taken into consideration.

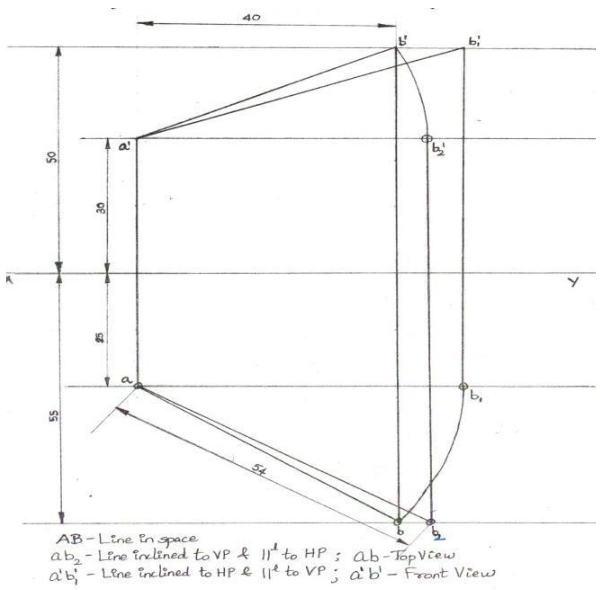

Fig. 2(a). Projection of lines inclined to both planes

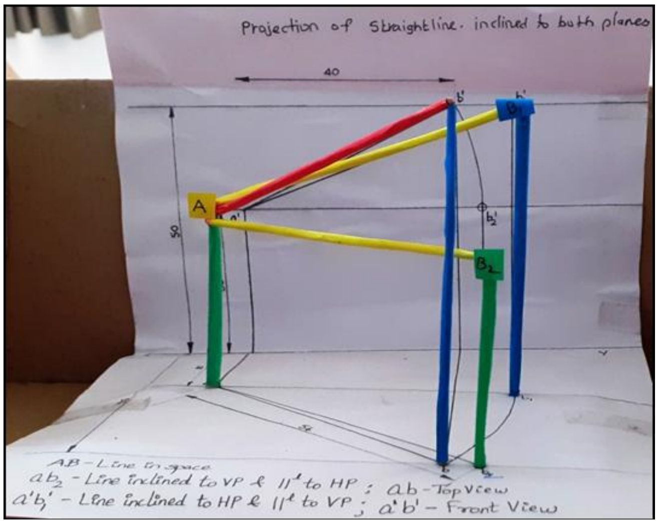

Fig. 2(b). Model of Projection of lines inclined to both planes

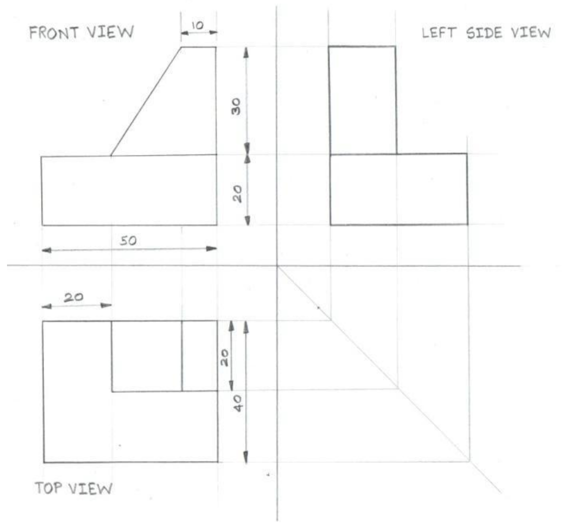

Fig. 3(a). Orthographic projection of an object

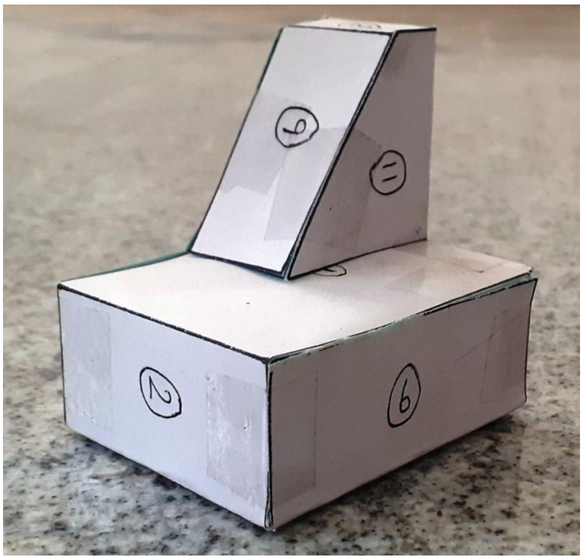

Fig. 3(b). Model of orthographic projection of an object

V. DATA ANALYSIS AND INTERPRETATION

From the below bar chart it can be understood that the pre test and post test scores for the Experimental Group is greater than the control group. However, it is not justifiable to measure the difference considering the mean scores of the tests alone. Hence a paired sample test was carried out to test the influence further.

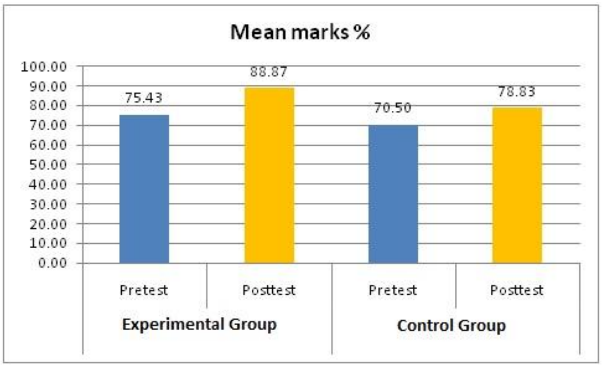

Fig.5. Mean scores for fundamental comparison

Table-I: Paired Samples Statistics

Mean	Std. Deviation	Std. Error Mean	T	df	P value		
Experiment al group	Pretest	75.433	18.8017	2.427	-6.365	59	0
	Posttest	88.866	7.40469	0.956			
Control group	Pretest	70.5	17.53109	2.263	-4.437	59	0
	Posttest	78.833	16.06888	2.074			

First a pre test influence is tested by paired sample t test. However, the data does not justify there is no pre test effect on post test since paired t results shows significant (p<0.01) for both control and experimental groups (H_1 is not supported). Therefore covariance effect of pre test was to be eliminated mathematically when the comparisons were made. Therefore, anlysis of covariance (ANCOVA) is applied for the second hypthesis (H_2).

Table-II: Analysis of covariance technique (Dependent Variable: Post test result)

*Model and components are signifcant at 1% level

Source	Type III Sum of Squares	df	Mean Square	F	P value*
Corrected Model	8487.463	2	4243.732	38.188	0
Intercept	22053.353	1	22053.353	198.452	0
Pretest	5467.43	1	5467.43	49.2	0
Group	1973.34	1	1973.34	17.758	0
Error	13001.837	117	111.127		
Total	865188	120			
Corrected Total	21489.3	119			

Table-III: Descriptives of Pre and Post on Experimental and Control groups

Group	Pre-Test				Post-Test		
	N	MMean	SD		MMean	SD	Adj. mean
Experimental	60	75.43	18.8		88.87	7.4	87.94
Control	60	70.5	17.53		78.83	16.07	79.76

Experimental group showed highly significant improvement than the control group (since P<0.01, Table.1). The mean score of experimental group (88.87±7.40) is greater than control group (78.83±16.07) and this difference still exists after the elimination of pre test effect (Table.2 and figure.5) and so H_2 is supported.

VI. CONCLUSION

Hence, from the above results it is understood that the Model-based Teaching Learing of the course *Engineering Drawing* had a positive impact in the learning process. Since courses like these, demand high level of visualization skills, adequate preparation is required on the part of teachers to provide a unique learning experience for the students in the classroom. Such interactive teaching technique can be applied in a way that it activates the participation of learners in the course. Feedback can also obtained in between to monitor the effect of the teaching tecnique. Although there are other methods of teaching Engineering Drawing in 2D, the physical model created by students themselves have a long term effect on their learning. It is important as educators we also focus on the joy of learning in the class while imparting technical konwledge and skils to students.

Similar experimentations can be carried out to capture different learning expereinces of students in the classroom.

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